AN APPROACH TO THE SCIENCE AND TECHNOLOGY PLAN

V.S.

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NATIONAL COMMITTEE ON SCIENCE AND TECHNOLOGY

DEPARTMENT OF SCIENCE & TECHNOLOGY

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FOREWORD

As India enters the twenty-sixth year of her independence and approaches the last quarter of this century - a century that truly belongs to science and technology - she carries with her substantial scientific and technological capabilities. These have been built up over the last two decades in the belief that science and technology will make their contribution to the economic, social and cultural transformation of the country.

There can be no denying that science and technology have made significant contributions to India's development. Nevertheless, there is an unease about the rate and direction of our scientific and technological progress. Are we pursuing the right scientific goals? Are we undertaking enough Research and Development? Are we getting value for the money we spend on scientific and technological research? Is the balance between so-called "basic" and "applied" research about right? Are we training the right kind of scientists and technologists? Can we plan science? These and similar questions are being asked of those inside and outside government who are engaged in the funding, management and performance of the nation's scientific and technological effort.

It is the conviction of government that if science and technology are to make an impact on the quality of life in our country, then scientific and technological activity must, and can, be planned and deliberately directed towards the fulfilment of national goals.

Planning for science and technology in the context of national goals is a formidable task. Nevertheless, for the first time in this country, a Science and Technology Plan is being prepared by the National Committee on Science and Technology (NCST) through the active participation of several hundreds of working scientists and technologists and economists, town-planners, public-health officials, industrial managers, administrators and other professionals. The range of expertise required and the variegated nature and interrelatedness of the issues, ranging as they do from defence to ecology, require the adoption of an integrated systems approach in planning and implementation.

A large number of complex issues arise in the course of preparing a Science & Technology Plan. This document is an exposition of the current thinking of the NCST on these issues. The policy frame and proposals set forth in this document have the general approval of the Government.

The NCST is deeply conscious, however, that it is not the repository of all the wisdom on the issues involved; nor does it envisage that current thinking on these issues will not undergo modification and change. Accordingly, the ideas presented in this document are offered for public discussion and debate and the NCST invites all to help it with the task of preparing the science agenda for a new generation.

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1st January 1973

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0. INTRODUCTION

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0.1 *On Science in a social frame*

The idea that the laws of nature can be understood by man, and that man can use this knowledge for his own ends is, historically considered, a relatively new idea. It has, nevertheless, proved to be a powerful one: the dominating feature of the contemporary world is the intense cultivation of science on a large scale, and its systematic application to meet the economic, social and cultural needs of the peoples of the world.

Science & Technology have led to a radical transformation of man's material environment. They have also given him new tools of thought which have, by displacing respect for authoritarianism and acceptance of revealed knowledge by rationalism and experimental method, played a most significant part in the transformation of traditional, closed societies into modern open ones.

The pursuit of scientific enquiry and the systematic application of the fruits of such enquiry to the task of bettering the human condition are activities performed by people in intense communication with each other. Scientific research and the application of technology are thus social activities. It is this view of science as a social activity, and hence with a historical character, which enables one to conceive of the planning of science.

If science be thus viewed, it is not enough for scientists to proclaim and demonstrate, by borrowed or indigenous example, the impact of science on society. It is also required of them to understand the inverse interaction - the impact of society on science; for, the religious and social impediments in our society to the deployment of science and technology are long-standing and deep-rooted. We cannot deploy them in such a way that they merely outflank and then co-exist with these impediments. We cannot also destroy existing social relationships at such a rate as to leave a multitude of rudderless beings in an unfamiliar sea. If scientists are to ply their powerful tools with wisdom and humanity, they must fully comprehend the role of science and technology as the chief agents of contemporary social transformation. This they can only do by going out into the milieu in which they are placed and understanding it.

0.2 On Science, Technology and Development

Following the realisation that science as a means of understanding the natural environment, and technology as the means of controlling and managing it, are essential tools for the efforts of achieving national objectives, the industrially advanced countries spend large resources on scientific and technological activity. Typically, they spend between 2 and 3 per cent of the total value of their goods and services - their gross national product (GNP) - on Research and Development (R&D). Several times this amount are additionally spent in converting the results of this R&D into a socially valued artefact which is then made readily available to the potential buyer or user. This may be a product, such as a new variety of wheat, available in a shop; or it may be a manufacturing process such as a method of converting low-grade coal into oil, available with a firm of consulting engineers; or it may be a method of operation, such as a new way to organise information, which is taught in educational institutions.

By contrast, a characteristic feature of developing countries, such as ours, is the meagre resources devoted to science and technology. Typically, these countries spend about 0.2% of their respective GNP's on R&D and not much more than this on the follow-through activities so essential to carry the results of this R&D into society. This gross neglect of science and technology has had far-reaching deleterious effects on the ability of our countries to develop and organise indigenous technology to the purpose of raising the nutritional, health and living standards of our peoples. Not only that, the neglect has also adversely affected the ability of our countries even to absorb foreign technology.

It has also meant that we have been unable to capitalise on the role of science as a modernizing force; a force which injects into society a certain world view. The world view of science implies that nature can be understood and that this knowledge can be used. This idea is still alien to a large segment of the peoples of the developing world.

Science and technology are basic to our efforts to increase production and, above all, to make such increases cumulative and self-sustaining. Every "model" of development, implicitly or otherwise, presumes the application of science and technology to agriculture, industry, health and family planning and the service sectors of the economy, in whatever other respects the models may differ.

The increase of land and labour yields in the agricultural sector especially depends upon higher levels of understanding about the environment and the technological means to control and manage it. It depends upon an understanding of genetic principles; of season and weather; of plant nutrients, both natural and artificial; of the problem of pests and blight. It also depends upon the judicious manufacture and development of proper tools, machinery and skills. Industrialisation means the introduction of a host of technologies from manufacture to distribution, periodically updated and renewed. Health demands the generation and effective deployment throughout the population of the knowledge and skills to prevent and cure disease whilst the rapid spread of education requires the technological tools of mass communication.

These are some of the most obvious senses in which science and technology are necessary to development. But there is more to development than a mere quantitative increase in production. Indeed, an increase in production may well be more a consequence of development than its essence. Development is thus more than just growth: it encompasses the spectrum of total human betterment which includes healthy, social well-being and the maximal realisation of human potential. Good nutrition, family planning and maternal and child health services are some of the principal requirements for healthy growth and development. Social, economic and health factors are involved in human development in an interrelated manner. To these must be added education which has a profound influence on, and can be a vital factor in enhancing, the level of development.

Moreover, even in the context of growth, what is at issue is not so much an increase in production per se but a sustained and cumulative increase in the capability to produce. This capability ultimately is developed within people with the outlook, knowledge, training and equipment to solve the problems posed by their own environment and to thus be able to control their environment rather than be controlled by it. The capability has grown in the now rich countries by a historical process, sometimes natural and slow, sometimes planned and even forced, not infrequently aided from abroad but always also indigenous.

The result of this historical process has been a qualitative social change in the now industrially advanced societies. A change which, admittedly, has not always been such as to raise the sum of human happiness. But the people in these societies are generally aware that the environment can be understood and managed for their benefit; and a large number of them are trained in the systematic use of scientific method in order to do so. It is this awareness and these skills which are necessary to development and which underline the application of science to production. Development can only take place if science and technology are viewed as organic parts of society rather than as esoteric "inputs" externally injected into it.

0.3 *On development through imported technology*

The international division of effort in science and technology is heavily weighted in favour of the industrialised advanced countries of the world. For instance, it has been estimated that over 90 per cent of the world's R&D expenditure takes place by, in and for the developed countries, of which about half is spent on research for military ends. Ninety per cent of scientists that ever lived are living today and 90 per cent of them are now in the few developed countries of the world. In addition, a significant fraction of competent scientists are lost to the developing countries through migration to the developed world. Furthermore, an overwhelming proportion of the industrial output of the developing countries is based on technologies imported from the developed countries. These statistics typify a "technological gap" between the developed and developing countries; a gap that is widening all the time.

Often the case is made that this vast expenditure on science and technology by the developed countries represents a store-house of technology which can be relied upon and utilised by the developing countries. It is argued that, by being latecomers to the process of technological development, the developing countries have the advantage of being able to import directly the technologies already available in the advanced countries without having to expend time and effort in "re-inventing" these technologies.

According to the above view, all that is needed is a clearing of the channels for the "transfer of technology" from the developed to the developing countries. Experience of policies based on this view has shown it to be not only naively simplistic but frequently detrimental to the development of countries such as ours. The lack of relevance for developing countries, most of which are tropical, of much of applied agricultural and medical research carried out in temperate parts of the world is obvious enough. According to a recent UNCTAD study, even the direct costs of the technology imported by the developing countries during 1968 was around $ 1500 million - an amount equal to 5% of the exports of developing countries other than oil, about 40% of their debt servicing costs and nearly 60% of the inflow of direct private investment. Thirdly, industrial technologies in the developed world have a pronounced labour-saving bias and are consequently judged to be inappropriate to the general situation in the developing countries where capital is scarce and labour relatively abundant. The question of choice and appropriateness of technology available from the developed countries is thus becoming a major issue as the size of the problem of unemployment in the developing countries continues to grow.

The choice of technologies is, of course, not always a matter of technology alone. Thus, whereas in an overall sense the ~~opportunity cost of~~ social cost of not using labour may be very high, prevailing pricing policies may be such as to cause the market price of organised labour in any given sub-sector to be high in relation to the price of capital. A rational decision will, in such a situation, be a choice in favour of capital. Where the choice is a purely technological one, much research is needed to adapt foreign technology to the needs of poor countries such as ours. Research of this kind is not going to be performed in the developed countries. What is more, there is evidence to suggest that in certain sectors there is not much adaptation possible in the closely interwoven technologies that characterise modern industry.

It therefore becomes imperative that a developing country should have an indigenous science and technology capacity of its own. Without it, and particularly without trained people, a developing countr country will not be able to know what useful technology exists elsewhere, to understand it, to select it, to adapt, to absorb, to repair, to maintain, to operate. At best, only in the short term can these tasks be performed from the outside.

Furthermore, the terms and conditions under which foreign technology, industrial and non-industrial, is available to a recipient country depend upon its own scientific and technological capacity. In the real world, the bargaining power of a country in the international technology market is directly related to the extent of its indigenous capability in science and technology. In the absence of such a capability, a developing country is placed in a posture of perpetual dependence <u>vis-a-vis</u> the suppliers of technology, be they the governments of the advanced countries or the large international corporations. Technology then becomes an agent of foreign domination rather than the vehicle for international development.

All this is not to imply an autarkic approach to technological development. No country can afford such an approach, least of all one that is developing. For some time to come the developing countries will have to rely largely on technology developed in the advanced countries. Although this is true of the majority of the developing countries, we in India have a large and comprehensive scientific and technological base which can, if properly utilised, provide the majority of the technologies we need for ourselves and even help the technological development of some of the other developing countries. We will, nevertheless, have to evolve a self-consistent package of policies to exploit to the full the world fund of technological knowledge. Indeed, the design of such a package could turn out to be a major, if not the central, problem of the nation's science and technology policy.

0.4 *On the fashioning of science and technology policy: the multi-dimensional problem*

Development is a process of social, cultural and technological innovation; the first two being made possible by the last. Technological innovation is a dynamic, self-generating process. Whereas the goals of scientific and technological activity are defined by human needs, the results of such activity often reveal new ways of achieving national goals in which these needs are manifested. Indeed, they sometimes reveal the possibility of setting new goals. The efficacy of the contribution of science and technology to development is determined not only by how well we utilise existing scientific knowledge to the fulfilment of national goals; it is also determined by the wisdom, skill, and vigour with which we pursue the promise of emerging scientific and technological possibilities.

