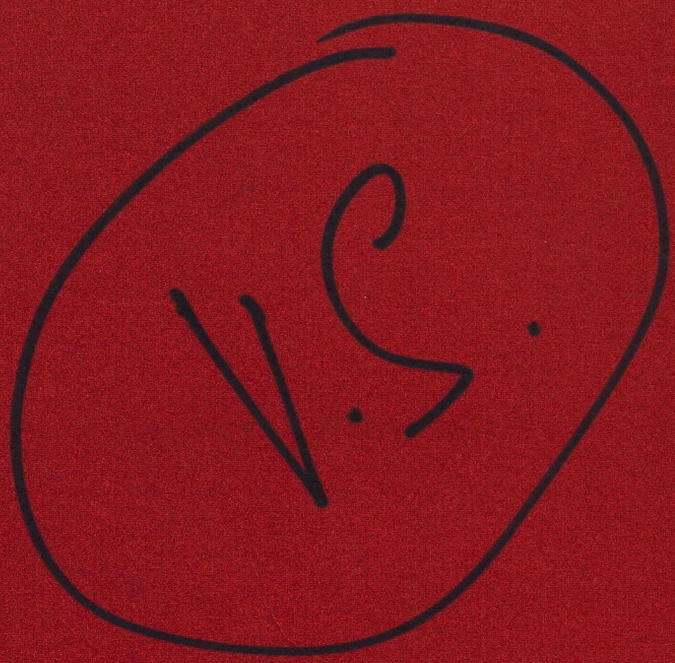
Science Advisory Council to the
Prime Minister

# An Approach to a Perspective Plan for 2001 AD : Role of Science and Technology




July 1988
Technology Bhavan
New Delhi 110 016

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## FOREWORD

The remarkable economic development that this country has witnessed in the last 40 years has been governed by a series of Five Year Plans, drawn up after extensive discussion and analysis by the Planning Commission. The Science Advisory Council to the Prime Minister has been charged with the task of suggesting strategies for incorporating science and technology in a perspective plan for the period upto 2001 AD. While attempting to carry out this task, it has become clear to the Council from its discussions with the Planning Commission and the Economic Advisory Council that planning *for* our science and technology is not yet integrated with planning for economic development. Whatever may be the compulsions that have been responsible for this dichotomy in our Plans till now, the Council is convinced that the time has now come for close integration of S&T *into* planning, and indeed that without such integration it is most unlikely that we will achieve the ambitious social and economic goals that the country needs, and is being asked, to set for itself.

The purpose of this approach paper is to indicate, in the light of the above considerations, certain new directions in which we believe it is now essential for us to move. First of all, we consider that plans for S&T must be geared directly towards meeting the basic needs of the population (food, housing, health, employment and education) and modernising our infrastructure in such major service sectors as energy, transport and communications: support for relevant research and development in these sectors has with rare exceptions been inadequate. Secondly, the crucial role that materials technology will play in national development - in areas ranging all the way from housing for the poor to chips for new computers - has to be appreciated and consciously planned for. Thirdly, the revolution being wrought by developments in information technology needs to be harnessed for the national effort - once again in all areas, ranging from health to technology assessment and forecasting. Finally, it is important to ensure that industrial growth goes hand in hand with greater technological capability. We also have to appreciate that there is no real conflict between working towards the primary social goals of the nation and promoting an efficient, internationally competitive industry with a certain export orientation.

In moving in these directions, we should in particular select and stress those areas of science and technology that can help to yield the following outcome by the turn of the century: a targeted deceleration in population growth, a doubled food production from agricultural and other sectors and a substantially larger gross domestic product, health for all and literacy and housing for the vast majority of the population, a comfortable situation nation-wide in the primary service sectors of energy, transport and communications, a reversal in ecological erosion, an increased export market for Indian manufacturers and services, and world leadership in selected areas of science and technology. We state this with the feeling that a time has come in our nation's life when the propensities are right for progressive developments to occur.

We are convinced that to achieve such goals some restructuring of the management system for S&T *in* planning for economic and social development is essential. In particular, we suggest the establishment of a National Science & Technology Commission, to help in integrating S&T into planning, to identify appropriate technology missions, and to coordinate and whenever necessary to manage collaboration between the different agencies of the Government concerned with technology development, economic planning and financial resources, as well as with private and public sector industry. We also suggest selective efforts in higher education and research and promotion of excellence in a concerted fashion.

This approach paper is not intended to be comprehensive, nor can it replace the massive exercises that the

Planning Commission has necessarily to carry out in formulating our Five Year Plans. We have raised several issues that appear crucial to us and suggested certain strategies in an effort to present a philosophy of perspective planning wherein S&T plays a key role. We would feel rewarded if the attention of planners and scientists is drawn to the major new directions that seem to us to be now necessary, and would welcome comments from them on the proposals contained here for the integration of S&T with planning and, as part of this effort, for the measures to be taken for promotion of S&T in general. We also hope that the approach paper will act as a catalyst in the preparation of innovative perspective plans by all the concerned departments, agencies and institutions.

We would like to express our sincere thanks to the Prime Minister for his encouragement and support.

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Secretary

# AN APPROACH TO A PERSPECTIVE PLAN FOR 2001 AD:

# ROLE OF SCIENCE AND TECHNOLOGY

## I PROLOGUE

1 After 40 years of independence, the process of economic planning through the Five Year Plans has become an accepted mechanism for national development. Any approach to perspective planning for the future has to be necessarily based on our past experience and an objective analysis of our past successes and failures. It is obvious that our approach now requires a sense of urgency and dedication to the concept of "getting things done", in a given time frame, by evolving appropriate and effective implementation mechanisms. We are convinced that the tools of science and technology are ideally suited for such an approach. This paper therefore emphasises the effective use of science and technology in economic planning as well as the importance of planning for science and technology.

2 National planning, as conceived by Pandit Jawaharlal Nehru, is the lynchpin of India's economic development. While we can argue as to how much better off we might have been if all the Plan targets had been achieved during the past few decades, it is important to note that the economic gains we have made have not been insignificant. Until recently, there were doubts about India's ability to produce surplus food. Today there are questions about our ability to control our population and eradicate poverty. In the case of food production, the doubts turned out to be challenges which we have successfully met. The principal instrument was planning, while the motive force was the political will to use science and technology as vehicles for development.

3 This element of using S&T in planning, highlighted by Mahalanobis and others, when coupled with the intense efforts of Bhabha and Bhatnagar in planning for science and technology, became the essence of Panditji's approach or the "modus operandi" of economic planning for the country. It was Panditji who clearly enunciated these concepts by assigning to science and technology a pivotal role, when he stated in the Scientific Policy Resolution (1958) that:

> "The key to national prosperity, apart from the spirit of the people, lies, in the modern age, in the effective combination of three factors, technology, raw materials and capital, of which the first is perhaps the most important, since the creation and adoption of new scientific techniques can, in fact, make up for a deficiency in natural resources, and reduce the demands on capital."

4 The establishment of the Atomic Energy Commission, the modernisation of the Defence research establishment, the initiation of the green revolution, the exploration of oil and natural gas and the entry into the space era are some of the examples of the application of science and technology to the nation's development plans which were adopted by Panditji and subsequently by Smt Indira Gandhi. It was recognised that when critical targets had to be achieved, political will and vision for the application of science and technology had to be interwoven into our planning process. Such a missionary zeal for the application of science and technology has been eloquently defined by Shri Rajiv Gandhi, who, through the identification of priority National Technology Missions, has provided renewed impetus and imparted a sense of urgency to solving some of the crucial problems faced by our society.

5 Although S&T has been utilised earlier in the mission mode for achieving certain goals in programmes in Atomic Energy and Space, it did not become an integral part of overall national planning. The national plans were, and continue to be, mostly dependent on economic exercises and allocation of funds derived from it. These allocations include funds for sectors such as Education, Health, Communications, Energy and the varied aspects of Science & Technology. We are convinced that for planning to be more effective and to more accurately reflect our aspirations, there is need for considerable change in the manner in which we use S&T in the total planning process and the way we execute the plans.

6 Planning must start by taking into account the needs and aspirations of our people at the grass-root level and build up from there into an integrated and meaningful national plan. The concept of district level planning is therefore very relevant in this context, and it is essential that S&T inputs at the district level are visualised as a means of planning for some of the major sectors of our economic activities. On the eve of the Nehru Centenary Year, it is most appropriate to reinforce the planning process which was a gift from Panditji to the nation and which has achieved so much. It is necessary to formulate a Perspective Plan which gives the rightful role for S&T and at the same time more accurately reflects the aspirations of those for whom plans are meant. Given our limited resources, we must find ways and means to apply S&T to achieve some key economic targets.

