Science and technology in independent India: Retrospect and prospect*

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If there is one field in which India has shown herself to be up to the challenge of global competition, it is science. No one can deny this. Indian names appear in the list of authors of some of the world's best scientific periodicals. Indian faces are seen in some of the world's best laboratories. Indian voices are heard in some of the world's most respected scientific meetings. Several thousands of a million Indians today in the USA – a world leader in Science and Technology – are scientists of repute. Above all, alive in India is the invaluable tradition of scientific research.

It is India's good fortune that during the best of times, and the worst, the country has had leaders of science who have assiduously striven to nurture and build schools of research that measure up to the demands of the most difficult scientific challenges. And so has come to be ingrained a cultural trait that naturally motivates, even today, a young researcher, entering the portals of Indian Institute of Science or Tata Institute of Fundamental Research, or an active and leading group in the University at Varanasi or Hyderabad, or a laboratory like Jawaharlal Nehru Centre for Advanced Scientific Research or Raman Research Institute, to aspire for and strive to produce research output that is publishable in internationally reputed journals acceptable to the best peer groups anywhere in the world. As science is judged with reference to an absolute scale, international competition is the norm and India has not been found wanting.

When we celebrate 50 years of India's independence, let us look upon this scientific value system as our country's asset of immeasurable worth. The sustained scientific tradition and the notable strengths in science are returns that we have obtained from modest investments and from laboratories far from comparable in infrastructure to those of the advanced countries. That the investments have been modest should be clear from the fact that, while the world spends annually 500 billion dollars on R&D, India's expenditure stands at about 2.5 billion dollars only. At best, about 15% of this amount goes towards basic research. It should become immediately obvious that the return on investment in science, return in terms of what I have just outlined, is one of the best when compared with that in other fields of productive activity. This must gladden the hearts of the financial managers of our country.

Leaving aside the question of economic parameters for a while, what we must not fail to appreciate is that the asset of scientific ability, capability and performance, which we owe to the support of the political leadership and the toil of the scientific community over decades, has not been easy to acquire. The edifice of science, thus erected, must not be allowed to decay. In our drive towards achieving a paradigm shift towards technology or product development, about which too I shall have more to say later, let it not be forgotten that fundamental research is indispensable, and actually far less expensive, but that kind of research tradition takes *much longer* to take root. *In our anxiety to accelerate the pace of the so-called applied research, let nothing be done to besmirch the research tradition as we have come to understand, practice and, in certain instances, excel. As one who has been active for two decades in product development and application-oriented R&D, I strongly urge that we do not forget the value of basic, open-ended, research experience from which to feed off in a high technology regime. We need to cultivate quality soils if we want rich produce.*

Growth of S&T institutions

Prior to independence

What were the scientific institutions that we inherited from the British raj? If we step back a little and scrutinize, we can discern an interesting pattern in the growth of the scientific institutions during the British rule in India.

Major scientific agencies, research institutions and academies established during this period are given in Table 1. Most of the institutions in column 4 came into

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Table 1. Growth of scientific institutions before independence

Survey of India	1767	Maps	Calcutta, Bombay & Madras Universities	1857	
Geological Survey of India	1851	Minerals	Indian Association for the Cultivation of Science	1876	Mahendralal Sircar
India Meteorology Department	1875	Weather	Banaras Hindu University	1916	Madan Mohan Malviya
Botanical Survey of India	1890	Plant resources			
Haffkine Institute, Mumbai	1896	Vaccines	Indian Institute of Science	1909	J. N. Tata
Agricultural Institute, Pusa	1903	Agricultural research	National Academy of Sciences, India	1930	Meghnad Saha
Forest Research Institute, Dehradun	1906	Forests	Indian Statistical Research Institute, Calcutta	1931	P. C. Mahalanobis
Indian Research Fund Association	1911	Medical research	Indian Academy of Sciences, Bangalore	1934	C. V. Raman
			Indian National Science Academy, Delhi	1935	
			Council of Scientific & Industrial Research	1942	A. Ramaswamy Mudaliar S. S. Bhatnagar

being thanks to the initiative of great patriots (whose names are given in the last column). These were cast in the mould of academic science whose seminal importance was appreciated by the Indian mind even during the colonial rule, which provided no great encouragement to such endeavours. On the other hand, the scientific agencies of column 1 served a utilitarian purpose, the need of which was strongly felt by the British Government. Thus, Survey of India, Geological Survey of India, the India Meteorological Department and Botanical Survey of India catered respectively for topographical mapping, mineral exploration, weather forecasting and plant resources survey. The need to develop vaccines (anti-plague) and conduct agricultural, forest and medical research provided the *raison d'être* for the later institutions of column 1.