The backbone of innovation is Research and Development. A characteristic feature of the industrialised countries is their considerable expenditure on Research and Development and their substantial investments in the training of scientific and technical manpower. There is a body of opinion on science and the economy which, having recognised this fact, suggests that the key to rapid development is massive investments in Research and Development. Were it but so! Our own experience, together with that of many other developing countries, and the wide variation of the growth rates of different industrialised countries with similar investments in Research and Development teach us that there is far more to gearing science and technology to the national purpose than a mere expansion of education and an increase in Research and Development.

Whereas higher education and Research and Development determine the inputs or the supply of scientific and technological resources, the capacity to use them depends upon the structure and organisation of production in the economy, upon the availability of capital and upon the quality of local manpower. They also depend upon a variety of institutional and other factors sometimes proximate to, but very often remote from, the identifiable connection between technological activity and economic performance.

It is the effectiveness of the meshing of the supply of science and technology with the capacity to use them which determines the efficiency with which science and technology are used to fulfil national goals. It is necessary that the perceived needs for scientific and technological inputs be translated into what may be called a "demand pattern" that will sustain the supply of these inputs and that will be able to absorb these and the current outputs from the substantial scientific infrastructure already established.

Central to the policy issues which relate to the utilisation of science and technology are policies which regulate the production, deployment and use of trained people in all sectors of the economy. It is most important that we enunciate a range of policies directed at ensuring the quality and relevance of education in schools and universities if we are to prevent the stupendous waste of human resources that is currently taking place. The proper response to educated unemployment and mal-employment is a deliberate restructuring of the demand pattern for human skills in both the private and public sectors together with the provision of facilities and mechanisms for continuing education and training. A mere cut-back in numbers of educated people will be counter-productive.

In order to give meaning to our determination to be self-reliant, it will be necessary to enunciate policies that will translate the felt need to use indigenous technology into a positive predilection for such technology. This will require a major commitment on the part of government to use all the instruments of public policy, be they financial, economic, legal, political or cultural to promote, sustain, deploy and effectively use domestic technology, utilising domestic natural and human resources, even if this involves distinct short-term technical, economic or other types of costs.

The preparation of a Science and Technology Plan, the formulation of policy and the provision of financial resources only secure the necessary conditions for the use of science and technology to fulfil national goals. In themselves, they are not sufficient. Implementing the policies will require a commitment on the part of government to undertake drastic organisational and managerial reform not only in agencies and institutions that generate science and technology but also in all government departments and publically owned enterprises that use science and technology. It will also require government to set up and adequately finance machinery that will monitor, evaluate, correct and re-direct the implementation of the various programmes in the Science and Technology Plan.

The attempt to fashion so wide a range of policies may well reveal the need for a new approach to the entire scientific and technological system and this in turn may depend upon basic socio-political changes. Science is not necessarily a development investment; whether it is, depends upon the form of economic and social organisation in the community at large no less than on the organisation of science itself. There is more to Science Policy than policies for science. This theme will be the thread that binds together the arguments to be unfolded in the rest of this document.

1. SCIENCE AND TECHNOLOGY POLICY IN INDIA: THE PRESENT STATE

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1.1 *Scientific and technological activities: some definitions*

The spectrum of activities covered by 'science and technology' is broad. Not infrequently they mean different things to different people. It is therefore important to define what is meant by science and technology.

Although any classification is bound to be somewhat arbitrary and will do violence to the real complexity of scientific activity, some breakdown is essential for serious analysis and policy formulation. The guiding principles of classification into the four categories below is that they all have direct relevance to the development process and will require systematic support.

1.1-1 *Research and Development*

At the heart of the "science and technology system" are those activities which are generally known as "research and experimental development" (R&D). Included in these activities are the following.

a. Basic research: research directed towards a fuller understanding of nature and the discovery of new fields of investigation, with no practical purpose in mind.

b, Oriented basic research: research focussed on a given theme directed towards a well-defined objective. Included within this is research which aims to bring within the realm of theory that knowledge which is at present empirical.

c. Applied research: research directed towards a specific practical aim to serve societal needs. Included in this are activities such as the following:

Research directed primarily towards understanding and improving agricultural productivity.

Research aimed at understanding human diseases, maintaining and improving human health.

Research aimed at increasing scientific knowledge in a specific field of industrial activity.

d. Development: the systematic use of the results of basic and applied research directed to the introduction of new materials, devices, products, systems and processes, or the improvement of existing ones. Design and construction of prototypes and pilot plants would also be covered under Development.

1.1-2 *Scientific and technological services*

Closely related to R&D are the following activities which either support and provide the raw data base for R&D or help to diffuse the results from R&D.

Geological, geophysical, meteorological and natural resources survey work, including mapping.

Scientific testing and standards services.

Scientific library and information services.

Museums, zoological and botanical gardens.

Technical and scientific advisory services including patent offices and related activities.

General purpose social and economic data collection, e.g. census, sample surveys and their analysis.

1.1-3 *Creation and diffusion of scientific and technical skills*

Scientific and technical education at all levels through the mass media or in institutions. These would include the following:

Science education at primary and secondary school level.

Science education at university, undergraduate and postgraduate levels.

Engineering colleges and the Indian Institutes of Technology.

Industrial Training Institutes.

Training in industry, apprenticeships, etc.

Field work and extension training.

Manpower planning for science and technology.

1.1-4 *Application of Science and Technology*

Application of science and technology in all sectors of the economy such as agriculture, health, industry, etc. This activity includes all the post-Research and Development elements of the 'innovation chain' such as:

Rural extension.

Marketing and storage.

Inventory control, productivity enhancement, etc.

Project implementation, scheduling.

Fabrication and construction of plant and equipment.

Design engineering services.

Technical consultancy.

In this document, 'science' will mean all of the categories of activities listed above.

1.2 *Policies for science: the pre-independence period*

India differs from many other developing countries in that it had a flourishing scientific tradition in the ancient and medieval periods. In mathematics, the names of Aryabhata and Bhaskara are familiar. In medicine, Charaka and Susruta are well known. The early developments ranging from the tables of mathematical functions to the more concretely visible observatories built in later eras bear witness to our scientific capabilities in astronomy. Iron and steel have been known and made in our country since antiquity. The use of metals in building construction, for making cannons and for making and coating household utensils were some of the early developments in metallurgy.

The development of modern science in our country is, however, not an organic extension of this earlier tradition. It is the growth of an implant by the British in a language that was alien to our people. Modern science in India thus constitutes a break from its historical antecedents.

Until the last years of British rule, the role of science and technology was understood to be strictly limited. Only such scientific and technical developments were introduced as did not lead to conflicts with the interests of the colonial power. As a consequence, science developed in an uneven, patchy way and industrial technology developed hardly at all. Thus, while efforts were made to increase the availability of exportable raw materials (and later food) or to serve the needs of the army with its Engineer and Medical Corps, very little industrial research was carried out to further promote the industries which had developed in India, or to create new ones. Notable among the institutions set up in this period were the following:

Survey of India, 1767;

Geological Survey, 1851;

India Meteorological Department, 1875;

Imperial Bacteriological Laboratory, 1890;

Haffkine Institute, 1899;

Imperial Agricultural Research Institute, 1903;

Forest Research Institute, 1906; and

Indian Research Fund Association, 1911.

At the turn of the century and shortly after, as a concession to Indian aspirations, the foundation for the basic sciences was expanded and academic science in the universities received a fillip. Thus the Indian Science Congress was inaugurated in 1914, the Indian Academy of Sciences set up in 1934 and the National Institute of Sciences formed in 1935. Significantly, industrial technology continued to be neglected.

The outbreak of the second world war brought about a radical change in the pattern of scientific and technological research in India. The colonial government, being cut off from Britain, was forced to actively develop local resources to meet the demands of war and the then existing research institutions and universities were given considerable encouragement and research grants. The Council of Scientific and Industrial Research (CSIR) was set up as a society in 1942. After the war, the Central Water and Power Commission came into being in 1945.

Also in 1945, a mission led by Prof. A. V. Hill produced a report on the organisation of scientific research in India. This had a major influence on the policies of the British and post-independent governments of India.

1.3 *Policies for science: the post-independence period*

The major events in the post-independence period were the creation of an extensive institutional network, a chain of research laboratories and the expansion of university and technical education. The CSIR which was established in 1942 was reorganised on the lines of the former British Department of Scientific and Industrial Research: an autonomous Atomic Energy Commission was formed in 1948; the University Grants Commission (UGC) was set up in 1956; and the Defence Research and Development Organisation was established in 1958.

Pandit Nehru, who deeply believed that science and technology were a key factor in national development, was the main architect who laid the foundation for the major scientific and technological developments in the country. He moved in Parliament in 1958 the Scientific Policy Resolution which indicated the Government's intent to support science and technology in order to "secure for the people of the country all the benefits that can accrue from the acquisition and application of scientific knowledge". Since the enunciation of the Resolution, scientific activity has quickened in pace and broadened in scope so that now we have a substantial infrastructure of institutions and capabilities in a variety of technologies covering several fields from agriculture through medicine to defence, atomic energy and a host of industrial technologies.

This rapid development of scientific activity in India is reflected in the substantial increase since 1958 in the resources devoted to Research and Development (R&D) and the number of people engaged in R&D. Table 1 below shows the total expenditure on R&D and the number of scientific and technical personnel employed in R&D establishments in both the public and private sectors since 1958.

From 1947 to 1955, decisions on the setting up of scientific institutions and their funding were arrived at through a relatively unstructured policy process. Later, with the expansion of the Planning Commission in the preparatory phase of the Second Plan, the responsibility for integrating science into development fell to the Member for Perspective Planning and the Scientific Research Division of the Commission. The responsibility of the Planning Commission in the area of scientific research was spelt out in 1959 as: "... the setting up of such independent committees, panels, etc. of scientists, as need arises, and taking their views and recommendations into consideration in connection with Five Year or Annual Plans for economic development and the attainment of national aims..."

TABLE 1

YEAR	Total R&D expenditure (Rs in crores)	R&D expenditure as per cent of GNP	Total number of scientific and technical personnel employed in R&D establishments
1958-59	29	0.23	20,724
1965-66	85	0.39	-
1968-69	131	0.44	73,634
1969-70	146	0.44	87,613
1970-71	173	0.48	94,686
1971-72	214*	0.54*	103,767

* Figures based on budget estimates.

But during the Second and Third Plans, only one such panel was set up for formulating schemes for the research activities of the Council of Scientific and Industrial Research and the scientific organisations associated with the Ministry of Education. None of the other scientific agencies of government was brought in for coordination within what was meant to be the framework of a national plan for science.

With a view to designing a mechanism for obtaining scientific advice at the highest level, the Government set up the Scientific Advisory Committee to the Cabinet (SACC) in 1956, with explicit and wide-ranging terms of reference. This Committee had, however, no mandate for the preparation of national science plan. However, the SACC did set up ad hoc working groups, on specific scientific issues, involving some scientists and technologists.

The SACC was replaced by the Committee on Science and Technology (CoST) in 1968 with the Member for Science of the Planning Commission as chairman and comprising Agency Heads and a few individual scientists, an economist and a technologist as members. The terms of reference of this Committee were a little wider, but did not include the preparation of a science and technology plan. CoST did, however, set up a number of standing committees, working groups and ad hoc committees, involving a number of working scientists, technologists and industrial interests for many of the scientific and technical areas it examined.

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.