7 The purpose of this Perspective Plan document is to define ways and means to achieve a well-defined economic growth in key areas in the years to come, including a rapid industrial development. In an environment in which targets are set but not met, science and technology can render its greatest service by bringing to bear on planning the disciplines of defining missions, target setting, goal achievement, reproducibility and original thinking.

In this approach paper, we have attempted to indicate briefly some of the guiding principles of perspective planning in the light of the observations made above. This document is not a Plan document, but only an effort to highlight the varied factors of vital significance that have to be borne in mind in preparing a Plan and the crucial role of science and technology in planning for development. A proper Perspective Plan would not only help in preparing the country's Five Year Plans (the Eighth Five Year Plan to be specific), but also in giving better focus and direction to the efforts of our ministries, agencies and institutions.

## II SOME BASIC ISSUES

8 India is in a unique position as far as science and technology are concerned. On the one hand it faces the challenge of utilising science and technology for solving the basic needs of the people such as food, shelter, clothing, health etc, and on the other its large S&T manpower is awaiting challenging tasks where one could not only contribute to the frontiers of science and technology but also use these tools for modernising our economic and commercial sectors. Furthermore, there are areas of S&T of immediate concern to us where we must become world leaders. It is this special mix that necessitates that our approach to planning must be looked at in two parts:

(i) Use of science and technology in planning, and

(ii) Planning for science and technology per se.

9 Against this background, some of the basic issues which face us today, and will continue to face us at least for the next 15-20 years, relate to the control of population, the need for increased food production, protection of the environment, improvement of human health, control of hyperurbanization and reducing unemployment. A few of the other major problems are related to energy, communications, transport and materials.

10 In any plan that we make for a developing country such as India, conservation and efficiency have a big role to play. We must combine the efficient use of natural as well as human resources if we wish to achieve spectacular goals. Science and Technology should be applied to maximise conservation and reduce wastage. This concept would apply to all areas and all our endeavours related to human resources management and development, energy, water, food, agriculture, fertilizers, insecticides and so on. In certain crucial sectors such as energy there may be a necessity for a national policy for conservation.

11 Given the size of our economy and its future prospects, Indian exports and India's international trade must become a vital component of our Perspective Plan. Any such plan for exports has two important goals. One is earning a larger share of international trade, and the other, generating employment for manufacturing goods and services for nondomestic markets. Increasing our export market will become possible if we take initiatives in certain sectors and this would require S&T inputs.

12 The plan to upgrade existing industries in order to make them domestically attractive as well as export competitive will not happen within a short time frame. This process must however start due to the compulsions of our own economy, and it is critical that there is an export focus which is in tune with the rapidly changing global scenario. In considering international trade one cannot ignore global competition, especially from our Asian neighbours.

13 While the industrial growth we are experiencing may be considered reasonable, our technological capability has not necessarily improved as much as expected. The desired impact of R&D on industry is yet to occur. Then, there are problems related to modernisation, productivity and the competitiveness of our industry. While tackling these problems, our perspective plan should take all these realities into account.

14 It is estimated that by the year 2000, about 70% of our population will be less than 35 years of age. S&T can play an important role in providing jobs to our vast population. It is not enough if mere employment is provided. Our people must develop pride in their professions and the all too important scientific attitude. It is only when a large majority of us have the scientific temper that the country can really hope for a better quality of life and strive towards excellence in all spheres. We have to ensure that in all our developmental plans and educational programmes, inculcation of the scientific temper should form an underlying theme.

15 Many socio-economic Ministries and Departments in Government operate in a manner that is not conducive to involving S&T for improving performance and efficiency. Our administrative procedures are not in tune with the times. Furthermore, there is no accountability in the administration, a situation that is often aggravated by a lack of continuity in administrative heads. Unless we make departments/agencies/ individual administrators fully responsible and accountable for our developmental programmes, it may be difficult to accomplish the desired goals.

## III A POSSIBLE SCENARIO BY 2001 AD

16 We believe that if our resources, the needs of our people, the S&T expertise and our managerial and administrative talents are all carefully interwoven, we will start producing a tapestry of change which will start meeting the needs of larger and larger sections of our people in the coming years. We are of the firm view that S&T has a major role in making it possible to bring about such a change. We could set ourselves the goal to double our gross domestic product by the turn of the century (i.e. achieve in the next 10 years what we have achieved in the last 40). The task may appear daunting, but a 5-7% average annual growth would suffice to achieve this in real terms.

17 If we are successful, what can we expect by the turn of the century?

(a) We would achieve a certain targeted deceleration in population growth.

(b) We would have doubled our food production through a combination of application of modern biology, planning for agro-climatic zones and the use of the best long-range weather forecasting available.

(c) Health for all and literacy for the vast majority would be within reach.

(d) There would be major changes in our management of energy and transportation.

(e) There would be better communication facilities in rural and urban areas.

(f) There would be a reversal in the erosion of our ecology through S&T inputs.

(g) Problems related to rural housing and selective habitat development would have been tackled adequately.

(h) We would be world leaders at least in a few selected frontier areas of science and technology.

(i) We would have made a major dent in lowering poverty and unemployment.

If this scenario has to be a reality, there is much we need to do; S&T has to become an integral part of our thinking and being.

## IV SCIENCE AND TECHNOLOGY IN PLANNING

18 In spite of the best efforts, the S&T component of the plan allocation of all the economic ministries could not be clearly identified during the Sixth Five Year Plan; even where identified, the utilisation of resources for the purpose was rather meagre. Part of the difficulty in identifying the S&T components of the various economic sectors is due to the fact that the demand for science and technology in many of these sectors has not been articulated through carefully structured exercises. The situation has no doubt improved during the Seventh Five Year Plan, but is still far from satisfactory. On the one hand, there is the claim that science and technology can provide valuable inputs in improving the productivity of various economic sectors, and, on the other, despite the large S&T infrastructure available, there is no demand on this sector

from potential users. *We believe that it is this aspect of providing the S&T inputs in planning which needs much greater focus and attention than what has been given hitherto.*

19 With the emphasis given to S&T since Independence, a massive infrastructure covering a broad spectrum of disciplines and capabilities has been built up in our educational and research institutions. However, it has often been felt that S&T has not made the kind of impact it ought to have, possibly because the crucial role that science and technology can play in planning for growth was not realised fully. The time is certainly propitious to more systematically integrate science and technology in the process of economic planning and in setting targets. In formulating a perspective plan, an orchestrated increase in efforts and ambitions needs to be built into the Eighth Five Year Plan and beyond.

20 It is therefore felt that some of the important criteria for developing the perspective plan should be:

(a) to set priorities in areas of importance as perceived nationally;

(b) to unambiguously assess the national S&T capability, current and future, as applicable to various sectors of national development;

(c) to explore new strategies for development and to identify those efforts that would help the country to make major strides in spite of various constraints;

(d) to assess the socio-political will which will be required in pursuing the plans for various sectors;

(e) to estimate the availability of and the requirement for resources in each specific sector; and

(f) to identify the social and managerial inputs required for achieving the objectives of the Plan.

21 Serious efforts would have to be made to deploy the vast S&T resources available for achieving the national objectives of providing the basic needs such as food, shelter, clothing, health, education etc. At the same time, we must build and modernise our infrastructure in the major service sectors such as transport, communications and energy which are vital to the overall socio-economic growth of the country. We believe that in the past these sectors have not received adequate S&T inputs during the process of planning, and have therefore slowed down the progress which could have been made through these sectors.

22 An approach to provide the required S&T inputs to planning should deal with the following two aspects:

(a) S&T for providing basic needs; and

(b) S&T for strengthening infrastructure support.

The guiding principles for planning have generally been to emphasise programmes which promote foodgrain production, increase employment opportunities and raise productivity. In the context of equity and social justice, it becomes necessary that all efforts are made to provide such basic human needs as health, food, shelter and environment. If S&T inputs are carefully planned, it is possible to meet the requirements of basic needs in a planned manner as has been demonstrated in the case of foodgrain production. Then, there are resource areas such as energy, transport, communication and materials which

are most crucial for progress and development, where only through a judicious planning through S&T will we be able to meet the developmental objectives and the cherished goals of this nation. The on-going technology missions on drinking water, immunisation, oil seeds, communications and literacy have been set up to solve some of the pressing problems, but there is need for constant vigil to avoid and eliminate the crisis situations frequently developing in the country in relation to essential requirements. In the following sections, we dwell on some illustrative efforts which could be made in the areas related to the basic needs as well as in some other areas of importance for economic growth and for improving the quality of life.

*(a) Population & Health*

23 The mid-term appraisal of the Seventh Five Year Plan is alarming. It shows that the rate of our population growth continues unabated. In other words, in spite of the enormous amount of work done with social, S&T and modern communications inputs, the end results have not been achieved. We face the frightening prospect of an uncontrolled chain reaction into the next century with the inevitable catastrophic consequence. This aspect must receive the topmost priority in the perspective plan.