The first group of 'modern' universities was established only in 1857 at Bombay, Calcutta and Madras and only to serve the objective of the British rulers. As Macauley's Minute of Education of 1835 states, 'we must at present do our best to form a class who may be interpreters between us and the millions whom we govern, a class of persons, Indian in blood and colour but are English in taste, in opinions, in morals, and in intellect'. *The state of higher education in India in 1947 may be gauged from the fact that a dismal figure of only about 50 out of every 100,000 Indians were on the rolls of higher education system, not just in science but in all of the disciplines put together, arts, commerce, agriculture, engineering, medicine and science.*

The only agency, the Council of Scientific and Industrial Research (CSIR), mandated to undertake industrial research had come into existence some 5 years prior to independence, and this because of the momentum imparted by Ramaswamy Mudaliar and the sustained drive of indefatigable Shanti Swarup Bhatnagar (whose contributions as the first chief executive are an indelible part of CSIR history).

After independence

Since independence, S&T has received considerable attention and occupied a notable position in the management structure at the highest level. This is evident in the tradition of the Prime Minister holding charge of science departments, regardless of the party in power. During the last 50 years, our Prime Ministers have consistently adhered to the practice of addressing the annual session of the Indian Science Congress Association. These features are a reflection of a positive public attitude towards S&T which deserves to be looked upon as yet another of the country's invaluable assets and instrumental in framing the scientific policy. *The Government of India scientific policy resolution piloted by Prime Minister Nehru and adopted by the Indian Parliament in 1958 is one of the first official statements in the world on science, its cultural value and relationship to national development. The announcement of a technology policy followed in 1983. India was also perhaps ahead of several other countries in terms of Apex Level Advisory Committees for Science and Technology, which have been in place in one form or another since 1948.*

The major outcome of Government's attention to S&T is the evolution of a fine institutional framework. Several agencies, some referred to above, have set up universities and academic institutions, national laboratories and autonomous research institutions. The numbers enrolled annually into higher education has risen from 50 to more than 600 per 100,000 population. Though not high on an absolute scale, this signifies a phenomenal growth. The State Governments have established S&T institutions as well, wherever they have felt the need for the same to serve local demands. In the area of agriculture, extension centres have been brought into being. Many industries have in-house R&D units. As a result, the scenario of laboratories and institutions in our country has changed dramatically. In 1947, there were just 20 universities in India and 60 national laboratories. Industry was rudimentary. Today there are more than 200 universities, 400 national laboratories as well as 1300 in-house R&D institutions of the industry and over 200 voluntary organizations with S&T involvement. *More than the numbers, what this has led to is that, in almost any discipline, India's map is dotted with institutions that have the capability and persons to carry out R&D.*