Thus in 1970-71, while agriculture contributed to roughly half the gross domestic product, the central and state R&D allocation for this sector was about 21% of the total. Whereas the Atomic Energy and Space programmes alone accounted for 20% of the total expenditure on R&D in the central sector, medical research, health and family planning absorbed only about 5%. While the share of research and development on defence was 12%, irrigation and power accounted for less than 2%, and natural resource surveys (excluding oil) together accounted for less than 8% of the total expenditure on scientific activity in the central sector.

1.4 *Major deficiencies in our Science Policy*

The first major deficiency of Science Policy in our country is thus revealed. It is an absence of rational policies for science or guiding principles for decision-making on the magnitude and distribution of funds for scientific research. This deficiency is, in part, a consequence of others discussed below.

The question "how much for science and technology?" can only be answered by asking and answering two other questions; namely, "what is this science for?" and "what is the technology supposed to do?" Neither question appears to have been asked in the past, at any rate not explicitly within our planning machinery.

An attempt to answer the questions would involve an analysis of the broad social and economic setting of each of the areas of scientific activity. It would also require an analysis of the pattern of the demand for science and technology inputs in the existing system of production and industrial and non-industrial services. These demands would stem from (a) an array of direct requirements from import substitution to waste utilisation; and (b) a range of indirect requirements from the necessity to build up and diffuse on a large scale various capabilities in science and technology. Demands would also be perceived in work directed towards enhancing the productivity of existing agricultural and industrial activity and from the two important welfare services of health and education. Such analyses have not been made.

The second deficiency is in the set of policies relating to the performance of our scientific institutions. The most serious of these has been the continued neglect of badly needed organisational and administrative reform, including personnel policies. Where reforms have been recommended, these have not been fully implemented. The values and methods of decision-making in the majority of our scientific institutions continue to be either feudal in character or they tend to subordinate the role of the scientist to that of the bureaucrat.

The third major deficiency concerns our policies towards the import of technology. It has not been recognised in adequate measure that it is very necessary to gear the indigenous scientific effort in such a way that it complements and, in time, displaces the imported technology. Also, there has not been a determined effort to utilise the capabilities already developed in the country. This lack of effort has, in considerable degree, been due to the absence of an active agency to promote indigenous technology.

The fourth deficiency has been in the area of matching the demand for science - such as has been perceived, with the supply of science - such as has been performed. The communication gap between industry and the industrial research laboratory remains large. When scientific institutions have had to interact with government departments, the latter have been totally unable to appreciate the imperatives of science and the requirements of scientists. Emphasis on financial trivia and a lack of appreciation of the cost of lost time are the chief characteristics of the existing situation.

These deficiencies cannot be dealt with piecemeal and one at a time. The task of utilising science and technology to provide the minimum needs of our populace is all of a piece. It is the firm conviction of the NCST that only through comprehensive planning and determined execution can the crushing burden of poverty be lifted from the backs of our people.

We turn now to the basic strategy of the Science and Technology Plan.

2. THE STRATEGY FOR SCIENCE AND TECHNOLOGY IN NATIONAL DEVELOPMENT: SOME ISSUES OF POLICY

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2.1 *Preamble*

The setting of priorities in R&D and the enunciation of scientific and technological tasks in the context of national goals, constitutes a formidable challenge to the making of Science Policy. The "system" within which the policies have to be framed is a large and complex one. We do not, as yet, have an adequate rationale for dealing with such a complex system. Inevitably, a process of trial and corrected error must be the methodology of policy formulation. Such an approach raises a very large number of issues which may, for convenience, be classified into four categories.

Firstly, there is the question of the basic strategy of the scientific and technological effort we are going to undertake during this decade, and the policies needed to execute it. This has four aspects: policies relating to the provision and satisfaction of the basic minimum needs of the population; those concerning the achievement of self-reliance; those connected with the import of technology and those involved in deriving maximum socio-economic benefit from the scientific and technological resources built up so far and the activities currently under way.

Secondly, there are issues of policy which arise in considering the choice and appropriateness of technologies being used in the economy. These issues arise in the context of each of the four aspects of the strategy mentioned above.

Thirdly, there arise issues pertaining to the supply of science and technology from our scientific and technological institutions and educational establishments.

Finally, there is a range of policy matters associated with the problem of matching the demand for technology with its supply.

The sections below deal with these four policy categories in turn.

2.2 *Strategy of the science and technology effort*

2.2-1 *Meeting minimum needs*

Of late, a useful distinction has been made between growth of GNP and development. It is necessary to explain the distinction and to connect it with the demand for scientific and technological inputs into society and the economy.

It is obvious enough that the objective of development is a sustained increase in the material well-being of society as a whole through the better utilisation of natural and human resources. It is equally clear that if there is such an increase in material well-being, it may well be reflected in a growth of per capita gross national product. But it is a well-known feature of our economy that in the past the benefit from these increases has accrued largely to the metropolitan centres at the expense of the rural areas. As a result, the prevailing consumption pattern is dominated by the outputs from past investments made, and appetites whetted, in the "metropolitan" sector; while a significant section of society and the economically viable resources are still cut-off from the market. This persistent "dualism" is reflected in the Planning Commission's estimate that between two-fifths and one-half of our population exists in abject poverty and that the absolute number of people in such a condition is just as large today as it was two decades ago.

Since a very large proportion of our people functions outside the paraphernalia of a market economy, it is clear that the demand for technology (and hence the capacity to absorb and utilise it) comes largely from a small urbanised, economically and socially privileged group. Development on the other hand, must involve the integration of the society and the economy to create the conditions for a sustained improvement in material well-being for the whole society. It must be emphasised here that eliminating "dualism" is not simply a matter of reducing income disparities. Dualism will be eliminated only if the ability to mobilise, deploy, and manage human and natural resources is distributed widely through the economy. This can be done only through the fullest possible application of scientific and technological knowledge.

The pattern of demand for such knowledge as will affect the rural sector will depend very crucially on how well we orchestrate a whole gamut of policies concerned with that sector. For example, policies concerned with land tenure and reform; cooperatives; resource surveys; pricing of agricultural commodities; markets, storage and distribution; rural credit; extension services; technical assistance; irrigation programmes; health schemes; forestry and fisheries development etc. In a very direct way, the question of whether we should undertake R&D into new types of tubewells or tractors is related, apart from technical considerations, to such issues as the size of land holding; the availability and the price of electricity; the provision of repair and maintenance facilities and the price of credits, all of which are not in any sense "given" but very much matters of government policy. We should add that it is only through such coordination of several sets of contingent policies that we have been successful in bringing the benefits of agricultural technology (the "green revolution") to a significant proportion of our rural population.

2.2-2 *Achieving self-reliance*

Self-reliance implies an inherent strength in the community for growth and development and, for the economy as a whole, a long-term equilibrium in the balance of payments including payments for technology in all its aspects. In other words, our legitimate concern to be independent of external financial assistance should not lead us to become even more dependent on external technological assistance. A continuation of our present state of technological dependence will lead to significant financial costs in both domestic and foreign currency; perpetuate the fragmentation of our industrial system which foreign collaboration has brought about; continue to deny challenging employment to our engineers and scientists and compromise what is perhaps even more important than production per se - the capability to produce. In sum, the nation has to recognise that technology is a major national resource and a vital element in the task of achieving self-reliance. We have recognised the validity of this assessment in times of military confliects; it now has to be appreciated in the context of the 'war on poverty'.

In the economy as a whole then, the basic thrust of the scientific and technological strategy must be the achievement of self-reliance. This means the utilisation of a mix of imported and indigenous scientific and technological resources; a mix in which the proportion of the indigenous component will steadily increase both in quantity and, more importantly, in the number of critical national projects that are based upon indigenous technology. Our attempt will be to fashion a strategy which is the application of the adage of the late Homi Bhabha: if technology is regarded as the engine of the development process, then foreign technology is acceptable only as the super-charger of a domestic engine and never as the engine itself.

Whereas self-reliance is our goal in the economy as a whole, in the areas of food, energy and to the extent possible in defence equipment, our goal must be self-sufficiency. This will imply that the entire resources base in these areas - materials, manpower, technology and management - is sought to be generated within the country. Strategies of self-sufficiency make special demands on domestic policies and programmes in a number of areas including science and technology. For instance, policies of pricing and government procurement (e.g. price support in agriculture, procurement of defence stores, differential tariffs for feed-stock for power stations) need to be properly meshed into such strategies of self-sufficiency in order to generate and sustain the supply of the relevant technologies and ensure their utilisation. In science and technology proper, two sets of policies will be required. One to ensure that we derive the maximum benefit from the existing infrastructure and another to secure the future through a strong programme of oriented basic research in practically all the scientific and technological fields relevant to each sector where self-sufficiency is desired.

Hitherto, there has been no institutional framework within which such a strategy of self-reliance and self-sufficiency could be systematically formulated in the various socio-economic sectors. However, with the decision to bring all our scientific and technological effort within a Plan interwoven with the national development plan, the situation has changed. It will be the endeavour of the process of planning science and technology for development, to first itemise the scientific and technological tasks that need to be undertaken in order to execute the projects to be included in each sector of the national plan; to then assess, in the context of the available scientific and technological resources, the extent to which those resources can be augmented, and the lead-time available, for those Fifth Plan projects for which the necessary technology can be supplied by domestic sources. To supplement our efforts some imports of scientific and technological resources may still be necessary. Such planning will call for considerable analysis and evaluation at the micro-level; tasks which are inevitable if we are to give real content to our determination to be self-reliant.

An important consideration in any effort to use science and technology to achieve self-reliance is the realization that R&D projects may have gestation periods of five years or more. If economic and social policies are changed in the meantime, thus changing the demand for technology, some of the resources deployed on R&D may not yield the expected results.

There is also the possibility that once R&D activity gathers momentum, there develops a lobby for it and it becomes difficult to shift economic priorities or to terminate research projects that no longer serve economic or social goals. Special care must be taken to ensure that "planning" for science and technology does not become a matter of acquiescing to the power of advocates of this or that project rather than a matter of rational decision-making.

In case of the industrial sector, the strategy for self-reliance implies three types of policies. The first relates to the vigorous promotion and use of domestic technology in all areas where the factor proportions demanded by such technology match the existing supply. The second set of policies relates to the financial and managerial control of industrial enterprises. The third set is associated with the tactics of import substitution and export promotion. Because the influence of such tactics on the demand pattern of domestic technology (and hence upon the goals of R&D) is considerable, they bear elaboration here.

If import substitution essentially means the replacement of imported machinery, components and materials, by one-to-one indigenous substitutes, then it is implicitly assumed that the present pattern of consumption in the country will continue. But it was noted that this consumption pattern is dominated by the "metropolitan sector" (which would, of course, include the richer farmers). R&D resources devoted to import-substituting the relatively sophisticated "metropolitan" technologies will, therefore, have a distinct "opportunity cost" in so far as R&D resources are not being devoted to other areas for which there is no market demand, though there is social and political demand. The distinction is between "demand" and "need".

Similar observations are in order in respect of the consequences for R&D of export promotion strategies. Export promotion in the non-traditional sector (without excessive subsidy) will demand the adoption of technology policies that enable indigenous manufacturers to match the productivity of their competitors in the advanced economies. This might require, in a particular case, the substitution of capital for labour by the employ of such machinery as numerically-controlled machine tools. In so far as R&D resources are devoted to the development of such machines, there is a potential loss of technological effort in other areas which are also defined by social goals; employment creation for example. Even if it is not possible for us to compute these opportunity costs, it is necessary to be aware of their existence and to make a conscious effort to reconcile competing demands. It is also important to recognize that considerations of this kind have a major bearing on the composition and effectiveness of the nation's scientific effort.