24 The solution of the population problem requires a strong political will, appropriate socio-economic measures and modern managerial and organisational skills. Newer approaches such as vaccines or controlled release drugs will not be available till the turn of the century. There are conflicting reports regarding the present status of fertility antigens, and vaccination as a means of fertility control is today primarily experimental. Long-term safety aspects related to auto-immune diseases and teratogenecity remain to be answered. This scenario puts a major limitation on the S&T inputs available in this area. However, this equally strengthens the case for renewed and massive S&T efforts in developing new methodologies. If necessary, we must show our willingness to draw upon global expertise wherever appropriate. Modern communication technology should be made an integral part of the programme. In general, there must be a resolve to tackle this menacing problem on a war footing.

25 As a result of our planning efforts so far, substantial quantitative changes have been achieved in the field of health but without a radical qualitative transformation. Thus, the average life expectancy has creditably increased, maternal and infant mortality reduced and some communicable diseases partially controlled. An infrastructural chain for health care delivery, even to the remotest areas of the country, has been established. These efforts have been further supplemented by the Technology Mission on Immunisation of the vulnerable population. However, the curse of malnutrition, unhygienic environment and communicable diseases still persists. Simultaneously, noncommunicable diseases, generally believed to be associated with developed societies, have already acquired epidemic proportions. Therefore, in our future planning, while we need to strengthen our efforts in controlling communicable diseases, especially with the application of biotechnology, we should initiate action to tackle the emerging problems of noncommunicable diseases like cancer, cardio- and cerebro-vascular diseases, traffic accidents, drug abuse and diseases due to occupational and environmental toxins.

26 We should also anticipate and work towards providing health care for the hundred million or so people who would be above the age of 60 by the year 2001 AD. Furthermore, while planning, we must be conscious of the urban and rural needs that are distinct, and take region-specific health care and delivery to the district level with the equipment required to derive maximum advantage.

*(b) Food*

27 One of the most important achievements of S&T in India has been its role in the green revolution brought about by developing high-yielding crop varieties and the package of practices for their full expression. This itself was made possible by a strong political will. However, the scenario for the coming years is rather alarming unless food production increases from the present annual figure of 150 million tonnes to 180 million tonnes by the start of the Eighth Five Year Plan and then to 300 million tonnes by the turn of the century. If this does not happen, India is likely to face a food crisis that will be reminiscent of the 1960s. Such targets cannot be reached without new scientific breakthroughs backed up by an overhauled, vibrant and innovative research and laboratory-to-land management.

28 Major S&T inputs will be needed to get breakthroughs in achieving higher genetic production potential, efficient use of plant nutrients, soil and water management, tissue culture, arid zone cultivation etc. While expanding the irrigation facilities, greater attention will have to be paid to the improvement of drainage so that the soil-plant relationship is not lost sight of. Constraint analysis for the unsatisfactory increase of production in irrigated areas should be taken up on a priority basis. Urgent steps should be taken to grow crops suiting different agro-ecological conditions so that the concept of specialty agriculture can gain ground and all crops are not grown in all areas. Improvement of productivity level of rain-fed agriculture, with emphasis on improved breeds with high genetic potential for productivity, is another crying need in this area. Whereas the problem with oil seeds persists, the one on pulses is beginning to assume alarming proportions and may need attention on a mission mode. Establishment of downstream food processing industries will help in preservation and value addition and in turn will lead to higher profitability for the farmer and greater opportunities for rural employment.

29 Tapping the source of vegetables, fruits and also food of animal origin is another priority area. Modern S&T inputs in food storage and transport are crucial, considering the enormous losses that now occur and that the country can ill-afford.

*(c) Housing*

30 The congenial surrounding of a home is necessary for an individual's growth and also for national economic growth. The provision of urban and rural housing is a complex issue with the question of urban land reforms, difficulties in providing serviced land etc, being quite important. We must realise that a major amount in housing is spent on building materials. It is here that S&T can play a major role. Whereas spectacular advances have taken place in the general area of application of new materials in sectors such as transportation, communication, energy etc, as regards building materials there has not been much progress. An examination of the present production of conventional building materials in India shows that there is a major shortfall in practically all areas. A significant breakthrough in the S&T linked to the development of low cost and alternative building materials is necessary if we plan to fulfil the resolve of providing shelter for all our people.

31 Nearly 60% of the rural population in India will continue to depend on mud and thatch for housing for at least another 2 to 3 decades. However, there are possibilities of creating improved housing by upgrading these materials with polymers, which will not only improve their structural attributes but also durability. The combination of providing rural housing with appropriate ecological plans and meeting domestic energy needs should be a major focal point for village and block level development programmes which could be

the quintessence of district level planning. Although over the years, S&T has provided varying inputs and models for rural housing, these have not been used extensively because of the problems of delivery on the one hand, and, on the other, issues of architectural and civil engineering codes which need to be reassessed and reexamined. The issues concerning housing in rural and urban areas, and eradication of slums in the latter, are different and will require solutions for different approaches, regarding materials for example.

32 Continued usage of certain traditional materials in building construction is likely to have disastrous consequences. Let us take wood as an example. We know that our resources of wood are fast depleting. It is likely that wood will not be a common material for construction in the near future. Yet, when we consider that several million houses would be required in the next few years, to plan for such constructions without the use of wood appears to be a formidable task. We have not given sufficient thought to the replacement of such a common material as wood. In the future, we will require several million doors and windows for the houses to be built. Use of other types of materials such as glass, polymers and metals as structural materials has not been fully explored and included in our plans.

*(d) Ecology*

33 Continued intensification of resource use in India has been pursued in a manner that has led to a depletion of the capital stock of renewable resources. Furthermore, the costs of environmental degradation accompanying the intensification of resource use have been largely borne by the weaker sections of our society, while the benefits have accrued to those already better off. S&T inputs in this area are urgent and crucial to change this unsatisfactory scenario.

34 Collection, analysis and interpretation of information concerning all aspects of the environment, which is the mainstay of environmental research, should be a vital component of our scientific enterprise, but is largely missing today. It is an endeavour calling for a massive, decentralised effort. While this is fraught with difficulties, it affords a unique opportunity to involve large numbers of our people in a meaningful scientific effort. Only such an effort would furnish the required background information and make possible a holistic plan for resource use that could enable us to turn back the tide of environmental destruction.

35 The selection of soil-specific and region-specific plantlets, and their propagation and distribution through appropriate nursery practices, calls for massive deployment of S&T management throughout the country. The degree of social involvement necessary for success in this area is possibly the highest, next only to population control. In view of this, our scientific effort needs a radical reorientation of its focus on the problems of the environment at the field level, and efforts to bring in our vast network of educational institutions and voluntary agencies as active participants in science and technology assume crucial importance.

*(e) Energy*

36 Energy has already been recognised as an essential element in development, with practically 30% of the Plan outlay earmarked for this sector in the Seventh Five Year Plan. The demands for energy in India will continue to increase in view of the growth of agriculture and industry. There appears to be some imbalance in terms of the availability of power in different regions. S&T has a key role to play in the energy sector covering all conceivable areas including exploitation of primary sources, conversion, transmission, distribution etc. Unfortunately the usage of S&T in the energy sector has been unsatisfactory. Presently,

coal, oil, natural gas, nuclear energy, renewable resources etc contribute to the energy sector. There is an urgent need to work out a national energy policy so that the role of each of these could be properly delineated in the coming decades. Such a policy is also necessary because of the crisis situation in certain parts of the country where there seems to be no hope of getting sufficient electric power in the next few years.

37 In the area of coal there is growing concern that the average calorific value of the available noncoking coal is declining; coal beneficiation should therefore receive top priority. Experiments on *in situ* gasification to enable power generation at the pit heads should be encouraged whenever appropriate. Natural gas is emerging as a major energy source, and policy regarding its usage to meet energy and non-energy requirements needs to be clearly defined with a long-term perspective that keeps material and energy conservation in view: there is an urgent need to define a long-term natural gas policy. In the case of liquid fuels, the demands on middle distillates will continue to increase and major S&T inputs are needed for the development of new catalysts and processes, which do not interest the western world. In the area of nuclear energy, the country has developed good capability but we will have to take a realistic view of the net contribution nuclear energy can make to the total energy scenario in India in the coming decade.

38 About 40% of the country's energy consumption is derived from non-commercial sources such as fuel-wood and agricultural and animal wastes. Biogas chulahs with improved energy efficiency are critical. The importance of S&T in such areas should not be underestimated, since this will bring in a change in rural energy consumption patterns and will have a direct impact on the continuing fuel-wood consumption and its devastating ecological consequences.