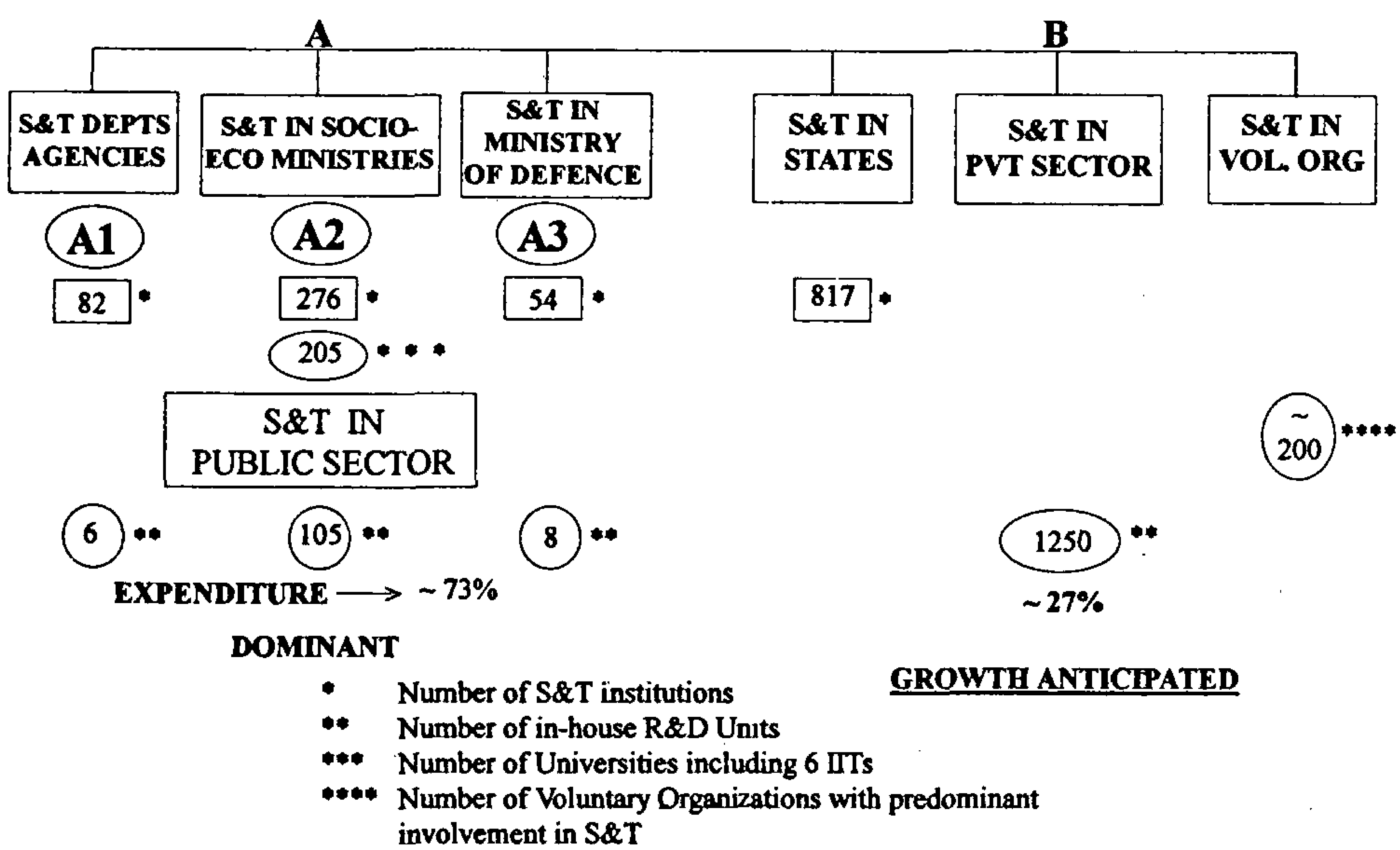
S&T system in India today

The growth of scientific institutions during these 50 years has brought into existence a sizeable S&T system in our country (depicted in Figure 1).

Part A is the dominant part accounting for about 73% expenditure of S&T and may be subdivided into A1 to A3. A1 consists of six Central Government Departments of science, namely: (1) Space (DOS), (2) Atomic Energy (DAE), (3) Science & Technology (DST), (4) Ocean Development (DOD), (5) Biotechnology (DBT) and (6) Scientific and Industrial Research (DSIR) which has under it the Council of Scientific and Industrial Research (CSIR). There are six public sector companies with the Departments covered in A1. While A2 comprises S&T component of the several socio-economic ministries and as many as 105 public sector manufacturing units, the third part A3 is S&T part of the Ministry of Defence including the Defence Research and Development Organization (DRDO) and eight public sector units. The socio-economic ministries are Ministry of Human Resource Development, Agriculture, Electronics, Environment & Forests, Non-Conventional Energy Sources, Health & Family Welfare and about 250 other economic Ministries such as Steel and Mines, Coal, Petroleum & Natural Gas, Chemicals & Petrochemicals and Water Resources.

The model of the CSIR (Ministry of Science and Technology) was adopted, after independence, for the Indian Council of Agriculture Research (1947) (Ministry of Agriculture) and the Indian Council of Medical Research (1949) (Ministry of Health & Family Welfare), both of which established a network of research and development laboratories in the country. The Councils, registered as Societies, enjoy a certain degree of autonomy, although they are funded substantially by the Government.

The subsequent modality in the Government for promotion of S&T in various other sectors was in the



A1 refers to 6 Departments, viz. Space, Atomic Energy, Science and Technology, Biotechnology, Ocean Development and Scientific & Industrial Research (with CSIR).

A2 refers to Ministry of Human Resource Development, Agriculture, Electronics, Environment and Forests, Non-Conventional Energy Sources, Health & Family Welfare and about 25 other economic Ministries like Steel and Mines, Coal, Petroleum and Natural Gas, Chemicals and Water Resources.

Figure 1. Indian science and technology system.

shape of Government Departments, which in some instances derived management support through a commission structure (Atomic Energy Commission, Space Commission, Telecommunication Commission). Government Departments in the socio-economic ministries as well as scientific agencies and the State Governments invariably set up a number of autonomous laboratories, each of which was designed to carry out focused research in a chosen area. These together, to which has to be added the research units of the non-Governmental organizations (NGOs), in-house R&D units of the public sector and private sector industry, and the universities (the number of such institutions is indicated in the respective boxes in Figure 1) constitute a sizable scientific institutional base in the country.