2.2-3 Policies towards the import of technology

A great many issues of policy are involved in executing strategies of self-reliance. But perhaps no other single set of government policies has such a profound influence on the demand for, and utilisation of, domestic technology as policies towards foreign investments in the manufacturing and mining industries and the import of foreign technology in, besides industry, such sectors as transport and communications. The considerations that are relevant to this issue are many and complex but there are five basic points worth mentioning here.

The first point to be borne in mind is that the price one pays for foreign technology (either as a lumpsum or a continuing combination of royalties, dividend repatriations, technical fees, etc.) is not in any way "fixed" by market for such technology. The market is a monopolistic one and the price of technology is a matter of bargaining between the potential supplier and his client.

Secondly, the frequent tying of 'aid' from the developed countries restricts the "market" from which technology may be bought. Even in normal circumstances the cost of items of technology from the aid-giving country may be high in relation to that available elsewhere. When the seller of technology is aware that the buyer is restricted by 'tied aid' to his market area, the price of technology invariably rises steeply. Furthermore, the technology imported under 'tied aid' has, in the past, often been inappropriate or obsolete.

Thirdly, our private sector has, by and large, no compulsion to bargain with the suppliers of technology because, internally, it enjoys a seller's market and price is not of prime concern.

Fourthly, the public sector is unable to bargain for two reasons; those who negotiate agreements for imports of technology by the public sector often do not have the knowledge of the minutiae of the technology to estimate its value nor do they have the detailed knowledge about alternative sources of technology, domestic or foreign, to establish the price. There is only one way to bring down the price in any bargaining situation: hold out the possibility of going elsewhere or of developing the technology domestically.

Fifthly, until now, except for some isolated instances, our domestic scientific and technological system, and particularly that part of it dealing with R&D, has not been coupled to the institutions importing technology nor has it been charged with the responsibility of learning, adapting, improving and then displacing further imports of similar technologies. It has been argued that this kind of an approach is not feasible in the real world. But the instances where such coupling has come about indicate that the actual problems of adaptation at the enterprise level are entirely manageable. What is needed therefore is the enunciation by government of explicit policies for the gearing of the domestic scientific effort to complement imported technology.

Three main policy conclusions may be drawn from the above.

a) The import of technology should not be tied to the availability of aid.

b) It is of the utmost importance that we are thoroughly familiar with the alternative types and sources of technology to perform the same task.

c) We must explicitly gear the domestic scientific and technical effort to learning, adapting, improving and then displacing continuing imports of similar technologies.

The last two tasks will make specific demands on domestic technology and will necessitate the involvement of working scientists in policy making and implementation in respect of foreign investment and foreign technology; for, it is only they who generate, or have ready access to, the kind of information that is crucial to redressing the bargaining balance in favour of the buyer of technology.

2.2-4 *Policies towards maximising the utilisation of existing scientific and technological resources*

As we enter the 26th year of our Independence we carry with us a considerable stock of scientific and technological know-how which is far from fully utilised. An important component of our science and technology strategy must therefore be the immediate application of this stock to prevailing national problems. The problem areas of standardisation, quality control and the technological elements of better plant utilisation, maintenance and safety are all amenable to solution by a concerted application of existing skills. The rural sector could greatly benefit from programmes of crop storage in hygienic pest- and weather-resistant structures, repair and maintenance of pumps and preventive maintenance of agricultural, transport, crop-spraying and pest-control equipment. All these activities will make heavy demands on the "software" or management aspects of technology utilisation and will require systematic planning and support.

In so far as the results of R&D per se are concerned, there is need, particularly in the area of industrial research, to utilise fully all the available institutional capabilities without being constrained by departmental jurisdictions. At present there is a tendency to regard the CSIR as the only government scientific agency capable of, and responsible for, generating industrial know-how. But a large part of the research, design and engineering capabilities built up in the Department of Atomic Energy, the Railways, the Defence R&D

Organisation and even the Department of Space, are relevant to the technological needs of our general industrial development effort. The impetus to develop these capabilities has come from the specialised primary missions of those agencies should not prevent recognition of the fact; by the agencies themselves, by industry or by government. It is important therefore to bring the know-how and expertise already developed by those agencies into the national pool, and to commit a systematic effort to commercialise the relevant technology, wherever it has the potential to meet specific national requirements. In this connection, there is urgent need to bolster the efforts of such agencies as the National Research Development Corporation and the Inventions Promotion Board to commercialise the know-how already developed in government laboratories and by individual inventors. If this is not done on a priority basis, we may well find ourselves importing know-how which is potentially available indigenously.

The same approach also needs to be adopted in regard to the utilisation of the R&D capacity of agencies other than CSIR for generating new general industrial technologies needed during the Fifth Plan. This may be done, for example, by agencies taking on R&D projects for the results of which the customers are public or private sector companies in the general economy, rather than only production enterprises associated with the agencies themselves. At the same time, systematic efforts must be made to see if some of the technological needs of agencies such as Atomic Energy and Defence cannot be provided by the R&D laboratories of CSIR, of specific public-sector companies, or of one another. Such integration of the various elements of our R&D system will not be easy, but the returns to the nation are likely to be sufficiently great to warrant a major exercise in rational integration of our scientific and technological effort.

2.3 *Policies towards the choice of technologies: the question of appropriateness*

A technology does not exist in isolation. It grows out of, and is closely fitted to, the technologies, resource endowments and pool of human skills already existing in the economic structure of a nation where the technology is developed. But the technologies that comprise our economic structure, particularly in the industrial sector, are essentially transplants from the industrially advanced nations. Our resource endowments, on the other hand, are different from those existing in the industrialised nations. In particular, we have an abundance of manpower whose skill endowments do not match the requirements of the industrial technologies we possess. We are also short of capital and our effective markets are much smaller than those in the highly industrialised countries. In consequence, questions of appropriateness have arisen in the context of the choice of technologies, imported or indigenously developed, whether in agriculture, industry, transporation or other sectors of the economy.

A judgement on the "appropriateness" of a given package of technologies can only be made at the time of project appraisal in the context of the rest of the innovation chain in which such a package is placed and in the context of the goals to be achieved in a specified time-span. The key element in the problem of the choice of technologies is thus not only the labour/capital ratio but also the gestation period of any given set of interwoven technologies to yield economic and social returns.

A balanced approach to socio-economic development in our predicament must involve increases of output and surplus and the provision of employment, occuring simultaneously in both space and time. Such an approach requires us to use a judicious mix of technologies ranging from the most capital intensive to those amenable to the utilisation of organised labour. In the area of natural resources survey and mapping, for example, it is imperative that we utilise fully our large stock of trained technologists in such a way that their work on the ground forms part of an integrated approach to resources survey that includes remote sensing from satellites and aircraft. Self-reliance will also mean the use of skill-intensive technologies to provide the large-scale inputs to agriculture; for example, fertilizers and pesticides. In the industrial sector, materials handling is an activity that lends itself to the use of low-skill labour and attention needs to be paid to developing a set of technologies intermediate between carrying-on-the-head and the conveyor belt.

An approach which needs special attention is the use of capital intensive production techniques in the machine-building sectors to manufacture plants capable of producing consumer goods on a relatively small scale, and with high labour/capital ratios. For example, using complexes like that of the Heavy Engineering Corporation to produce a large number of small-scale plants, such as those for the manufacture of sugar, which should enable us to combine the economics of large production runs of standard equipment, with small-scale output from that equipment.

The issues involved in the choice of technologies are many and complex in character. There is a great need for setting up within the planning system institutional mechanisms and analytical methods which will enable determination of the "level" of technology (as determined by the labour/capital ratio, scale of output and skill intensity for routine operation as well as for maintenance and repair) required for each type of activity, within the context of the overall development strategy chosen. This will call for close cooperation between economists and technologists and for greater sensitivity on the part of the scientific and technological community to the problem of choice of technologies.

2.4 *Some issues of policy relating to the supply of science and technology*

While research policy sets the goals for R&D and translates them into specific scientific and technological tasks, several other policies influence the supply of scientific and technical effort.

The first set of policies relates to scientific and technological education, training and research. The workability of the entire scientific and technological effort depends upon the availability of sufficient numbers of people, appropriately trained and educated. It will be necessary to enunciate policies that will help to ensure the quality of our scientific and technical personnel and the relevance of the education they receive for the tasks they are scheduled to perform. In personnel policies and career development in our scientific and educational institutions, reform of a fundamental kind is long overdue. The issue is simple. It is people who do science; if we treat badly, we will get bad science.

people

The productivity and effectiveness of personnel with higher-level skills is crucially dependent upon the support they receive from middle-level manpower such as technicians, overseers, supervisory staff and administrative assistants. Policies for the proper education and training of adequate numbers of such staff is an integral part of manpower planning for science and technology. Such policies will include programmes for the production and dissemination of technical manuals in Indian languages.

Rapid obsolescence in technical education is a recognized phenomenon. We need to realise that education is a continuing process that does not end with a university degree. It is essential that we have policies that enable people to obtain continuing education throughout their working lives.

Hitherto, the academic sector has been outside the main-stream of research directed towards the solution of problems posed by our efforts to fulfil national goals. Outside of a few notable but exceptional programmes, we have not benefited from the obvious advantages of utilising the substantial store of scientific talent in our universities.

Two different, but related, policies are necessary for the programme to support research in the academic sector. The major scientific agencies will need to formulate policies that farm out to the universities most of the basic research relevant to their respective programmes. We also need a central source of funds to promote general and oriented basic research in universities and other academic institutions.

Two other matters bear mention here. The first relates to our policy in respect of utilising Indian scientific talent resident in the advanced countries. It is becoming clear that policies designed to bring back all personnel resident abroad may be counter-productive. Policy in this area must be designed to fill gaps selectively in high-level scientific leadership in well-defined fields that derive from well-perceived needs. Such policies should go a long way in displacing the need for "science aid" from the developed world.

The second matter relates to imparting job experience to students. The organised sector, both public and private, must be made to discharge its social responsibility in respect of providing work experience for students in agricultural and technical universities, colleges and training institutes.

The second set of policies relates to what has been defined in section 1.1 as scientific and technological services. These need to be greatly strengthened and supported both quantitatively and qualitatively. We have been very tardy in realising their value. We have, for example, long neglected the entire area of natural resources survey. It is plain that it will be impossible to achieve the twin goals of self-reliance and providing minimum needs until we enunciate policies that enable us to fully survey, map, and carefully manage the exploitation and use of our natural resources to best advantage. Virtually all our other policies for scientific and technological development will come to nought if we do not secure for ourselves the use of our natural resources.

To mention another example, we need to realise that the acquisition, storage, retrieval and dissemination of economic, social and technical information in time and on a scale that meets the requirements of other scientific tasks are activities that cannot be performed on the cheap. The development and use of information technologies together with the enunciation of a national information policy is of prime importance.

The third set of policies relates to the setting up of new institutions or organisations in areas such as research, design and testing whose purpose is to intensify activity in specific, closely defined fields in order to better serve the needs of user enterprises in industry, agriculture and such utilities as electricity and transport. Typical examples would be the setting up of design engineering organisations either attached to public-sector enterprises or as independent units, particularly in the areas of mining, shipbuilding and power engineering; a High-Polymer Laboratory; a Corrosion Control and Advisory Service and a National Remote Sensing Agency. The characteristic features of such institutions should be their growth out of research and design groups in existing institutions and their close institutional alliance with the users of the technology. Where feasible, the laboratories could be formally associated with academic institutions.