39 Millions of two and three wheelers will be on Indian roads in the coming decades. Mixture short-circuiting in the present day two and three wheelers results in poor energy efficiency and very high unburned hydrocarbon emissions. If the engine designs are not suitably modified, almost one million tonnes of hydrocarbons will be discharged into the atmosphere by these vehicles as we reach the year 2000 (practically 15% of the total gasoline consumption in the country by the time).

40 Finally, the development of the energy sector has a high probability of success with the help of S&T inputs, the presence of a vast market, and the availability of certain material and human resources. India should be in a position to become a leader in a variety of energy technologies and a major supplier of heavy power equipment in the world.

*(f) Transport*

41 All forms of transport are severely strained today because of the extraordinary demands being placed on them. A good transport system will not only quicken industrial growth, but will have wide ranging repurcussions on the distribution of food, petroleum products etc, removing the isolation of specific areas in the country (for example the North-East) and, in general, promoting national integration.

42 Development of energy-efficient practices, technological upgradation of the present modes of transport and promotion of a multi-modal transport system are of top priority. S&T inputs in these sectors will be of key importance. The railways continue to carry the main burden of transport in India. There is tremendous scope for using S&T in modernisation and upgradation of railways, including signal controls, use of new light-weight materials and technologies in fabrication of railway coaches etc. In the case of road transport, again there is scope for development and usage of new road building materials (for instance,

modification of asphalt by polymers to impart more desirable characteristics), modern methods of road construction etc. The automotive sector in India has undergone a major transformation, but S&T inputs to make sure that we have fuel-efficient, environmentally clean and modern vehicles on the road need to be defined and used. As far as buses are concerned, both chassis and bodies continue to be built with age-old and outdated technologies. There is immense scope for improving riding comfort and reducing fuel consumption. Technological upgradation in buses is badly needed.

43 New strategies for transport also need to be planned. An important area that needs urgent attention is pipeline transport, which will ease the load on the conventional transport system. Already some progress has been made in transporting gas, petroleum products, minerals etc, but there are other sectors where this mode of transport could be introduced. One of the key areas is coal. There is scope for conveying 15 to 20 million tonnes of coal by this mode over distances of the order of 50 to 100 km. This will not only be an energy-efficient mode of transport, but will also reduce the pressure on the railways, especially when wagons have to be used for short distance transport.

44 We must develop the S&T base required to utilise the emerging technologies in the fields of civil aviation and inland waterways, the latter particularly because of energy efficiency.

*(g) Communications*

45 Telecommunciation is essential to our national development and is indeed a resource for tomorrow. This area is dominated by complex national, developmental, operational and service issues. The national mission on better communications has proved to be a step in the right direction and its objectives are being enlarged to fit into the overall priorities and targets for the year 2001. New strategies in terms of increased accessibility, improved reliability, development of rural communications, building of national networks, offering new services in urban areas, utilising advanced technology etc have been already incorporated in the Plan.

46 Although there is some cause for satisfaction in the way we have planned and moved ahead in recent times, we must realise that communication technology is changing very rapidly. There may be a need for examining all the S&T aspects in terms of actually incorporating the results of research, design and development work in improving communication facilities. Methodologies to integrate appropriate elements from rapid technological developments in satellite communication, optical fibres and photonics as a part of the overall plan are especially important.

*(h) Materials*

47 Materials, both advanced and traditional, pose yet another difficult challenge today. The absence of certain materials may in fact be the biggest bottleneck in our progress during the next few decades. It has been said that the possession and understanding of materials and the ability to use them are the determinants of a civilisation. Materials today figure extensively as an enabling parameter in nearly every system associated with modern technologies in a wide spectrum of sectors like heavy engineering, transportation, aerospace, power generation, microelectronics and bioengineering. In each of these sectors, progress has been aided by a continuous development of critical materials with improved performance capabilities. Invariably, the shaping of these materials in the form of components or devices under production conditions has called for development of new, expensive and complicated processing methods. On the one hand, the

situation is quite mind-boggling in terms of the bewildering variety of basic materials (metals, intermetallics polymers, ceramics, glasses), their combinations (alloys, blends and composites), the demands of advanced technological systems and the related processing and manufacturing techniques. On the other hand, the scenario is fascinating because of the potential of the role of scientific inputs in materials development, the commonality of concepts that underlie seemingly diverse materials (leading to substitution for conservation of materials, e.g. plastics in place of wood packaging, composites in place of conventional structural materials, and optical fibres in place of copper cables in communications), the challenge to innovate processing methods and the need to generate new design methodologies. The prospects become astounding as the materials engineer sets out to model his products on the basis of nature's own handiwork.

48 Materials are now being recognised as one of the basic resources of mankind, ranking along with living space, food, energy and human knowledge. The growing awareness of the paramount importance of materials development is reflected in a number of initiatives launched by policy-making bodies of governments in advanced countries. It is in this context that an advanced materials programme for our country should be formulated, keeping in view not only the needs of our technologies, but also the national resources position and the indigenous situation in the area of materials processing. Clearly, there arises an essential need for selection of materials for concentrated research, for integrated development and for establishing manufacturing processes.

49 Leadership in the materials field is not a new experience that we shall be reaching out to. There are several instances of achievement of ancient India (Chola bronze idols, the Delhi iron pillar) that cause us to recognise that we have a rich heritage in the materials field as well. More than three centuries ago, during 1660-1670, India exported to Western Europe nearly 6.5 tons of 'Wootz steel' in small lumps of unspecified size made by the native crucible process in the Deccan. The famous Damascus swords were made from this Indian steel. The inspiring question is, what can we attempt today in the field of advanced materials that will match the Wootz steel record?

*(i) Manufacturing*

50 Productivity is central to industrial growth. In the most successfully industrialised nations, "electronification" has been demonstrated as a key strategy in the modernisation of manufacturing to achieve at once higher productivity and enhanced quality. The advent of microprocessors has aided process engineering in chemical, metallurgical and other industries and facilitated better control of process parameters for higher precision in operations, data acquisition and application. New technology developments in computers, lasers, fibre optics and robotics have resulted in computer-aided design (CAD) of engineering products and systems, computer-aided manufacturing (CAM) leading to integration of the entire manufacturing area through computers (CIM) with benefits to productivity in a manner unimagined hitherto. Similarly, application of scientific principles to business in the areas of forecasting, marketing, production planning and control, materials and inventory control, financial planning and management, maintenance, quality management and productivity monitoring is having a marked effect on achieving efficiencies higher than ever before. There is considerable room and opportunity for planning for these inputs in indigenous manufacturing.

*(j) Information Technology*

51 Information technology will play a key role in all our national endeavours and its importance has to

be properly recognised in the planning process. Thus, for instance, health information systems will be important in generating and disseminating high quality data useful for analysis, policy formulation, and design of suitable health-care delivery systems. Similarly, accurate meteorological data coupled with modern weather prediction techniques and transmission of data through telematic networks, with suitable back-up agricultural support systems, will imply a sea-change in our ability to plan our agriculture in an optimal way for a given set of weather conditions. Similar examples can be cited in several other areas such as transport, energy, technology for industry etc. It is therefore necessary that appropriate information systems are provided for in our plans for all the important sectors.

## V SCIENCE & TECHNOLOGY IN INDUSTRIAL DEVELOPMENT

52 The industrial base in India has been expanding very rapidly with enormous diversification in recent years. The efforts of the Government in recent years to accelerate the pace of growth by eliminating constraints are beginning to pay dividends. Increase in industrial production has been satisfying, but one has to realise that industrial production and technological capability are not synonymous. The latter depends so critically on the industry's ability to make use of high level inputs arising out of its own R&D capability. The health of industrial R&D in India is a matter of great concern today. Although over a thousand R&D units exist in both public and private sectors, only 0.7% of the sales turnover is invested in R&D, most of it by the Central Government. The output from most industrial R&D is poor, both in quality and quantity, and is certainly not adequate to meet the challenges of today, let alone those of the coming decades.

53 It is recognised that the advent of modern industrial development and culture in India is hardly 40 years old and is still evolving. Till very recently, due to the shortage of resources, industrial development was closely controlled and directed by the Central Government. In this policy, social and economic goals had significantly greater priority compared to efficiency and competitiveness. But we see no conflict between the two. Industry today faces the urgent need for modernisation and improvement of productivity, and for developing the ability to withstand competition. In certain cases, these factors could determine the very survival of the industry. It is not therefore difficult to see how the improvement of the state of industry is closely related to bettering employment opportunities and to achieving socio-economic goals.

54 Although there are some healthy trends and some examples of successes in R&D in selected sectors of Indian industry, these are small in number and not proportional to the inputs. The establishment of R&D units in the private sector, in most cases, has been triggered by tax concessions offered by the Government rather than an intrinsic feeling of need for R&D. In the name of R&D, only the mundane functions of quality control and analytical services are often carried out.