There are two corollaries to the brief description given here about the size and complexity of the S&T system as of today. *One is the need, at this point in time, for an appraisal of the effectiveness of the Councils, the Government Agencies, with and without the Commission structure and then the autonomous laboratories and centres under the Government Departments, which together present a complex of management models that have evolved in the country.* The reason for suggesting such an appraisal is that not all the Councils have succeeded to the same extent, so also not all the Commission structures, for that matter not all the Government Department-based S&T programmes. Determination of success or otherwise is to be related to function and mandate of the organization in question. Carrying out an informed and objective assessment therefore requires senior persons who have worked in the system and understand the implications of management structures for tangible scientific output of the type expected. In any event, restructuring and/or fresh governmental agencies may become necessary as economic and technology scenes change rapidly. An appraisal of the type suggested would prepare us for appropriate responses to the dynamics of the coming decades.

The second pertains to R&D expenditure (much of it by the Government at the Centre as shall be explained in the next section), which is modest (0.85%) in comparison to India's GNP as well as in relation to amounts invested by the scientifically leading nations. *An inevitable consequence of sub-critical investments in India is that relatively small amounts of R&D have been spread over a large number of institutions and industry in-house units, like in A2 and especially in part B of Figure 1, leaving several of them poorly funded. Urgent measures to remedy the situation have to be adopted.*

Growth in S&T expenditure

The Central Government S&T expenditure (Plan + Non-Plan) from the first to the eighth Five-Year Plan periods is given in Table 2 which shows that from a level of Rs 200 million in the first Five-Year Plan, the expenditure in the current Plan has grown to nearly Rs 240 billion. The factor by which plan allocations were enhanced from plan to plan has been indicated in Table 2. The largest enhancement occurred in the 5th Plan and this warrants elaboration.

In 1971, thanks to C. Subramaniam, the Government set up a National Committee on Science and Technology, (NCST). NCST brought out in 1973 a policy document entitled 'An Approach to S&T Plan'. This approach was developed reckoning that a sum amounting to 1% GNP would be made available for R&D in the last year of the Fifth Plan. The quantum jump in the allocation in the Fifth Plan, nearly 5 times that in the Fourth Plan, was due to this visionary NCST initiative of the Government. Thus were set up three Departments, viz. the Department of Science and Technology (DST), the Department of Electronics (DOE) and the Department of Space (DOS). The dates when some of the other S&T departments came into being are also given in Table 2. Department of Ocean Development (DOD), Department of Environment (DOEn) (now the Ministry of Environment & Forests), Department of Non-Conventional Energy Sources (DNES) (now the Ministry of Non-Conventional Energy Sources) and the Department of Biotechnology (DBT) came into being in the period between 1982 and 1986.

As far as I am aware, no initiative comparable to those mentioned above, up to the point of creation of the Department of Biotechnology in 1986, has been taken in the last 10–12 years. Investment of 1% GNP in R&D, suggested by NCST, appeared to be taking shape but has never been attained, with recent declining trends actually bringing it down to about 0.85%. This situation warrants a major revival operation to be put into place.

NCST recommendations guided, 25 years ago, the development of an approach to S&T plan which led to enhanced investments in S&T. As we have just crossed the 50 year milestone and are situated at the threshold of the 9th Plan, an altogether new 'Approach to S&T in India' is called for. Such a new approach, for which some suggestions will presently be made, should clearly spell out measures and mechanisms that can demand, attract and absorb investment of at least 2% GNP (which will still be lower than the quantum, 2.5–3.0% GNP, that leading industrialized nations invest) for S&T by the end of the 9th Plan.

A policy announcement to enhance the annual R&D expenditure to 2% GNP by the end of the 9th Plan, as soon as the new Government takes office, will mean much to bring S&T on to the centre stage of programmes for national development. A policy statement has been made already at the highest level, that the allocation to education in the 9th Plan will be built-up to a level of 6% GNP. If both of these targets can be set, and achieved with judicious management, India is bound to recover much of the lost time and opportunity. What a wonderful prospect this is, even to visualize!

Why 2% GNP?

Science in universities

The growth in S&T institutions and the present size of the scientific establishment has been outlined. Among the institutions whose number has grown significantly while support to them has not, is our university system. I say this with much sadness.