A characteristic feature of industrial research in our country has been that the bulk of the effort has been carried out in government laboratories. Companies, whether public or private, have played a relatively small role. Although there has been some change in this situation since 1968, the fact remains that today R&D expenditure in public and private sector industry amounts to only about Rs 14 crores a year. With output from large-scale industry running at around Rs 5,000 crores, it is evident that even in purely financial terms, the R&D outlay being made by industry is woefully inadequate. However, surveys have shown that much of this outlay on "R&D" is actually spent on routine operations such as quality control and testing and that genuine innovation in product design or process development is extremely rare. More seriously, it appears that, except in a few companies, the issues regarding the way in which R&D resources are deployed and the goals towards which they are directed are not perceived by company managements to be important aspects of corporate policy.

This state of affairs is a source of serious concern. It is important therefore to devise policies, additional to the generous tax provisions which already exist, which will enhance the amount of innovation-directed R&D being undertaken by industry and to bring it within the mainstream of the national effort to attain technological self-reliance. There are two categories of issues here. The first relates to R&D directed at introducing technological improvement in the production of products already in the market. Here, it would appear necessary to assure private industry that the regulatory practices of government will allow enhancements in production capacity beyond the formally licensed level, when independent technical assessment by specialist government teams has shown that genuine technological development has been responsible for the possibility of increasing capacity.

The second issue relates to R&D aimed at developing technology for new products and processes. Our past experience with industry on this type of R&D leads us to believe that if such R&D, including pilot-plant and prototype work, is to lead to technological self-reliance, it is necessary that government play a dominant role in raising resources from industry and allocating them to scientific and technological tasks in a planned manner. It is therefore necessary for an R&D cess to be levied on all industrial units on a graded basis. The finances so raised should be deposited with a central agency which would make disbursements from the "Industrial R&D Cess Fund" primarily to companies, public or private, whose R&D programmes have been approved by the NCST for inclusion as an integral part of the total national effort involved in the concerned sector of the Science & Technology Plan. At the time that these R&D programmes are approved, government will ensure that they are consistent with the prevailing industrial licensing policy particularly from the point of view of products whose manufacture is reserved for certain types of companies. For their part, the companies will be assured in advance that, should the R&D projects fructify, they will be able to commercialise the results without coming into confliect with the policies and practices used by government to regulate industrial development. If companies wish to pursue R&D projects 'outside the plan', they will have to finance them from resources additional to those needed to meet the R&D cess. Furthermore, unlike in the case of the 'plan projects', no forward commitment would be given in respect of the commercialisation of the results of such projects by the companies undertaking them.

2.5 *Policies towards employment generation*

It was noted earlier that a very major aspect of development process is the creation and distribution of the capability to produce in society as a whole. This capability is an amalgam of many ingredients - capital, skills and management - to mention only the primary ones. But the availability of skills and their deployment is of particular importance, and most of the skills involved are scientific or technical in the broadest sense of those terms. It is clear that the process of skill formation in our society, particularlv through the structure of formal educational instruction must undergo drastic reform if we are to derive the maximum benefit from the use of our skilled manpower. But what causes greater immediate concern is the fact that many of our policies and programmes do not permit full utilisation of our available manpower, even where it has relevant skills and is readily available.

For instance, it is well known that technical activities such as the preparation of feasibility and project reports, design engineering and the preparation of manufacturing drawings, maintenance manuals and such other "software" form a large part of the content of a foreign collaboration agreement and involve considerable investment in engineering and technical man-hours. The skills and manpower to undertake these activities are readily available in the country. What is more, given the present wage-rates for such manpower, undertaking these tasks within the country is also highly cost-effective in purely economic terms. Yet, it is not recognised that every time the nation permits a foreign collaboration agreement which includes the import of "software" of the above kind, it is destroying employment potential for its engineers. Thus, a pre-requisite for increasing employment opportunities, and for diffusing the capability to produce, is a vigorous and steadfast commitment to the policy of technological self-reliance which eschews turn-key and near turn-key contracts with foreign suppliers of technology.

A particularly important area for the productive use of technically trained personnel is in the maintenance of plant and equipment; indeed, of all capital stock. Where the economic value of capital assets is particularly high, it would appear that the task of prolonging the life of those assets and keeping them at rated performance during their lifetime should receive high priority. But we find that a number of policy measures and management practices militate against this. Budgetary restrictions, for example, seem to fall often on the manpower needed to maintain a piece of equipment. Such manpower ought to be regarded as an essential financial component of the acquired capital asset.

Personnel practices and salary scales which prevail in installations vital to national development, such as power plants, water-supply systems, or agro-service and repair centres are distinctly poorer than in R&D or manufacturing establishments. As a result, many important installations are unable to attract the skills required to run them and continue to malfunction without them. We must re-structure the market for technical manpower in favour of technicians and skilled workers, if we are to resolve the paradox of the present situation where poor output and productivity co-exist with unemployed scientific and technical manpower.

We have already noted that much greater use of technically trained people can be made in the whole area of natural resource survey assessment and exploitation. Such use will call for two important decisions; one to have a large and sustained programme in this area and another to make deliberate choices in favour of manpower, as opposed to machine-intensive technologies. For instance, it is possible to analyse geochemically samples of rock collected from a given area in the same time-span either by using a large number of technicians and a simple set of chemical tests, or by using analytical instruments with high throughputs, such as atomic absorption spectrometers. The training and reflexes of many scientists may lead them to choose the latter; but the former may generate far greater productive employment, while being just as efficient. Adoption of such an approach may well call for generation of new technologies and equipment which do not exist in the industrialised countries. But if we are keen on productive employment generation we must develop these techniques through the commitment of the necessary R&D resources.

There is a growing awareness that the investment we have made so far on services to extend various kinds of scientific and technological knowledge and expertise into the productive sectors of the economy, into R&D, into planning and management, and into education, has been very inadequate in relation to the needs. In particular, our information and documentation services are very poor. A major effort to intensify and upgrade the existing systems of industrial extension, not only to the small-scale sector but also to large companies is necessary. Such an effort will call for managerial change in the organisations and for programmes for training science graduates and engineering diploma holders in the necessary skills.

These few instances reveal some of the basic characteristics of programmes designed to employ productively scientific and technical personnel - choice of technology, commitment to self-reliance, undertaking managerial and personnel-policy reform and training of persons who have already been through the formal educational system in skills specific to particular programmes.

2.6 *Policies relating to the matching of supply and demand for science and technology*

These can be divided into three categories:

(i) Policies relating to change and augmentation of the existing scientific and technological effort. These would be institution-specific and would set the goals of R&D.

(ii) Policies relating to management all along the innovation chain, i.e. those relating to the transfer of technology from one link in the chain to the next; from R&D to design engineering/pilot plant/clinical trials/rural extension; through plant and equipment fabrication, plant operation repair and maintenace to storage, marketing and delivery of services. At each point along the chain, foreign technology may be involved and policies relating to it will need to be integrated into the whole.

(iii) Policies relating to shaping the economic and social environment in which science and technology are placed.

The methodology for setting the goals of R&D is, we have noted, a process of trial and corrected error. We must be prepared to accept that any particular approach is a tentative first-approximation and we may have to start over again after proceeding some considerable distance.

For the economy as a whole the following three-stage procedure would appear to be involved.

(1) Preliminary analysis of the overall development strategy required by the economy (i.e. the fifth five-year socio-economic and defence plans) in order to identify bottle-necks (e.g. power and transport) and "motor-sectors" on which development seems likely to hinge (e.g. agri-culture and petro-chemicals);

(2) Examination of these decisive sectors to assess the present state of the technology involved and the contri-bution that science and technology can make to future development;

(3) A subsequent iterative process correcting the preli-minary overall development strategy in the light of the possibilities for increasing the quantity, impro-ving the quality and for changing the product-mix of sectors through science and technology, and esti-mating cost involved.

In approaching the task of setting the goals of R&D in this fashion, we are, willy-nilly, being forced to proceed along two parallel paths. The setting of priorities between these paths involves the delicate balancing of short-term and long-term considerations. One path is a short-term approach based on current data and under-standing; the other is a set of long-term programmes of basic and oriented basic research aimed, not at immediate applications, but at keeping fully abreast of developments in international science and technology; at building up human skills over a broad spectrum of scientific activity; and at inculcating the scientific attitude amongst our people. We cannot predict in advance when such programmes will yield insights pointing the way towards new applied research directed at concrete solutions, or which may indicate reformulation or reorganisation of our applied goals.

The process of successful innovation whereby an idea is trans-muted through successive stages into a socially valued artefact that is made available to society is a connected chain of discrete events. The chain is only as strong as its weakest link. The management of innovation is essentially the task of identifying and transferring rele-vant elements of technology and information from one link in the chain to the next, in both directions. Policies which directly or other-wise regulate the management of technology and information transfer all along the chain have a most profound influence on the innovation process.

Perhaps the most influential of all the policies is that relating to the mobility of scientific and technical personnel between insti-tutions. The best way to transfer technology is to transfer the people who generate or use the technology. The existing rules of such transfers need thorough revision particularly those relating to the transferability of accumulated service benefits.

At each point along the innovation chain where technology transfer takes place, foreign technology may be involved. It is important to design policies that will ensure that the elements of foreign technology do not have tied to them items which can be supplied by the domestic scientific and technological infrastructure.

Policies governing the environment in which science and technology function have an important role in ensuring that mismatches between supply and demand do not occur. Some of the policies involved are indicated below:

a) Economic: for example;

- finance (credit, interest rates, attitude of public finance institutions to indigenous technology)
- fiscal (tax incentives for R&D exchange rates, exchange control)
- external trade (import substitution; export promotion; tariff and non-tariff barriers)
- internal trade (prices and pricing of services, e.g. electricity and transport; marketing; government procurement)
- wages and labour compensation policies
- foreign investment (control, compensation, nationalisation)
- specific industrial policies (consumer/intermediate/capital goods balance; backward and forward linkages; incentives; licensing and control)
- specific agricultural policies
- policies towards regional development

b) Manpower: for example;

- educational system (literacy, primary, secondary, vocational, etc.)

- higher education policies (university curricula; training institutes; management training)

- industrial training and retraining, technician training

- policies relating to emigration of skilled professionals (the so-called "Brain Drain")

- policies relating to the mobility of qualified personnel

- salary structure, awards and career structure

c) Demographic and social: for example;

- health care and health management

- sanitation and public health

- mortality rates, epidemic control

- preventive/curative balance in health programmes

- population control programmes

- food adulteration

- income policies, distribution of income

- policies towards increasing social mobility

d) Ecological: for example;

- policies for the exploitation and preservation of natural resources

- policies towards environmental control, pollution

- policies towards waste utilisation, recycling and reprocessing

e) Cultural: for example;

- mechanisms (e.g. advertising) to modify the general value structures, attitudes, norms, etc.

- popularisation of science and technology (films, displays, exhibitions, museums, TV-software, etc.)

It has been possible in these few pages to only outline the basic strategy which we have to employ if the nation is to make science and technology productive. The issues involved are large and the task of preparing the science and technology plan for the first time is complex and difficult. The next section presents some of the high-lights of the Plan now under preparation.

3. THE SCIENCE AND TECHNOLOGY PLAN: AREAS OF PRIME IMPORTANCE

3. THE SCIENCE AND TECHNOLOGY PLAN: AREAS OF PRIME IMPORTANCE

The formulation of a Science & Technology Plan is an inter-active and iterative process - a process involving examination of not only the scientific and technological effort required but also of the policies and administrative set-up necessary for maximising returns from the existing investments and achieving self-reliance. The Plan needs to cover not only the quantitative aspects of scientific and technological manpower creation and deployment, but also qualitative aspects ranging from the generation of a scientific temper throughout the populace to the creation and nurture of pools of scientific excellence from which technological breakthroughs could emerge in the future.