55 We should also think of the village and small scale industries, which, apart from providing employment, make a major contribution to manufactured exports. There is an urgent need for modernisation in industries related to coir, silk etc, so that productivity and product quality improvement will help them to avoid stagnation. This can be achieved only through appropriate S&T plans.

56 There are several unhealthy trends due to which S&T has not contributed to industrial growth. Lack of long range corporate plans for R&D and dominance of defensive R&D linked to depackaging of imported technology are common features of much of the industrial R&D in the country. In the innovation

chain from concept to commercialisation, support in the latter part of the innovation chain by a 'product champion' at the senior management level becomes critical. In the absence of research directors on the Boards of Directors, it is difficult to complete this chain with tangible results. External inputs in planning and evaluation besides contacts with high-level academics have been missing. In the case of evaluation of R&D, short-range commercial considerations have dominated the evaluation. 'Inputs' in R&D rather than 'outputs' have been taken to be the indices of performance.

57 It is often argued that our production in many sectors is not of sufficient magnitude to warrant inputs of R&D. This is clearly fallacious. We are the largest producers of bicycles, fans and sewing machines in the world and yet no R&D inputs have gone in these areas. We are the largest producers of sugar, but again our technology remains old and outdated. We are not competitive where we should have been - say, in the area of garments (where we account for only 1% of the world market with one-fifth of the world's population), and steel (ours is among the most expensive in the world, although we have excellent iron ore), power generating equipment (with a significant share of the world market today we could have been among the world leaders as technology suppliers). Lack of S&T inputs in these sectors is obviously the reason for such deplorable conditions.

58 The creation of the Technology Information Assessment and Forecasting Council (TIFAC) and the Technology Development Fund (TDF) are major steps forward. We must see how these can be used in promoting industrial R&D and inducing the industry to make more use of S&T. The Council has to provide advice on the technologies that we have to opt for in priority sectors. There may be a need to consider new and innovative models for cooperative research programmes supported by a sector of industry with common goals. Traditionally planned and managed research associations such as in jute, fibres etc have been failures and have not been able to prevent sickness in the related industries. New thinking is therefore urgently needed. Even trans-national programmes in chosen sectors of industry with common goals should be promoted in areas of mutual interest. We must recognise our intrinsic strengths and exploit these. Considering the limited materials and financial resources, it is important to rely on India's potentially most valuable resource, viz. scientific and technical knowledge. Knowledge-based industries such as software production present certain advantages in the Indian context since the usage of primary resources is low but that of human resources is high. We must systematically plan on exploiting this resource for national benefit. In addition, the atmosphere should be such that good ideas for initiating industries get support through venture capital and other means. Many novel efforts requiring relatively small investments may enable us to become competitive internationally in certain sectors.

59 The lower productivity of a worker in Indian industry in comparison to those in advanced countries is often attributed to factors that are totally non-scientific. However, major changes in human and capital productivity in industry can be brought out by S&T inputs, both directly as well as indirectly. In more direct terms, improved productivity, higher utilisation of plant capacity, improved product quality etc will directly reflect on better human productivity. On the other hand, even indirectly, injection of the scientific temper in an industrial worker can impart major benefits.

60 Finally, the state of application of S&T in industry will improve only when we can understand and stimulate those factors which will kindle the innovative instinct and force the pace of R&D through competition, market pressures and reward for achievement.

## VI PLANNING FOR SCIENCE & TECHNOLOGY

61 We must distinguish between planning for science and technology, which is our concern in this section, from science and technology in planning which was discussed earlier in this paper. S&T must progress and advance if it hopes to be the beacon for our economic development. Planning for science and technology has goals in the longer term; its basic objectives are to improve the climate in which S&T work is undertaken in the country, provide a pool of talent and achievement that in later decades may even determine the directions which our plans will take, and retain a certain flexibility in our approach to ensure that in the long term options available to the country will not be limited because of lack of manpower or know-how in areas which assume importance beyond what may have been anticipated.

62 If our vision for the new century is that India will win for itself a position of pride and respect in the world of science and technology by virtue of its scientific achievements and of its presence as an internationally competitive force in at least some areas of science and technology, there are certain considerations we cannot forget. To achieve these goals there are first of all two traps to be avoided. The first is to pursue everything that is 'important', 'interesting' or even 'feasible'. The second is to over-plan (especially in science but also in technology) to a degree where flexibility of response is lost and new opportunities cannot be seized.

63 It is suggested that the criteria for choice of areas in fundamental research must therefore be promise of achievement of excellence, and the existence of special advantages that India or Indian scientists may possess, either because of our situation or because of resources specially available in the country. As examples of advantages of situation, we would suggest such subjects as the dynamics of the monsoons, the science of Himalayan geology and the Indian Ocean, the science of materials (especially those that are abundantly available in the country, such as titanium, zirconium, and rare earths), tropical diseases, plant resources in medicine, solar and other alternative sources of energy etc. Among those areas where we may have an advantage because of our manpower resources or the strength of our current research effort, we may mention sophisticated software development, parallel computing, numerical mathematics, superconductivity, photonics etc. Similarly, it is essential to create institutions to preserve what may be called national 'scientific property'. In this category would be (a) a human health databank, (b) a national germplasm bank, (c) a centre for the protection of national scientific property rights, (d) information banks for networking of Indian scientific talent in the country and abroad, and in general (e) centres of informatics and networks that will provide vital information that the nation needs to ensure that the priorities suggested above get the attention they deserve.

64 Instrumentation has to be given serious attention and support in order to promote experimental research as well as innovative R&D. Instrumentation is a crying need in our schools, colleges, hospitals and industry. Without an instrumentation culture, it will be difficult for us to provide proper support for our proposed efforts in high science and technology as well as to our educational and medical system. Know-how for developing most of the instruments already exists in the country, but linkages between institutions for the purpose of producing the instruments on an industrial scale are poor.

65 In India, planning for science and technology in the last 40 years has mainly been focussed around governmental support to various S&T sectors identified through government departments. As an indication of political commitment to growth of science and technology in the country, several government departments and agencies have been set up over the years dealing with Atomic Energy, Space, Electronics,

Agricultural Research, Medical Research, Ocean Development, Non-Conventional Energy Sources, Biotechnology, Industrial Research and Defence Research. These S&T organisations have pursued the growth of disciplines allotted respectively to that sector of science and technology. Recognising the wider scope of science and technology and with the continuous emergence of new and inter-disciplinary areas, the Department of Science and Technology was created precisely with the view of cutting across sectors to evolve, in a coordinated manner, various policy guidelines necessary for the growth and application of science and technology in the country. These government agencies have pursued their programmes through autonomous institutions attached to them as well as by supporting research and development activities in academic and other research institutions through financial support on a time-bound project basis. Certain capabilities in fields such as nuclear research, space research, defence research, agricultural research, medical research etc have grown as a result of efforts of these S&T agencies through the activities pursued in autonomous research laboratories and academic institutions. The growth of research in our educational system has partly been encouraged through these S&T agencies. While these S&T agencies have taken the responsibility for evolving major national projects and missions in well defined areas, there is a pervasive feeling that the knowledge generated through governmental S&T efforts is not being adequately utilised in the growth of the national economy or of productivity in various economic sectors and industry. Even the S&T agencies mentioned above have not been able to fully participate in the economic development of the country through well-planned mechanisms of integration of science and technology with development planning. As was indicated in the previous sections, the need for S&T in planning is increasingly being felt, and to meet this need it is necessary that our planning for S&T is done with a view to dovetail our S&T priorities with our national needs on the one hand and on fostering excellence on the other. It is therefore imperative that our national S&T agencies prepare well through our perspective plans which will not only bring together expertise of the highest kind with excellence in selected areas of national importance, but also make a meaningful contribution to the growth of productivity of our wide ranging economic sectors.

66 While planning for S&T activities of these specialised agencies, it is necessary to set inter se priorities so that the growth of various S&T sectors does not take place in isolation and at the cost of one another, but is harmonious in all the various S&T sectors relevant to national needs. In this process, the inter se priorities of our Plans have not been properly set, and the mode of allocation of resources has been based more on the absorptive capacity of a particular S&T sector than on the identified priorities of economic growth. The perspective plans of individual S&T sectors would therefore have to take this into account; at the same time, there is a need for a national mechanism to decide our national inter se priorities amongst the various S&T sectors which have grown during the last 40 years.

*Some aspects of higher education and research*

67 Normally, the development of new S&T might be expected to involve, and indeed proceed from, the University system. It is widely recognised, however, that education in high science and technology today presents a discouraging picture. There are numerous reasons for this state of affairs, some having to do with complex social factors. It needs to be recognised first that the university structure in the country has rapidly expanded and made available higher education of a certain quality to a large number of poeple, and this should be taken as a welcome sign of wide awareness in the country of the social and cultural value of education. At the same time, however, it is important to realise that the vision we have demands education of a quality that has not been possible in the prevailing academic system. A large number of universities are ill-equipped, and lack that actual demonstration of excellence in teaching and research which is essential for promoting achievement. On the other hand, the universities turn out a large number of graduates many

of whom end up by being unemployed or underemployed, being perhaps even unemployable. Some of the following measures to improve the situation with regard to education need to be considered while planning for S&T.