Universities are the most congenial homes for creativity in any society. Research thrives best in the university environment which is unrivalled in its ambience to stimulate interaction of the young minds with those of the experienced. They are also the fountainheads for technology innovation. There are exceptional examples like the University of Sheffield in England from which sprang many developments in steel technology in the steel city of Sheffield, in a period when steel was a prime material. In the modern age of silicon, Stanford University in US has proven to be a monumental success in the creation of the silicon valley. Above all the *Universities the world over have shown themselves to be the single most enduring of institutions during the present millennium, since inception of the first University in Bologna in Italy in the 11th century.*

In this perspective, it is heart-rending to hear about the inexorable decline in research standards in several universities in our country. Enfeebled is university basic infrastructure, such as a modern library, laboratory instrumentation, computing facilities or connectivity and communication with the other centres in the country and abroad. Rejuvenation of the universities, their capability and vitality is a paramount and urgent need. A Science Congress is justifiably the forum to declare this urgent requirement, as the annual sessions, such as the present one, have invariably been hosted by a university, everyone of which has carried this burden so far despite their mounting inadequacies.

The least that one can attempt is to select immediately at least one university in every State for strengthening research infrastructure and skills.

The situation in central universities, though better, is certainly not up to the demands of today. All of these central universities, which were indeed intended to develop as the country's educational research centres of excellence, have also to be given fresh inputs with respect to their research capabilities and infrastructure.

In the above context, the initiative, some years ago, of the Department of Science and Technology to set up Regional Sophisticated Instrument Centres (RSICs)

Table 2. Progress of central sector S&T allocations in different plan periods*
(Rs in billion)

Five-Year Plan	Plan	Non-Plan	Total	Dates of major agencies
				CSIR set up in 1942 AEC set up in 1948
1st (51–52 to 55–56)	0.14 [2.3]	0.06	0.2	
2nd (56–57 to 60–61)	0.33 [2.1]	0.34	0.67	DRDO in 1958
3rd (61–62 to 65–66)	0.71 [2.0]	0.73 (1.03)	1.44 (1.74)	
4th (69–70 to 73–74)	1.42 [4.9]	2.31 (3.46)	3.73 (4.88)	DST & DOE in 1971 DOS in 1972
5th (74–75 to 78–79)	6.93 [2.9]	6.88 (9.49)	13.81 (16.42)	
6th (80–81 to 84–85)	20.16 [2.5]	16.52 (24.73)	36.68 (44.89)	DOEn in 1980, DOD in 1981 DNES in 1982
7th (85–86 to 89–90)	50.06 [2.4]	31.58 (56.39)	81.74 (106.5)	DBT in 1986
8th (92–93 to 96–97) (anticipated)	121.7 ↑ [Plan-to-plan enhancement factor]	57.61 (116.1)	179.3 (237.7)	

*Defence research has a significant non-plan allocation; figures within brackets under column headings Non-Plan and Total are inclusive of defence research allocation.

has generally proved to be a success. The concept of RSICs deserves to be revisited. We should undertake strengthening of RSICs and Sophisticated Instruments Facilities (SIFs). There are only three such centres in the university system. We should establish at least one such centre in every central university and one such centre in the university selected by each of the States for particular attention. Combining this with a massive upgradation of the infrastructure of the library, computing and networking facilities will do much to restore some of the shine of what was once a glittering university system.

Technology for domestic economy

A question frequently asked, and more forcefully so, during the recent years is why, although India has such a credible record of S&T accomplishments, the impact of S&T on the national economy is not readily observed. This question as well as the issue of 2% GNP by the end of the 9th Plan will be addressed together.

There are three sources of funding R&D, viz. 1. Central allocation, 2. State allocation, and 3. Industry investment.

Of the three sources of funding, it is well known that, in our country, the dominant fraction is borne by the central sector. In the 8th Plan, out of approximately Rs 360 billion spent on R&D during the five-year period, about 67% was provided by the Centre (Rs 245 billion), about 9% (Rs 33 billion) by the States and about 24% (Rs 82 billion) by industry, public and private industry put together. Each of these components warrants discussion in the context of our expectation that S&T should make a difference to the economic situation in the country, as indeed has happened in the western nations and, more recently, in a country like Japan, where S&T has been responsible for unprecedented economic prosperity.

Central sector. A study of the changes in the pattern of investment for S&T in various sectors, since the plan concept came to be adopted, is necessary. This study may reveal that the investment pattern changed not so much because of a comprehensive assessment of the needs of various sectors, but, perhaps, because of segmented emphasis that selected sectors received from time to time. Central sector divides itself into two parts, A1 and A2, as in Figure 1.

In part A1 (Figure 1), for example, let us consider CSIR and DAE R&D allocations, two science agencies which were prominent in the first three plan periods (Table 2), thanks to two of the redoubtable institution builders in post-independent India, Shanti Swarup Bhatnagar and Homi J. Bhabha.