The preparation of such a plan requires a detailed study of the existing scientific capability in the country in relation to the world stock of knowledge and a fostering of strategies to utilise that capability for the achievement of national objectives. This requires first a detailed micro-analysis and the NCST has divided the national economy for the purpose of such analysis into several broad sectors. Thereafter, it is necessary to programme the integrated deployment of our scientific and technological resources in achieving the national objective of providing the basic minimum needs of the common man such as food, clothing, housing, health, education, water supply, communication and adequate employment opportunities, the development of self-reliance, the reduction of import of technology and the maximisation of returns from the existing investments in science and technology. These detailed exercises in planning, programming and budgeting are now being undertaken by the NCST in association with a large number of scientists, technologists, economists and administrators. An attempt will be made here to provide a broad over-view of the areas of prime importance that have emerged from these preliminary exercises. These are more indicative than representative since the tasks of identifying crucial areas, detailed analyses relating to the matching of supply and demand for scientific and technological resources, and inter-sectoral allocation of resource are still under-way.

With a population which will exceed 600 million in a few years the primary requirement of the nation is an increase in agricultural output so that there is relative stability in foodgrains availability and a substantial bufferstock contained in quality storage facilities. The meeting of this requirement will necessitate an expansion of the cultivated area, intensification of cropping, extension of irrigation facilities, appropriate measures for accelerating improvement in yield, new patterns of land use, water management, grain storage, and the application of genetics for breeding better yield varieties. Techniques for soil conservation and dry farming will need attention as well as basic research in crop production physiology, genetics of photosynthetic efficiency, nitrogen fixation by non-legumes, etc. Since disease and pests assume importance with application of higher levels of technology of crop production, a programme of surveillance and forecasting of pests and diseases will need to be initiated. Although there has been significant success in increasing cereal output in the country, no such increase in production of pulses and oil seeds, which form the main source of protein and fat has been possible. Protein-calorie malnutrition, particularly among growing children and expectant and nursing mothers, will require increasing agricultural production of plant and animal protein. Research efforts are also necessary in new areas such as cultivation of sunflower for extracting edible oils from it and soyabean, which is both a source of oil and protein, and for extraction of protein from petroleum fractions. An organised thrust in agricultural engineering research has been lacking and a strong technology base also needs to be developed for post-harvest operations such as storage, transportation and processing including utilization of agricultural by-products for non-feed uses. The development of suitable agricultural machinery and other associated fields of activity need considerably greater investments. The productivity per unit of water needs greater emphasis than it has received so far and the choice of fertilizers and pesticides needs to be conditioned by the environmental implications of their wide-spread use.

Ours is a country with the largest number of heads of cattle but with the lowest per capita yield of milk. High priority will need to be given to programmes for augmenting milk production through development of suitable dairy type animals, including buffaloes with special reference to off-season breeding, as well as the evaluation of the energy contents of various indigenous feeds for ruminants. A major effort needs to be made for harnessting fisheries resources of the country not only to augment our food supply but also to mitigate protein malnutrition. Considerable research work is required both in the capture and culture of fishes and towards development of modern technologies for increasing fish catches, more efficient processing and transportation. A coordinated programme of research needs to be mounted including intensive biological studies of the sea, large reservoirs and rivers, aquaculture and diversified fishing techniques.

In the field of textiles, the science and technology plan has to cover problems relating to the production of more cotton, modernisation of textile mills, manufacture of newer types of man-made fibres and evolution of new uses for jute. Though we are the biggest cotton growing country in the world, we find ourselves in a paradoxical situation where even an import of a million bales of cotton per year is not enough to enable full utilisation of the capacity of the existing textile mills. A major effort thus needs to be mounted to increase the yields of cotton and modernise the textile-machinery industry.

During successive Five-Year Plans there has been an increasing emphasis on the promotion of positive health and on the development of effective family planning programmes. Until recently, considerable emphasis was laid in our public health programmes and R&D efforts on the control of communicable diseases such as malaria, tuberculosis, small-pox, cholera, etc. These have no doubt resulted in some decline in the incidence of these disorders and in some gains to public health. However, the mid-term appraisal of the Fourth Plan indicates that many of the controlled programmes in the field of communicable diseases have not made progress according to expectations for various reasons. There is an urgent need to mount major field programmes for the eradication of these diseases and for this purpose it is necessary that there is provision of adequate financial, managerial and political resources to apply known technologies on a nation-wide scale along with requisite support for R&D. The pressure of population poses a great threat to national health and well-being through the erosion of the quality of life and depletion of natural resources. The Family Planning programme has been given a place of key importance in the Fourth Plan. Efforts have been made towards building an extensive infrastructure necessary for the provision of integrated family planning, maternal and child-care services. However, there have been short-falls in orchestrating the various elements of this infrastructure into an effective operational programme. While approaches such as vasectomy camps have recently shown promise, there is need to convert into action the realisation that emphasis on contraception to the neglect of general improvement of community health is almost certain to lead to a dead-end. Until recently the physico-chemical and even social technologies involved in the family planning programme have been largely imported. While this may be necessary to start with as in the case of agriculture, the need for a sound indigenous technological base to keep the programme going is evident. The current annual outlay of about Rs 1 crore on all R&D related to family planning is a cause for concern. When it is realised that this innovational effort is expected to support a field programme with an annual outlay of Rs 63 crores during the Fourth Plan, this concern becomes especially acute. There is, therefore, an urgent need to enhance the R&D effort in this area not only in regard to the natural sciences but also in the social and behavioural sciences as well. Important elements of this enhancement may well be developmental research to find quick answers to the problems faced in the field, in the diffusion of existing contraceptive technologies, in orienting existing research efforts very sharply towards applied goals and in providing resources for the expansion of such an effort. There is a long-felt need for expanded efforts in pre-clinical and clinical testing centres in more intensive screening of synthetic and indigenous materials for active agents and in the quick induction of research findings into applied programmes. The vicious circle of environmental sanitation, infectious disease, malnutrition, high infant and pre-school child mortality has to be broken at its most vulnerable points. An integrated approach comprising health care, immunization, nutrition, health education and family planning has to be fostered through operational research. The research and development effort involved in this area relates to designing appropriate delivery systems for the nutritional and health protection of the mother and the growing child.

While the majority of our population lives in rural areas, village housing has been one of the neglected sectors of the economy with a consequent adverse impact on environmental quality. Over 90% of the houses are made of mud-concrete or a combination of wood, bamboo and thatched roofs and half of the villages have no 'pucca' residential buildings. These and other conditions of life in the rural areas push its residents into urban centres leading to the creation of urban slums. It has been estimated that about 46% of the population in urban areas with a population of more than 50,000 live in one-roomed houses and the average number of persons residing in each such house is about 4. In the metropolitan cities it has been estimated that about 75% of the urban households have less than 100 sq. ft. space per head. Insufficient attention has been paid to the provision of water supply and sanitary facilities in the development of cities. It is also estimated that about 1,50,000 villages out of a total of 5,67,000 suffer from either scarcity of water or special problems such as salinity, iron and fluorides or organic contamination. Provision of adequate potable water supply to the villages and towns, integrated with a suitable sewage disposal system including utilisation of waste would acquire a very high priority in the next plans.

Science and technology can play a significant role in the alleviation of the housing situation in the country by providing low-cost housing both in rural and urban areas through developing techniques of prefabrication, utilisation of locally available raw materials, special materials, etc. The housing problem cannot, however, be treated in isolation and would need to be integrated into the pattern of urban development in the country. This would require the evolution of a suitable land-use policy and the close integration of housing with mass transportation. The basic problems in urbanisation will be to improve the existing conditions through environmental upgrading in the urban slums and the rural sectors and the development of integrated plans for urbanisation in the future which will require the development of new towns and townships.

In our country, the main sources of energy are fire wood, charcoal and agricultural waste. This is resulting in progressive deforestation with consequent soil erosion and climatic changes as also impoversihment of the soil by the use of cowdung as fuel. Suitable schemes to enable substitution by commercial fuels will need to be identified and action initiated to implement time bound programmes.

Coal will remain the major source of commercial energy for the next few decades. Technologies involving more efficient utilisation of high-grade coal need to be developed with a view to conserve this depleting natural resource. Since the bulk of our coal resources are of non-coking and low-grade variety, technological inputs have to be directed to efficient methods of utilisation of low-grade coals. Low temperature carbonisation for production of soft coke, hydrogenation for conversion to oil and gassification are some of the possibilities. Promising schemes will need to be identified to set up pilot plants to develop technological skills for putting up commercial plants. Technological inputs to improve methods of coal transportation, e.g. unit/closed circuit trains, coastal shipping etc., will also have to be identified as these could lead to reduction in product costs.

Oil is likely to remain the second largest source of energy in our country. By 1978-79 the demand for oil products is expected to increase from about 20 to about 38 million tonnes, 75% of which would need to be imported if present trends continue. Whilst the oil exploration effort will be intensified, and a major effort launched to discover oil in the offshore areas of the country, steps will have to be taken for developing technologies which will reduce dependence on oil. Some of the possibilities to be investigated are reversal of present trends in replacement of coal by fuel oil, introduction of hydrocracking plants using cheaper imported fuel, production of oil from coal by hydrogenation, and replacement of kerosene by coal gas or LTC Coke.

For the foreseeable future, electricity will continue to be the largest source of power and one of the largest consumers of fuel. There is at present gross inadequacy of R&D activities in the field of power development. The total annual outlay on all R&D related to this sector, whether in central and State Government laboratories, public and private sector industry, IITs and universities is estimated to be only of the order of Rs 8 crores. Technological gaps are particularly acute in the fields of heavy electric equipment where present manufacturers depend largely on imported and "bought-out" technology and know-how.

Nuclear energy is an area of technology in which the gestation time for getting a return on R&D investments is long. As we enter the seventies, there are indications that the large investments we have made over the last 20 years on R&D and engineering in nuclear energy have started paying dividends. Our strategy must continue to be the placing of primary emphasis on natural uranium power reactors. The first system of this kind has been built with imported technology. There are indications that quite a few elements of this technology are not appropriate for our conditions. A major programme of design and engineering aimed at "Indianising" the imported Canadian design is a matter of utmost priority. Production of heavy water and fuel are important elements of the nuclear programme. The latter has been an outstanding example of bold indigenous R&D performed within an organisational structure capable of sustaining the innovation chain and which can yield positive results on an industrial scale. However, there is need to intensify both research and engineering work in regard to heavy water plants. Efforts are therefore being made to develop R&D in the field of heavy water production. An important factor inhibiting the maintenance of momentum in this direction is the absence of appropriate fabrication facilities in the country. The basic rationale for adopting the natural uranium CANDU type power reactor was to have a system which would convert uranium to plutonium with maximum efficiency. Only in this way can we combine the jump from our limited resources of uranium to our extensive resources of thorium, with the maximum power production in terms of thermal reactors. Consequently, an area requiring careful consideration from the points of view of our basic strategy, resource availabilities and technological feasibility is that of uranium enrichment. We have a vital stake in Fast Breeder technology. Now that we are thinking in terms of a decade long plan, it is essential that the lead-time available now is fully exploited to generate the requisite technological capabilities through indigenous R&D.

With the increasing demand for fuel and power, alternative sources of energy also require to be explored and developed. Furthermore, the presently known sources of energy are leading to severe environmental pollution problems in industrially developed countries. Therefore the potential of the alternative energy sources like solar, tidal, wind, chemical, geo-thermal etc. will have to be assessed.