68 While undergraduate education in engineering and technology, through such institutions as IITs and the Regional Engineering Colleges, has achieved a reasonably high standard in many cases, the quality of undergraduate science education available in the country tends to be poor. The factors mentioned above, as well as the extreme rigidity of the science curricula, have promoted substandard science courses in the country. A new institutional approach needs to be introduced to provide education in science, comparable in quality with what the IITs do in engineering. Such an institutional structure should be linked to the higher institutions of learning in the country, for example, TIFR, IISc, the IITs etc, drawing upon the human and material resources of these institutions to ensure that the quality of education provided remains high. Such a system would have the autonomy to devise its own curriculum and examination system independently of the 'norms' that govern the rest of the academic system in the country. We should not be afraid if certain centres of higher education and research become elitist.

69 In many areas of science and particularly in engineering, a new system of links between universities and national laboratories needs to be forged. (By national laboratories here we mean all those institutions that work under a variety of different public agencies such as CSIR, ICMR, ICAR, Defence, Space, Atomic Energy etc.) Many of these institutions have received substantial support since Independence, and the time has now come for them to plough part of that input back into the university system by such joint ventures. The organisation of the national laboratories permits them to undertake major projects of a kind that are difficult to undertake in most universities. The facilities available and the expertise built up can promote such excellence in research. On the other hand, these laboratories do not have easy access to the bright young talent that many universities still attract but cannot utilise because of lack of exposure, opportunity, or facilities. A system of joint centres of the kind that have so effectively been organised by CNRS in France, with joint appointments and shared research programmes, would seem to be particularly appropriate in India as a cost-effective and rapid method of raising the levels of university education and of enhancing research productivity in the national laboratories. Indeed, some national laboratories with a strong programme of research should in fact be encouraged to provide training programmes at Master's or higher levels involving substantial contribution in research. Selected laboratories could even be permitted to grant degrees to those trained by them, if necessary through a nearby educational institution (by formal recognition or affiliation). Many areas of technology (for example, parallel computing, turbomachinery, materials technology) are probably best developed through such programmes.

70 The UGC has evolved various methods by which selected departments or groups in universities are given special assistance or support to promote their research programmes. This is a laudable step, but we would like to recommend that the concept be extended to promoting centres of excellence around individuals or small groups of scientists and engineers instead of a whole department or institution. This will enable scientists and engineers with a proven record of achievement and bright ideas for future research to get the modest support that will make it easier for them to undertake projects involving higher scientific risks as well as high potential rewards. Such centres should be encouraged in universities as well as national laboratories.

71 In addition we would suggest that, perhaps as part of the celebrations of the Nehru Birth Centenary, two centres of advanced studies may be set up. One of them would be for demographic studies, and will

bring together the best talent and opinion in an effort to devise optimal strategies for population control and to constantly assess the results of our efforts in that area. The second centre could devote itself to certain chosen aspects of basic science, somewhat like the institute of advanced studies in Princeton, providing an environment where the best minds would be free to pursue their research ideas.

72 There are now a variety of institutions and agencies in the country supporting research. The availability of multiple sources is a healthy feature of the science scene in the country. Funding should be available for ideas, irrespective of the area proposed to be investigated, in particular where such areas fall between disciplines or are unusual or involve higher risks than are normal when seeking support for research projects, provided only that the record of the individual or group concerned has been demonstrably excellent.

## VII MODUS OPERANDI AND STRATEGIES FOR ACTION

73 An analysis of past experience shows that while the process of planning may have been sound, the implementation mechanisms and related strategies have not been adequate. Ambitious targets have generally been set but for achieving them, the modus operandi has not been satisfactory. We believe that it is in this area of implementation (of how to "make things happen") where the perspective plan should lay great stress. Science and technology have a role to play in evolving proper methodologies and in increasing productivity and efficiency. This faith is strengthened by the fact that in the past, whenever well-defined tasks were assigned and a dynamic leadership along with a responsive managerial system introduced, the S&T sector has risen to the occasion and achieved the set goals. The examples of the 'green revolution', exploration for oil and natural gas, the atomic energy and space programmes, and more recently the experiments in the field of telecommunications through institutional mechanisms like C-DOT testify to this statement. It is based on this realisation that the Prime Minister has initiated a few societal and technology missions as well as several technology projects to be executed in a mission mode. These have already started to demonstrate a greater chance of success than was possible under the earlier implementing processes. Some of our glaring failures, for example, in the control of population, eradication of communicable diseases, preservation of our environment and development of self-reliant indigenous technology at least in some areas, are not primarily due to the failure of science and technology but are probably due to poor management and inappropriate mode of execution. It is thus necessary that some of our more difficult tasks are tackled in the mission mode.

74 In order to provide a greater degree of success in our future Plans, it is necessary to identify priority areas, unambiguously assess the available science and technology capabilities, define time-targeted goals, determine the relative role of social, economic and political factors and provide the appropriate managerial inputs. Coupled with this approach, there would be a need for an independent machinery to periodically monitor the progress achieved and introduce mid-course corrections wherever necessary. We therefore believe that a strategy for action and modus operandi for implementing these strategies have to be defined for the two basic aspects of planning discussed earlier: (a) S&T in planning, and (b) planning for S&T.

75 Traditionally, the economic sectors are grouped under the various departments and ministries of the government but, by and large, they do not have strong linkages with the S&T infrastructure in the country. As a result, S&T inputs for these economic sectors have never been seriously considered. It is necessary for every concerned economic ministry to draw out a perspective plan for the next 10-15 years with clear targets and identify specific science and technology inputs required to achieve the targets set. For this

purpose, it will be necessary that every economic ministry sets up a think tank in the form of a Science and Technology Advisory Committee which undertakes this task. While some of the economic ministries have initiated the setting up of such think tanks, these need to be activated and given specific tasks and responsibilities. Such advisory committees should be given a proper status so that the advice does not get ignored; the committees should be able to report to the concerned minister directly. As part of the S&T plans of these economic ministries, clear cut demands must be placed on the existing S&T sector including educational and research institutions in the form of time-bound and need-based projects and missions. The nexus between the S&T infrastructure and the economic ministries has to be strengthened and to a certain extent forced on the system. The user economic ministries should allocate S&T budgets for such activities and utilise the existing infrastructure available in the educational and scientific research institutions. The system should also encourage the academic community to take up challenging tasks to tackle socio-economic problems which would be assigned to them by the economic ministries. The S&T budgets of these ministries should not be diverted or cut for extraneous reasons.

76 By the turn of the century we need to produce around 300 million tonnes of foodgrains to meet the requirements of India's growing population. The increased production will have to be raised from the existing cultivable area. For meeting this target, management of the production package in areas suited for intensive agriculture will have to be optimised, improved production technology will have to be developed for rainfed agriculture and new techniques for upgrading the genetic production potential of our major food crops will have to be researched on and perfected. Simultaneously, attention will need to be paid to harnessing the potential offered by fruits and vegetables, acquaculture for fish and the marine food reservoir. For this to be effective, attention to food processing for preservation is crucial. Food should be a national mission for the next decade.

77 Unabated population growth, as at present, not only adds to the economic burden for all developmental activities, but also reduces the impact of economic growth on our society. Therefore, for the success of our planning, population control becomes the most urgent necessity. S&T inputs are only one of the important elements necessary for this purpose. A comprehensive national mission, with strong political backing and appropriate socio-economic measures, fully utilising the available scientific know-how, simultaneously making efforts for developing new methodologies, and supported by modern communication technology and managerial and organisational skills, is essential for success in this most difficult area. Population control should also be a national mission for the next decade.

78 In addition to drawing specific action plans for S&T inputs in the traditionally identified economic sectors, special measures would have to be taken in areas such as conservation, efficiency and export, where S&T inputs could make a major impact on our national development.

79 The conservation of soil should receive very high priority. It is claimed that in India every six months more top soil gets washed away than has been used to build brick houses across the country in one year. In the highly grazed Shivalik Hills 6 cm of top soil representing nearly 2,400 years of local ecological history gets lost every year. Intensive agriculture without proper supplementation is leading to alarming depletion of soil fertility. Indeed the loss in terms of fertilizers equivalent is considered to be a substantial fraction of the annual fertilizer production in India.