Homi Bhabha set up an economic study wing in DAE as early as in 1955 with nuclear power in mind and this has paid off. DAE R&D has given rise to the nuclear power programme which is saying a lot when you consider the daunting tasks of designing, building and operating, nuclear power plants. Fuel for the power reactors has to be extracted from a resource that contains mere 0.05% uranium and this has been done! Further, technology for the heavy water production has had to be developed. We see that heavy water plants have been built, are being operated and the product is exported as well. The multidimensional nuclear programme has had an impact on some agricultural products (e.g. 90% of all urad grown in Maharashtra and 11% of breeder groundnut seeds used in the country are based on Trombay mutants) and contributed to the growth of nuclear medicine in the country. Similarly, CSIR has had a substantial influence over chemical, agrochemical, pharmaceutical and petroleum industries and products. CSIR zeolite catalysts are a product which have been taken through the entire cycle of synthesis, characterization, testing, evaluation, pre-production trials and manufacturing. Twenty five per cent of all of chemical pesticides used in the country are based on CSIR technology. So also the CSIR refining techniques have been used in the petroleum industry. Centchroman of the Central Drug Research Institute is proving to be a magic molecule. Presently Rs 3600 crore worth of annual industrial turnover is attributable to CSIR technologies. CSIR is also making headway in export of R&D based products and services with a client list that includes GE, DuPont, FMC, Neste, Unilever and ICI in the chemical sector, Boeing and BOAC in the aerospace sector, to cite a few examples.

The two agencies are therefore capable of contributing, *via R&D*, to such activities as make a difference to the industrial technology scenario in the country, precisely what the open economic regime requires. The relevant questions are: have the outlays for R&D in CSIR and DAE kept up with their needs? How do the allocations correlate with the avowed goal of achieving economic dividends through investment in S&T?

With reference to part A2 of Figure 1, let us consider S&T components in various socio-economic ministries. It is difficult to fathom any policy for S&T investment in the economic ministries. It is only in the Ministry of Defence that there is the practice of allocating to S&T a certain percentage of the total outlay for the Ministry. The Defence Research and Development Organization currently is allocated a little more than 5% of the funds given to the Ministry of Defence. This has led to results which the country has sensed and appreciated. It is not the case that the Defence Ministry looks upon the allocation by the Government as more than adequate in terms of its requirements and therefore sets apart 5% for R&D. On the contrary, I would expect that setting apart 5% for defence R&D is a reflection of the Ministry's conviction about the importance of indigenous R&D for self-reliance in the development of defence-related products and systems needed by the armed forces.

This commendable policy of an unexceptionable share for R&D, in terms of a reasonable percentage of the outlay for the Ministry, is worthy of emulation by several economic ministries. National security lies not just in defence capability. National security has to be all encompassing, defence, economic and social. Technology has been at the core of defence products the world over. But national security cannot be comprehensively ensured if capability in defence technologies is not complemented by the economy-related production technologies. Recent events in the Soviet system poignantly bring home this truth. We have also faced a crisis of unimaginable proportion on the food front until agricultural R&D brought about a sea-change in the food grain production scenario. If the country today has a sense of food security, of no less significance than the nation's defence security, the nation has to salute the agricultural scientists and producers, indeed the system as a whole.

The relative success in the field of agriculture owes not a little to the importance given to agricultural research, education and extension programmes. This is reflected in the fact that, out of the total of Rs 10,000 crore for agriculture in the 8th Plan, agricultural S&T and education got Rs 1300 crore, i.e. 13% of the plan outlay.

India is still a largely agro-based economy, and therefore there should be no let up in the importance to be given to development of agricultural and agro-based products. Foodgrain production levels have to maintain a certain growth rate and this has been discussed at length by U.R. Rao in his Presidential Address in 1996. More and more attention to advanced techniques is necessary as results have to keep pace with the growing needs in regard to not only primary agricultural products but also products of the secondary and tertiary sectors.

Discussion of agricultural products is always heartwarming because of the following reason. People often ask, is India No. 1 in any field? The answer is, yes!, we are first in the world in the production of farm-products, e.g. jute, fruits and vegetables and raw sugar. As Table 3 shows, while India's position is No. 1 in the world in total annual production, we slip from this position in terms of productivity or quality.

This is a clear area for technology intervention. So also downstream processing of agricultural products, which has only begun to take shape with the recent initiatives for the promotion of food processing industry. This is another area brimming with potential economic rewards for technology programmes.

What has been done for R&D in the Ministry of Defence, and agricultural research in the Ministry of Agriculture, is not evident in several other socio-economic ministries. This is clear from the four examples, railways, coal, power and rural development (Table 4).

S&T allocation of less than 1% in the Ministries of Coal, Power and Rural Development, and less than even 0.1% for S&T by the Railway Ministry, can hardly make any impact on the development of associated technologies.