Another area which requires major effort covering a wide spectrum is the evaluation and development of our natural resources such as minerals, water, land, soil and forests. An indication of the extent of our neglect of the earth sciences is the fact that only 4400 earth scientists including metallurgists have been produced in India between 1921-1960; as against 21,000 earth scientists trained in China between 1950-1960; the fact that today about 55% of our total area is not even mapped on an adequate geological scale is another indication. There are tremendous backlogs in the entire area of resources research and development which needs to be rapidly covered by making suitable technological, administrative, organisational and financial management changes.

Work needs to be commenced on integrated development of our water resources through integrated river basin development programmes. Investigations need to be commenced for analysis of management of the ground water system; siltation rates of rivers and reservoirs, optimum design hydrological systems and the development of indigenous capacity for manufacture of equipment required for ground water and surface water investigations. There is also a serious technology gap in the country's use of remote sensing methods and surveys for natural resources. Improved soil survey techniques will need to be utilised for basic and reliable land resource maps and data. Intensification of the exploration effort to locate additional resources are required in the field of atomic minerals. This would require speedy implementation of aerial survey programmes, research and development efforts on ore beneficiation and uranium extraction methods and more extensive application of geochemical and geophysical techniques in exploratory work.

Accelerated mineral development programmes in respect of copper, lead and zinc are needed especially in respect of the 1200 known occurrences. In case of iron ore, manganese ore and chromite, resources under the 'referred' and 'inferred' categories need to be brought under the 'measured' categories by detailed exploration, while with regard to coal and lignite, exploration should be continued to locate new resources and covert the 'inferred' resources to 'indicated' categories and 'indicated' to 'proved' categories.

Though we have a coastline of over 5,000 KMs, very little attention has been paid to the development of its marine living and non-living resources. Even our continental shelves remain largely unexplored and a major programme needs to be launched for the more effective utilisation of our marine resources. A basic lack in this has been the absence of scientific and technological inputs in the shape of fishing gear, navigation, processing technology, fabrication and construction of marine vessels, trawlers and sophisticated instrumentation for location of fisheries as well as non-living resources such as oil, managanese-ore etc. For effective coordination and concerted efforts, a Marine Resources Development Commission may have to be set up, to take over the entire responsibility for the utilisation of our ocean resources and for all works regarding the improvement of our knowledge of the seas.

A glance at the Fourth Plan mid-term appraisal shows that there have been significant shortfalls in the production of iron and steel, copper, zinc, coal and coke. Some major areas which need to be focussed on are: survey of alloy steel requirements, development of methods for sponge iron to suit iron ores of different localities, attainment of the rated production of steel plants, manufacture of different types of ferro alloys and alloy steels; increase in the production of aluminium, copper, lead and zinc products and setting up of production of special aluminium alloys; design and development of equipment like mills, furnaces and production of materials such as argon etc. required for fabrication of metals; setting up of refractory development on a more comprehensive scale so as to produce normal refractories and refractory materials in sufficient quantities to meet the requirements of metallurgical aspects including production of powders, producing finished products, etc. and special techniques such as electroplating, metal finishing etc. used for metal conservation. Basic research on the beneficiation of low-grade ores and on alloy making etc. will need to be taken up. The important project of sponge iron should be looked at not only as a project for saving metallurgical coke but also one which would massively help to install mini-steel plants in several areas and development of sponge iron based on local materials.

Heavy engineering is a vital related area since it provides the plant, equipment and component needs for all highly capital-intensive industries. At present a major part of technology in the sector is based on foreign collaboration. We have to attain a substantial degree of self-reliance not only in design competence but also in all aspects of manufacture, production, installation and commissioning of equipment. High productivity, lowering costs of manufacture and the support of newly emerging innovations and processes in all other fields of science and technology depend upon the availability in the country of machine-tools and matching competence in their design, development and manufacture. The present installed capacity of the machine-tool industry is for the production of over Rs 70 crores annually and more than 40% of the installed capacity is idle because of the lack of vigorous, systematic, objective oriented, research, design and development effort in the industry. The basic requirements for rectifying this situation are: upgrading the production technology now in use in plants so as to increase the productivity of existing assets; attainment of a substantial degree of self-reliance in machine design, manufacture and production; the development of technology for minimising imports and the exploitation to the full of export possibilities.

The Chemical Industry covers a wide range of industries from the giant petro-chemical and fertilizer complexes to small light industries. It is an industry which is capital-intensive and has a high rate of technological obsolescence. The total investment in the Indian chemical industry has risen from Rs 304 crores in 1961 to Rs 877 crores in 1966 and to Rs 1600 crores in 1970 which is nearly one-third of the total investment of Rs 5100 crores in all industries in the organized sector. One of the vital areas in the development of chemical industry in India is in respect of petrochemicals, bulk organic chemicals, polymers and elastomers. This would cover the utilisation of downstream products of the petrochemical complexes to produce a variety of chemicals used in the polymer, agricultural, dyes, pharmaceutical and other industries. While conventional methods of producing bulk organics from the petrochemical downstreams may continue, newer methods would have to be explored. It is also proposed to set up a centre for research on polymers and elastomers. In respect of fertilizers and plant nutrients, emphasis must be on the development of newer techniques in fertilizer application including slow acting fertilizers, better catalyst systems, effective utilisation of indigenous raw materials for fertilizer production, economising use of imported sulphur and recovery of useful products from fertilizer waste materials. Design engineering in this field will require a number of studies on fluid-fluid contactors, liquid-liquid extraction with liquid ion-exchangers and on development of instruments and testing techniques.

As modern engineering practices become more demanding, there is a corresponding need for special types of materials with novel properties. Scientists, engineers and technologists are, therefore, continually on the look-out for special tailor-made materials which can act as substitutes for conventional materials or which possess such properties as would enable new designs and innovations. For example, the possibility of replacing conventional building materials by ceramized glass made of waste slag from the steel industry needs to be seriously explored. Fibre-reinforced materials can often replace various materials of construction. Then there are materials required by the electronic and electrical industries, like ferrites and semiconductor grade materials. There are also many sophisticated materials required by industry like phosphors, piezoelectric and other ceramic materials. It is important to note that materials become obsolete and that there is, therefore, continuing need for basic research in this area to keep abreast of the developments in materials science and technology. Special materials development also has considerable importance in the strategic and the export oriented sector of our economy. Typical examples are mica and manganese dioxide for which India is one of the world's biggest suppliers. It should be possible to develop a superior Indian technological capability in such areas.

With the increasing national development, transportation bottlenecks are being perceived as one of the major impediments to rapid progress. It is necessary to optimize the performance of the transportation of goods and passengers through utilisation of a systems approach between different modes of transportation - railways, roads, waterways and air. Particular attention needs to be given to inter-modal transportation and the technology inputs necessary at inter-faces of the various modes of transportation. Application of operational research both in respect of existing bottlenecks, and those likely to develop in view of emerging markets, would need increased inter-disciplinary and inter-departmental inputs to remove such constraints, to lower the cost of operations, as also to identify gaps in technology which require to be closed. Similar optimization studies would be necessary to derive the fullest benefits of modernisation wherever heavy investments have alreadv been made in transportation, such as in diesel and electric traction on the railways, taking into account the full system from source point to destination point. In the railways, special stress would be needed on traction equipment since energy consumption is one of the largest items of operational expenditure. Particular attention needs to be paid to the development of equipment and materials not indigenously available. Road transportation requires the selection of vehicles and road systems suited to our climatic, economic and social conditions. Increased emphasis also needs to be given to the development of rapid and mass transit systems. For inland and sea transportation wide varieties of recent technological advancements and construction and navigational methods need to be adopted. For transportation of goods, pipeline transport could be most beneficial and technologies developed for the utilisation of this mode of transport require assessment.

We noted in the introduction that technological innovation is not only a matter of applying existing knowledge to national problems; it is also an exercise in noticing and exploiting the promise of emerging technologies, relevant to priority in national tasks, even before the technologies concerned have been commercially proven in the industrially advanced nations. There are a number of such areas which can make significant contributions to our development; for example, cryogenics, solar-energy utilisation, magnetohydrodynamic power generation, desalination and biological control of pests. The work content and the technologies involved in these areas cut across the concerns and competence of several agencies. We need therefore to evolve institutional mechanisms and managerial practices that will promote and manage large, time-bound, "national programmes" in these areas. But we must take great care to assess where we should actually initiate full-fledged national programmes and where we should generate capabilities on a more modest scale even as we closely follow international developments. This assessment must be decided for each area in the light of the status of the technology in the industrialised countries, our existing capabilities, the minimum critical finances involved and the importance of the national need to be met by the technology concerned.

A possibility in the area of power generation provides an illustrative example. The costs of power generation may come down sharply if we adopt the technology of 500 MW single-unit generation sets, a technology just being commercialised in the advanced countries. Many of the elements of the infrastructure of skills and facilities needed for the development and manufacture of such sets exists in the country. But they are widely dispersed amongst manufacturing, applied R&D and educational institutions. We need, therefore, to weld these dispersed capabilities into a truly national effort and to charge the personnel involved with the task of formulating and undertaking a research, design, development and engineering effort, with sharply defined "milestone" goals to be achieved every two or three years culminating in a prototype 500 MW thermal station operating by about 1980.

Space technology holds the promise of contributing to many areas of national endeavour. Its application to natural resources survey, geodesy and mass communications could give us new developmental options and multiply our existing ones. While it may have been possible to take advantage of many of these options through international collaborative programmes alone, our concern to be self-reliant has led us to mount a major programme for developing space-vehicle and satellite-fabrication technology and to simultaneously work on applications technology. Although progress has been made on a number of aspects of our space programme, gaps in technology exist. Closing these gaps will call for considerable investments sustained over a long period of time. Consequently, the priority to be assigned to our basic capability in space technology will have to be decided in the context of overall national goals. Notwithstanding this caveat, in the case of space technology applications, it is important that priority be assigned, and resource allocated, in full consonance with investments made in using conventional technologies in the concerned application area. For instance, it would be necessary to ensure that the programmes chosen for, and the resources committed to, satellite-borne natural resource remote sensing are decided in the context of the corresponding programmes and resource allocations made for airborne natural resource surveys and to ground geological investigations. If this kind of integration and interface compatibility is not ensured, it may be difficult to actually realise much of the considerable potential of advanced space applications technology in terms of social and economic benefits to the nation. As for space science, while there are undoubtedly many interesting problems for investigation, we need to consider carefully the priority to be assigned to space science in the context of the basic science effort as a whole.

This rapid overview has attempted to indicate the areas of prime importance that have emerged so far from the on-going discussions and analysis of the scientists and technologists involved in the preparation of the science and technology plan. A clearer and more detailed account will emerge only when the draft plan is available in the latter half of 1973.

4. THE FOCI OF NATIONAL COMMITMENT FOR THE DECADE

THE FOCI OF NATIONAL COMMITMENT FOR THE DECADE

4.1 *The Science and Technology Plan*

The scientific and professional communities have come to agree that the single most important initiative needed in science and technology is a national plan. The importance of having a plan has also received support from planners, educationists, and industrialists. Most important perhaps, the political leadership has indicated in a number of ways and in several forums its commitment to the formulation and implementation of a plan. However, attempts to proceed further and examine the manner in which such a plan would actually be drawn up and implemented, have revealed that the conceptual and operational problems involved are complex.