80 While on the subject of fertilizers, it needs to be emphasised that by using modern S&T inputs a significant amount of conservation is possible. We can make careful choices of technologies. For instance,

hydrogen recovery from ammonia synthesis plants is being practised in India in only 15% of the fertilizer plants. Even with a modest 5% increase in ammonia production by purge gas recovery, it would be possible to produce additional urea equivalent to two 1,350 tonnes per annum ammonia plants saving several hundred crores. Much of the urea that is applied to the soil is lost due to leaching and nitrification. Controlled release urea could similarly offer impressive savings but we have not provided sufficient S&T inputs in this vital area to make this possible.

81 Another critical area is water management and conservation. After all India is not a desert and there is a tremendous precipitation, but much water is lost through run off, evaporation etc. Water harvesting technologies will require high level S&T inputs. A national water policy is badly lacking. Such a policy should be developed and enforced with a sense of urgency.

82 Conservation of food is another area of great importance. Innovative S&T inputs through scientific methods of storage, development and usage of appropriate post-harvesting technologies, improved methods of packaging of food with newly developed multilayer barrier packaging materials etc can bring in considerable savings.

83 In the case of energy, every unit of energy saved is a unit of energy produced. Considering the acute power shortage we can ill-afford to postpone the development of a strategy for energy conservation and recycling. Energy audit of energy-intensive sectors has to be undertaken on a scientific basis. Utilisation of high grade energy for purposes where low grade energy could be used should be avoided. This means that it is not only the amount of energy but also the quality or grade of energy that has to be conserved and efficiently used. A major systems approach to planning of energy production and distribution with appropriate packages of incentives and penalties is urgently needed. A national agency should be made responsible for enforcing energy conservation in all sectors.

84 Conservation of forests for ecological reasons (a subject touched upon elsewhere), conservation of materials and conservation and efficient utilisation of human resources should be given serious consideration. "Conservation from oil to soil" and "produce more from less" should become slogans for the coming decade. With serious S&T inputs, it is possible to meet the goals we should set for conserving and efficiently utilising the natural and human resources that this country is endowed with.

85 The Sixth Five Year Plan launched an important new initiative in the form of ecodevelopment action research programmes for the Himalayas, the Western Ghats and the Ganga basin. These have involved universities, colleges as well as a few voluntary agencies. These programmes have continued in the Seventh Plan, but have not made as much headway as was hoped because the university and college structures do not permit active pursuit of field research or interaction with the voluntary sector. We should now make an all out attempt to introduce appropriate changes in the way educational institutions function to promote a culture of multidisciplinary field research on problems of local relevance. This should be followed by substantial investment to encourage active involvement of educational institutions and voluntary agencies in the area of conservation and sustainable utilisation of natural resources.

86 In the vital area of telecommunications, there is already a National Technology Mission operating, with plans for making substantial improvements in the facilities and services that will be available by 2001 AD. We consider that this area is another vital infrastructural sector whose development is essential for the overall progress of the country. We propose that a Telecom Commission be set up as an apex policy and

regulatory body, with the full financial and administrative powers of the Government of India and charged with the overall responsibility for modernising India's telecommunication equipment and services in as short a time as possible.

87 Although there has been some research and development in the Railways, in general the total R&D effort in the transport sector in India is deplorably small. This could have a serious impact on our development plans, in both urban and rural areas. It is suggested that an intensive effort should be made to introduce S&T in the transport sector through the constitution of appropriate Scientific Advisory Committees in the concerned Ministries, utilising to the maximum extent possible the infrastructure available in the country for R&D in mechanical and electrical sciences. In particular projects should be undertaken for the design of more fuel-efficient road and railway vehicles. In major cities, planning for transport should become an integral part of urban development. In Civil Aviation an imaginative policy could now pay rich dividends to the country in terms of export as well: the large investments being made in imported aircraft for the airlines must in part be recovered through co-production arrangements and by earning foreign exchange by promoting tourism. In otherwise inaccessible areas, aircraft continue to provide cost-effective means of providing links with the rest of the country. The time has come to set up a Civil Aeronautics Board which can lay down balanced policies for the country in terms of industry for civil aircraft, indigenous technology development, co-production arrangements, flight safety, and the associated R&D effort required.

88 The importance of minerals and materials has become even more vital in the context of modern technologies as well as every day life. Minerals are non-renewable and finite natural resources. The dynamics of ore reserves needs to be appreciated and reflected in constant updating of data not only of the reserves position but also on the rate of consumption and projected demand for defence and developmental needs as well as the international situation. Since minerals represent a national asset, augmentation of their production and export should be strategically managed so as to maximise return benefits. While the scientific and technological inputs into our mineral exploration activities need to be considerably enlarged there is need to appreciate that from the ore to the eventual product in the shape of materials and their utilisation there exists a chain of activities. An integrated view therefore is essential to cover the range of areas from exploration of ore reserves, mining, beneficiation and establishment of extraction processes, leading to development of relevant products and their optimal utilisation. A dynamic stock-piling policy as well as development of and support to indigenous production technologies would have to form part of such an integrated policy. There is also a clear need to have a body at the national level to launch, coordinate, review and monitor programmes in the area of advanced materials. Only a national body such as a National Advanced Materials Research and Development Board, that needs to be created, can have the necessary knowledge and authority to mobilise the existing capabilities and organise installation of additional facilities to deal with the scientific, processing and manufacturing challenges involved.

89 In order to promote instrumentation in the country, an autonomous Corporation should be established. The Corporation should initially pick around ten most important instruments of use in research and industry, and produce them within the next five years in adequate quantities, taking care to maintain high quality. Important instruments required for school and college science courses should similarly be produced within a short time frame.

90 Planning for export through S&T has necessarily to take into account an increasingly competitive export market and hence our strategies would have to be based on a spirit of competition where quality control would play a dominant role. Since export industry is synonymous with modern technology, value addition

and competitive cost, building an export infrastructure will be dominantly S&T-based. Export commodities would include manufactured products, software, computer peripherals, minerals, biotechnology products, processed materials etc. Since world markets may differ from domestic situations, it would be necessary to establish exclusive export zones by providing "cordon sanitaire". Creation of such zones in places such as Andamans, Lakshadweep, Goa, Pondicherry etc should be considered. This may encourage foreign investment and foreign trade servicing India's plans without interfering with the social and economic changes in the domestic mainland. We must aim to cross at least Rs.100,000 crores for export by the end of the Perspective Plan period. This might appear to be, at first sight, a heady target. But we must for once tear ourselves away from our historical experiences and domestic preoccupations in order to add real strength to our economy. It should also be pointed out here that even in certain traditional exports (e.g. minerals), we should develop a conscious policy based on our needs as well as strengths in S&T.

91 Employment, especially in rural areas, is becoming a critical problem. Downstream food processing operations, pollution-free and less energy-intensive manufacture of low cost building materials etc are typical examples of areas with vast employment generation possibilities in rural areas. Export-oriented industries will not only give employment, but also improve the quality of life and attitudes of large sections of our people.

92 Science and Technology activities have not only to be promoted in educational and research institutions but should also be rapidly increased in our industrial sector. At the same time, research and development activities for industrial development should not be confined within the industry itself, but the educational and national research institutions should also appropriately participate in such programmes and carry out research on behalf of industry. Judicious allocation of specific responsibilities amongst the different institutions for industry-oriented R&D has to be prepared and adequate support provided for carrying out the tasks.

93 Planning and development of S&T manpower is a major responsibility of the educational sector. Our experience so far has been that the supply of S&T manpower, though substantially large, is not adequately qualified or trained for undertaking problems of development involving application of S&T knowledge. The supply of S&T manpower therefore does not at present match the demands in key sectors of our S&T activities. With the rapid advancement and new developments in science and technology several inter-disciplinary and new areas are emerging which need a different kind of training set-up than is available in our existing educational institutions. For example, some of the major national laboratories such as BARC, NAL, NCL, NPL and DMRL should train students at the Master's and Ph.D. levels in chosen areas of advanced technology. Areas such as advanced materials science and technology, parallel computing, photonics, robotics and automation, need expertise to be built up through careful planning in the educational system.

94 In our scientific institutions and agencies, there is a need for focussing greater emphasis on nurturing quality and excellence so that Indian S&T efforts would be in the frontline in new and emerging areas of science and technology. Discovery-oriented research has to be encouraged on a selective basis, ensuring that the quality is of international standards. While nurturing such types of research, efforts should also be made to see how the expertise available in our laboratories and research institutions can be geared towards solving the problems of our economic and industrial sectors. Challenging, time-bound and mission-oriented projects should be assigned to agencies/institutions in order to give better focus to our R&D efforts in our national laboratories and to improve the interaction between laboratories and industries.

95 A statutory, autonomous body to support science and engineering research has to be established early and charged with the task of ensuring support for excellence in science and engineering and of giving a general direction to science in the country. This body should publish annual "science indicators".