How much can be expected of one research organization, like Research Design and Standards Organization (RDSO, Lucknow) of the Ministry of Railways, when a wide spectrum of products, components or systems is needed by the railways on a scale that has to make a difference to their functioning? One has only to compare with the achievements of technologies in high speed traction in countries such as Japan and France to realize where we stand today. Railways could, indeed, absorb as large an R&D input as defence.

Similar arguments apply to the Ministries of Coal and Power, which are crucial for infrastructure development in India. Coal is our primary source of electrical energy. Clean coal technologies are yet to be applied on a large scale. Power transmission can gain from a technology like HVDC transmission whose impact is yet to be widely felt. Diffusion of S&T-based products and systems for the benefit of the non-farm sector in the rural economy has not happened in our country, as for instance in China. The lack of progress in these developments has been commented upon, often with laments about the insensitivity of the S&T community to such needs. However, for a change to be brought about, a fundamental reorientation of planning and technology management processes is necessary so as to draw in S&T elements to play their legitimate role as instruments of growth. The Ministries of Petroleum and Natural Gas (Oil Development Board), Steel (SAIL R&D) and Mines (Jawaharlal Nehru Aluminium Research, Design and Development Centre, Nonferrous Materials Technology Development Centre) have done better in this regard.

I would therefore plead that S&T allocation in socio-economic ministries be raised to at least 5% of

Table 3. What can technology achieve in agricultural products

	Production		Yield	
	Annual (in 1000 T)	World rank	Yield (kg/hectare)	World rank
Jute	1260	1	1465	10
Fruits and vegetables	100,000	1	Variable	Below 10
Raw sugar	13–14,000	1	10% (recovery from cane)	Below 5

Table 4. S&T allocation in selected socio-economic ministries

Socio-economic sectors	8th Plan 1992–97 S&T outlay	8th Plan 1992–97 Central sector outlay	% for S&T
	(Rupees in Crore)		
Railways	25	27,202	0.09
Coal	87	11,507	0.75
Power	251	25,920	0.97
Rural development	104	30,000	0.35

the total plan outlay made to the concerned sector and a higher percentage in certain sectors. This should not require imposition of an additional burden on the exchequer. The effort should be to make an appropriate slice from the sectorial allocations for strengthening respective S&T endeavours.

Obviously, a mere allocation of funds is not an end in itself. A judicious utilization of the same is needed in carefully selected projects which the economic ministries are best placed to prioritize and define. A methodology will also need to be devised to attract counterpart investments by industry and for the association of the S&T agencies.

The Technology Development Board has been recently instituted in the Department of Science & Technology. The Board has been empowered to provide bridging inputs, so necessary and not large enough till now, for the joint technology projects (JTPs) of the socio-economic ministries, S&T agencies and industry. Technology development and commercialization of technology bristle with risks and the role of Government in covering the risk element to some extent is crucial for industry participation. The progress from research to business involves a chain of activities. Each of the links in the chain, namely applied research, upscaling for assessment of technoeconomic parameters and precommercial trials before commercial launch requires investment, a proper organizational structure and management for that purpose. Finally, total involvement of industry is essential, for industry offers the right site for commercialization. It is in bringing about movement towards industry investment in technology that lies the role of the government agencies and the newly created Technology Development Board, as well as the venture capital schemes of financial institutions (also such promotional schemes as SPREAD of ICICI).

The concept of technology missions, experimented with during the Seventh Plan, is valid as a technology management strategy involving several players. Oil seeds and the telecommunication missions showed notable results. However, in these or other socio-economic sectors, one does not see more mission-oriented programmes on the same scale and intensity. Again the need to sustain strategies and investments comes ruefully home.

Finally, a word about choice of specific technology areas. Once larger allocations are made for S&T activities in the Ministries and appropriate management structures and strategies are determined, *careful design of investments has to be made with the help of an assessment of world trends in trade.*

Take, for example, the field of electronics. With all the technical knowledge available, as well as very early work on silicon in the country and despite the Bhabha Committee visionary report, India completely missed out the micro-electronics revolution. This was one area where India could have made a mark based on R&D capability. In any case, we could not have afforded to lose out so heavily. Non-availability of critical advanced electronic components and devices has had a negative effect on the pace of development of high technology systems required in our strategic programmes.