It is important to recognise, at the outset, that while the phrase "Science and Technology Plan" is a useful shorthand to describe what we want to achieve, the task involved is really "planning the promotion of Science and Technology and their application to the Development and Security of the Nation". This definition makes explicit three characteristics of such a plan. First, its formulation and implementation must be undertaken, conceptually, methodologically and institutionally, as an integral part of the process of socio-economic and defence planning. Moreover, the process must be an interactive one, i.e. while deriving its imperatives from the developmental and security goals which the nation sets for itself, the plan must also ensure that the opportunities which science and technology can provide us will also help to shape those very goals. Secondly, what we are primarily interested in, is not a plan merely for education and research in Physics, Chemistry or Mechanical Engineering, per se but a plan for Science in Development. Consequently, as indicated earlier in this document, even the direction of basic research, and the manpower training effort that is often closely associated with it, will need to be influenced by socio-economic goals. Thirdly, the plan will need to deal with "Science and Technology" rather than with merely "R&D". Consequently, scientific and technological education at all levels, extension and technical support services (e.g. quality control, standardisation, testing, etc.) and the utilisation of existing knowledge for the solution of socio-economic problems through both regulatory and innovative measures would also be encompassed by the Plan.

It is a Plan of this kind that government has charged the NCST to prepare and which the Committee is now embarked on. The planning effort is being organised at two levels. First, work is being undertaken on a sectoral basis, in which every effort is made to associate all the institutions that would be involved in the "innovation chain" from basic research to production. Second, an overview of the totality of the nation's scientific and technological effort is being undertaken to delineate the range of possible alternatives, to assess their relative costs and benefits and present these for political decision-making. Recognising that science and technology planning is highly inter-disciplinary, particular attention is being paid to involve not only a large number of scientists and technologists, but also economists, administrators and industrialists.

A planning effort of this kind is conceptually and analytically difficult. If this first attempt to accomplish the task is to have any measure of success, major commitments will have to be made by the scientific community, the government and the nation at large. The scientific community must not merely recognise, but positively accept the fact that, in a poor country with enormous problems, the social responsibility of scientists is best expressed through a determination of individuals to direct their professional efforts primarily and dominantly towards the attainment of social goals. Such an approach will also call for the community as a whole to set up and apply standards of scientific and technological achievements, merit and reward, which are national and which are relevant to our conditions. Indeed, it may call for entirely new interpretations of the role of a scientist.

For its part, the national leadership must commit itself to holding fast to the policies and goals within which the science and technology plan is structured, at least for the duration of the Fifth Plan; to indicate its resolve that all scientific and technological programmes, particularly those of importance and those which have hitherto utilised the largest proportions of the nation's scientific resources, will be brought within the Plan and that an integrated view will be taken of the costs and benefits of various patterns of inter-sectoral resource allocation. Above all, the national leadership must give concrete expression to the realisation that so much of the extent and pace at which science and technology contribute to national development depend on the policies evolved and the actions taken outside the scientific and technological system.

4.2 *Organisational and managerial reform: pre-requisites for implementing the plan*

There are many reasons for the shortcomings and failures in the country's effort to mobilise effectively science and technology for economic and social development. But the chief among them are the deficiencies in the organisational structure of institutions for evolving science and technology policy and in implementation. It is most important to realise that the national Science & Technology Plan can succeed if, and only if, considerable managerial reform is brought about in our centres of scientific and technological activity and the administrative departments associated with them. Neither the alterations of organisational charts nor a rigid adherence to the dictum of 'first find a man and then build laboratories around him' are sufficient principles to work on today - what is required are some basic reforms in the 'working culture' of our scientific and administrative establishments. By working culture we mean the totality of administrative practices, organisational structures and the commitment, motivation and effectiveness of the people working in these organisations. The scientific establishments in our country have, with rare exceptions, imbibed the culture of the administrative services, its extensive rules and regulations, its weighty statutes and precedents and its zealously guarded and regulated hierarchies and jurisdictions. Indeed, the two problems characteristic of this administrative system - heirarchy and detailed administrative regulatory mechanisms - are the very ones which are the most inimical to the development of effective scientific institutions. There is thus today a desperate need for innovations in both the style and methodology of administrative functioning inside and outside the scientific establishment if the latter are to fulfil the high expectations raised of the capability of science and technology for making major contributions to our development. Of the changes that are of crucial importance to the future of our science and technology, the following deserve immediate attention.

In approach, it is necessary to recognise that the initial stages of any institution are crucial to the working cultures developed and play a significant role in establishing the norms, procedures and practices of the organisation. Further, when an organisation with the right type of character and atmosphere has been created and developed, full use must be made of it to grow in its own form or pattern other institutions which may be needed for new tasks.

In the working culture of scientific institutions, a greater degree of democratisation and decentralisation needs to become the norm. Policy formulation must be the function of a body composed of specialists working in concert. Not only should this body make policy but it should also be responsible for the evaluation of the tasks being performed. This requires that a clear distinction be drawn between decision-making involving broad perspective and policy and the localised decision-making which relates to the actual implementation of programmes and formulation of policy in the areas connected with these programmes. Within the framework erected by the policy-making body, the executive authority should have the fullest freedom to proceed with the implementation of the programme without further reference to the policy-making body or to the secretariat handling day-to-day administration on its behalf. Whereas the delegation of powers must be carried out at all levels as a conscious act of policy, the vesting of authority and power at various levels of the organisation must be simultaneously associated with the concept of accountability. The solution of the problem of misuse or wrong use of authority does not lie in reducing autonomy all-round but in selecting the right people to manage the various laboratories and scientific organisations.

In the recruitment procedures it is necessary for all major scientific and technological organisations to evolve, and of course make public, procedures to suit their own needs and functions independent of the Union Public Service Commission. Moreover, the schemes for career advancement for scientists should ensure that the scientist who is above-average is not allowed to stagnate for want of higher posts in the department or organisation and that the pay of a scientist is determined by the quality of his work, not by a rigid pay structure. Furthermore, it should not be necessary for him to change the nature of his job to secure a promotion. The promotion aspects of scientific and technical personnel at all levels need to be brought on par with that in the administrative services and related to the former's experience, attainments and contributions to the national economy.

It is imperative that the scientific organisations, institutions and laboratories should be exempted from having to go through the Directorate General of Supplies and Disposals for procurement of stores and equipment and that they should be allowed to set up their own purchase sections. A material management and inventory mechanism also needs to be set up in the large institutions and organisations to coordinate the purchasing activities. Foreign exchange needs to be made available to scientific institutions on a liberal basis. The amounts sanctioned by the policy-making body of each institution should be considered by the Ministry of Finance as bulk amounts, specific details of which need not be submitted to the Ministry. The delays occasioned by numerous references and cross-references of scientific matters to non-scientific accounts personnel needs to be eliminated and the existing procedures of accounts and audit modified to take into consideration the special needs of scientific institutions.

4.3 *A Technology Policy*

The central thesis of this document has been that a strategy of technological self-reliance can be successfully pursued only if the output from our technology generating centres is effectively matched with the demand for them. The hard fact today is that the demand for industrial technology in both the public and private sectors is heavily biased in favour of the use of foreign technology. There is an urgent need to restructure the national market for industrial technology in favour of indigenous sources of supply. This restructuring can be brought about by carefully orchestrating the panoply of policy instruments already available to government. It would appear that a prerequisite for the coordinated use of these policy instruments would be the enunciation by government of a Technology Policy. While such a policy statement would need to cover a number of areas, many of which have been dealt with in the previous sections, it must include the following elements. –

First, the commitment to use all the instruments of public policy, be they financial, economic, legal, political or cultural, to promote national enterprises in which real control lies in Indian hands.

Second, the commitment to orientate policy choices in favour of utilising domestic natural and human resources even if this involves distinct short-term technical, economic or other types of costs.

To be really effective, the policy statement must cover such diverse aspects as the provisions of the Industrial Policy Resolution and the Industrial Development and Regulation Act, the pricing of capital, the lending policies of public financial institutions, the relative prices of indigenous and imported raw materials and intermediates, policies and practices pertaining to brand-names and patents, industrial standards and technical and commercial guarantees sought by customers of technology, particularly those in the public sector.

In general, the thrust of the policy statement should be the determination of the nation to follow the swadeshi road and to bring about such change in prevailing policies and practices as will make it more attractive for public or private entrepreneurs to adopt and exploit domestic industrial technology.

The Science and Technology Plan will provide government with a blueprint with which to chart the direction and thrust of a whole host of policies which will promote technological self-reliance. A Technology Policy could be the vehicle for traversing the charted course.

4.4 *An industrial R&D cess*

Most of our industrial companies have been set up on the basis of foreign technology. Many of them also function in what is essentially a seller's market. There is, therefore, little economic incentive to undertake R&D aimed at reducing real costs, improving the quality of products and the efficiency of processes or the introduction of new products and processes. Our past experience of efforts to promote an R&D effort in industry which will contribute to increased technological self-reliance leads us to conclude that a new mechanism for such promotion is needed. Basically, this mechanism must involve government playing a dominant role in raising resources from industry and allocating them in a planned manner for the execution of priority scientific and technological tasks, primarily within industry.

To this end, government should commit itself to the levy of an R&D cess on all industrial units in both the public and private sectors on a graded basis. The finances so raised would be deposited with a central agency which would make disbursements from the Industrial R&D Cess Fund primarily to companies, public or private, whose R&D projects have been approved by the NCST for inclusion as an integral part of the total national effort involved in the concerned sector of the Science & Technology Plan. At the time that these R&D projects are approved, government should ensure that they are consistent with the prevailing industrial licensing policy particularly from the point of view of products whose manufacture is reserved for certain types of companies. For their part, the companies will be assured in advance that, should the R&D projects fructify, they will be able to commercialise the results without coming into conflict with the policies and practices used by government to regulate industrial development. It is estimated that the R&D cess would realise resources in the neighbourhood of Rs. 300 crores over the Fifth Plan period.

4.5 *Financing the Plan*

The over view of any plan of action can be presented in a number of ways - in terms of its programme content, in terms of the benefits which can be expected to secure from it, or the money required to execute it. Attempts have been made in earlier sections of this document to give some indications of the first two dimensions of the Science and Technology Plan. If national needs are to be the controlling factor in resource allocation, rather than the absorptive capacity of the programmes of various scientific agencies and institutions, there must be some assessment of the total expenditure envisaged in the Science and Technology Plan. We must, at the same time, recognise that our needs are large. To meet these needs may call for investments in science and technology which are considerably in excess of extrapolations of what we have been allocating in the past. However, scientific and technological programmes are highly inter-related and there are no unique criteria for determining inter-sectoral priorities. Consequently, the exact magnitude of the outlay to be made can be decided only after the Drafts of both the Socio-economic and Science and Technology Plans are ready.

Meanwhile, it has been agreed that the NCST can proceed on the basis that national investment on R&D during the Fifth Plan would be such that a figure in the general neighbourhood of 1% of the GNP, is likely to be available for R&D in the last year of the Fifth Plan. This figure has not only been recommended by the UN CASTASIA Conference of 1968 and by several domestic conferences, but has been broadly supported in principle by the Standing Group of Ministers on Science and Technology, in 1971. While this outlay would be spent largely on R&D programmes, it would include some provision for scientific and technical services, such as, Natural Resource Surveys, Information and Documentation Systems and Meteorological Services.

AFTERWORD

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The task of implementing the Science and Technology Plan will make heavy demands upon the machinery of government. But, however heavy the demand and however great the challenge, all of us must resolve to meet it; for, we can formulate and we can project; we can envisage and we can programme; we can define and we can budget: but if we cannot implement with speed and efficiency, we would have failed a new generation and forfeited our mandate to plan.

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