96 If science and technology efforts have to provide inputs to our planning as was highlighted in earlier sections, it is necessary to devote adequate attention to ensure a planned growth for S&T. India today is devoting roughly 1% of GNP towards overall S&T activities in the country. The total allocation for S&T activities in our Seventh Plan outlay is about 2%. We believe that S&T has to play an increasing role in the economic growth of the country, a larger percentage of GNP would have to be devoted for S&T activities over the coming decades. While quantitative estimates cannot be made for increased allocation of S&T at this stage, based on the figures for developed countries, we estimate that we need to devote to S&T at least 2-3% of GNP over the coming decades. This sum would have to be carefully allocated giving considerable emphasis to quality and excellence rather than being preoccupied with numbers alone. Furthermore, the present method of allocation of resources for the various S&T sectors does not give adequate consideration to inter se priorities but is based more on absorptive capacities; the element of selective priorities has to be brought out even for planning the S&T sectors.

97 Presently, the allocation of resources to S&T activities in the States is much lower than what is being given by the Centre. While major S&T programmes such as atomic energy, space and defence research have to be undertaken by the Centre, there is still a need for the States to allocate a greater part of their resources to S&T activities than what they have been doing hitherto. There are a number of local and regional problems at the State and District levels which can only be solved through appropriate use of local expertise and administrative machinery, and through the use of existing S&T knowledge and development of adaptive technologies relevant to local needs. A greater S&T involvement at the State level is essential if S&T has to percolate down to the local population. For this purpose, the State Councils for Science and Technology as well as their Departments of Science and Technology have to be activated.

98 In order to accomplish many of these challenging tasks, we have to provide proper administrative support. Frequent transfers of officials responsible for major departments or programmes have often resulted in the absence of accountability. We have to assign responsibilities to concerned departments/ agencies/individuals and make them accountable for their performance at the end of a given time frame.

99 It is clear to us that not everything that we plan can be accomplished by government machinery alone. We need to fully exploit the potential of voluntary movements in crucial areas such as population control, family welfare, school education and adult literacy. It is likely that many of these tasks are better executed by motivated citizens, especially the educated women who are not yet fully utilised for the benefit of our society.

100 If the above concepts of using science and technology in planning are to be effective in our future plans, it is evident that the strategies indicated above should be effectively implemented. The existing structures for S&T and planning are isolated. Even within the S&T sector there is not sufficient coordination to determine the right priorities and basis for resource allocation to different S&T sectors as well as for fundamental research in science and engineering in the country. In order to make sure that adequate S&T

inputs are available for economic planning, to assist in determining national directions in S&T and to set the priorities in our plans, it is proposed that a National Science and Technology Commission (NSTC) be established. It would be appropriate here to quote the observation made in 1973 by the National Committee on Science and Technology:

> "There has been no explicit policy on the level and allocation of funds for scientific and technological activity, well over 80% of which is funded from the central exchequer. Each agency has submitted its proposals to the Planning Commission; the Commission has appraised them from primarily a financial point of view, endorsed the plans largely unmodified and recommended their funding to Government. Government, in turn, has accepted these recommendations and taken them to Parliament which, in large measure, has been generous and voted the funds asked for. In sum, the overall funding of scientific research has been decided more by the absorptive capacity of the agencies and institutions concerned than by considerations of the economic or social importance of the fields.
>
> The absorptive capacity of the different agencies and institutions has varied very widely. Part of the reason for this variation is the complexity of the technology handled by the different agencies, but, it has, in no mean measure, been also due to a range of factors external to the complexity of the technology and to whether or not the scientists were capable of doing good science. These reasons have often had to do with such things as the organisational flexibility within Agencies and Departments; the standing of the Heads of Agencies and other factors quite unrelated to the requirements of the national economy. The result of this essentially 'laissez faire' attitude to the allocation of funds has been a growing mis-match between the distribution of funds for scientific activity and the economic and social importance of the areas of funding."

We strongly believe that these lacunae still persist and should be remedied effectively through the setting up of the NSTC. The NSTC would not only consider the role of science and technology in planning, but could also help in deciding inter se priorities within the various S&T sectors and consider various issues such as technology forecasting, technology import and absorption etc which are vital to economic development through application of science and technology. NSTC will involve the socio-economic and other concerned ministries in its work besides the S&T ministries and agencies. It will promote and coordinate collaboration amongst the different agencies in the country with a view to ensuring the fullest possible utilisation of science and technology for national development. NSTC will work closely with the Planning Commission.

## VIII EPILOGUE

101 We have briefly described a possible philosophy for perspective planning and have suggested certain priorities. We have concerned ourselves with the essential aspects of S&T inputs to our national planning, and also touched on planning for S&T and the role of S&T in industry. The mechanisms for implementation are of great concern to us and we have made some suggestions in this regard. We believe that it is extremely important for us to succeed in our planning process, for it is only success that will vitalise our society and trigger it into further action.

102 In presenting an approach to perspective planning through science and technology, we realise that no

document prepared by a few individuals on a topic of such vital significance can be entirely complete. We have chosen a few aspects of crucial importance to development to illustrate how science and technology planning can be more effective and meaningful. We are conscious that there are many other areas which are likely to be of equal importance and which we have ignored. This document is not intended to be comprehensive but only illustrative and we hope that it conveys the spirit of S&T planning that we wish to suggest.

103 While planning is often understood to be a highly centralised exercise at the national or state level, it has to really happen at the working level. We have to prepare plans which address themselves to the burning problems of the present and at the same time address the future. Each institution will have to work out a perspective plan with the cooperation of the working people of the institution. Each ministry, department and agency will have to prepare a perspective plan which takes into account various institutional plans. It is only on the basis of such thoughtful and imaginative exercises carried out at all levels that we can develop a national perspective and find a modality for day-to-day action and achievement.

104 It is our hope that this approach paper may act as a catalyst in the preparation of perspective S&T Plans by institutions, agencies and departments. This would be a fitting tribute to Pandit Jawaharlal Nehru during his centennial year. This would also contribute to the preparation of the Eighth Five Year Plan and enable the country to achieve excellence and economic development.

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## ANNEXURES

### ANNEXURE 1A

### COMPOSITION OF SCIENCE ADVISORY COUNCIL TO THE PRIME MINISTER*

1. Prof. C.N.R. Rao,
Director,
Indian Institute of Science,
Bangalore-560012. — Chairman

2. Prof. V.L. Chopra,
Professor of Eminence & Head,
Biotechnology Centre,
Indian Agricultural Research Institute,
New Delhi-110012. — Member

3. Prof. Madhav Gadgil,
Centre for Environmental Sciences,
Indian Institute of Science,
Bangalore-560012. — Member

4. Dr. A.S. Ganguly,
Chairman,
Hindustan Lever Limited,
Backbay Reclamation,
Bombay-400020. — Member

5. Prof. R. Narasimha,
Director,
National Aeronautical Laboratory,
Post Box No.1779,
Kodihalli,
Bangalore-560017. — Member

6. Prof. J.V. Narlikar,
Prof. of Astrophysics,
Tata Institute of Fundamental Research,
Homi Bhabha Road,
Bombay-400005. — Member

7. Dr. Sekhar Raha,
Chief Executive,
IEL Limited,
Post Box No.267, Panki,
Kanpur-208001 (U.P.). — Member

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*Constituted by Cabinet Secretariat Notification
F.No. A-11019/1/86/Ad.1 dated February 4, 1986.

8. Dr. P. Rama Rao, Member
Director,
Defence Metallurgical Research Laboratory,
Hyderabad.

9. Dr. P.N. Tandon, Member
Deptt. of Neurosurgery,
All India Institute of Medical Sciences,
New Delhi-110029.

Secretary to the Council

Dr. P.J. Lavakare,
Adviser,
Deptt. of Science & Technology,
Technology Bhavan,
New Delhi-110016.

Terms of Reference

The Council will advise the Prime Minister on:

a) Major issues facing Science and Technology today;

b) The health of Science and Technology in the country and the direction in which it should move; and

c) A perspective plan for A.D. 2001.

The Council will also look at specific problems with different scientific departments, policies, priorities for research and technology missions, etc.

ANNEXURE 1B

## ORDER EXTENDING THE TENURE OF THE COUNCIL*

With the approval of the Prime Minister the term of the Science Advisory Council to the Prime Minister, which was constituted *vide* Resolution No.A.11019/1/86-Ad.I, dated 4th February, 1986 for an initial period of two years with effect from 4th February, 1986, has further been extended for a period of 2 years with effect from 4th February, 1988.

2. The Prime Minister has also approved that the Council would include the following two additional members:

1. Dr. R.A. Mashelkar, NCL, Pune.

2. Shri S.G. Pitroda, Adviser to PM on Technology Missions.

*Order No.84(A)/1/1/88 Cab. III dated 3.2.1988.*