Currently, *health-related products, environmentally friendly technologies and products based on biotechnology* are showing growing presence in world trade. Industrial products are still dominant, occupy a prime place in world trade and *manufacturing technologies* are on the anvil of revolutionary advances. And information and communication technologies have stormed the world. India cannot be simply left behind, because these emerging technologies have a vital impact on national economies. *A careful assessment of trends in a given discipline and their impact on world trade should be our parameters for decision making on investments, if we have to make a bigger dent in world trade through our exports.*

None of the above-named technology areas should seem daunting. Only focused attention is needed. Whenever such attention and the needed support are given, there have been results. Reference to defence R&D and nuclear power reactors was made earlier. Achievements in the Department of Space have been stupendous. Development of world class remote sensing and communication satellites and the progress in launch vehicles are no mean achievements. These and other specific successful development of high technology systems, such as the giant metre-wave radiotelescope, parallel processing supercomputers, power plant equipment and digital switching technology for 40,000 line exchange, bear ample testimony to India's inherent capability in technology development and for mustering and managing large teams.

The above technology accomplishments should lend confidence to launching a massive reorganization of economy-related technology projects in which the Ministries, the S&T agencies, industry, engineering consultancy organizations and financial institutions are coherently interfaced, once proper selection of projects has been done after due assessment.

Clear distinction in approaches will be necessary depending upon whether we are aiming at meeting our own needs like the infrastructural development or our aim is to be recognized as a dominant country in a globalized economic regime. In any case, levels of investment, project planning and management and sustaining all of these aspects over a long enough period should accompany our aims and aspirations.

State sector. The allocation made by the State Government and Governments of the Union Territories for Science and Technology so far has not been substantial. For instance, the States and the Union Territories, all put together, had 8th Plan outlay of less than Rs 200 crore for S&T during the whole plan period of 5 years with the average coming to less than about Rs 2 crore per year per State (including Union Territories). However, the allocation of this amount is as against the total outlay in the 8th Plan for the States of about Rs 182,000 crore. S&T allocation, thus, amounts to about 0.1%. This is a measure of the inadequacy in the capacity of the States to resort to S&T as a tool for dealing with societal or economic ventures.

In regard to S&T in the socio-economic sector, the only clear Head in the State plan budget is for agricultural research and education. There is no plan budget Head in other socio-economic ministries of States with research clearly mentioned. The amount allotted for agricultural research and education amounts to about 5% of the total outlay for agriculture. Again, one can see that regular, annual plan investment, of a viable magnitude, in a chosen sector has made a difference to the programmes related to S&T in that sector.

Diffusion of S&T advances in a large enough measure and a wide enough scale within the country is not possible unless the States are involved in the process. The State Governments are under severe budgetary pressure. All the same, with or without the help of the central sector, the situation in the States needs to be drastically improved so far as S&T programmes and interventions are concerned. In the same way as agriculture (speciality for which there are State Universities) has received attention by the State Governments, the other sectors which strongly influence the economy of the States require to be attended to. High level review and an altogether fresh approach are needed to make a new beginning.

Unless the State institutions are funded adequately, quality manpower is inducted, information on S&T capabilities and developments provided and senior level advice in S&T matters ensured, even the initiatives coming from the Centre for ameliorating any situation in the region may prove ineffective over a period of time. Any large scale programme, for example the cleansing of the rivers through effluent treatment and sewage treatment or production of potable water from desalination plants or any similar technical initiative is likely to encounter insurmountable impediments as long as the State institutions do not have the wherewithal to sustain the operations.

Let me make a reference to the area of forensic science which is a public science and a rapidly advancing science. Criminals are using advanced techniques to commit crimes. Criminal investigators have to necessarily use advanced scientific tools. Of the 19 State Forensic Science Laboratories, there is one in the AP State, Hyderabad. Hyderabad is rich in terms of scientific institutions whose capabilities have relevance to forensic science. For example, the emergence of DNA fingerprinting has been hailed as a breakthrough in forensic science in this century. The level of scientific knowledge and training necessary to do DNA analysis can be gauged by the progress made by the Centre for Cellular and Molecular Biology in Hyderabad. Especially due to proximity of these laboratories, the State forensic science laboratory is in a position to appreciate what can be done in their own laboratory to install new and advanced experimental tools, for training on them and to use them for investigation of crimes. But this requires financial support, autonomy to build up scientific staff strength, in quality and number, and opportunities of the kind the scientists of CSIR and defence laboratories have for interacting with peers nationally and internationally. Regular upgradation is essential in fields governed by rapid advances. However, forensic science does not find a place in the annual plan budgets of most of the 19 States. The same observation applies to science laboratories in other fields in the States.

There is also much that requires to be done for reaching out to the districts and the villages to carry, first of all, information on technology developments and then their application.

In this scenario, it is so pleasing to find the initiative that the State of Andhra Pradesh has taken to promote information technology and to set up an Institute for this purpose. More of this kind of enthusiasm and action are needed for the right S&T outlook to permeate the country as a whole.

Industry sector. The present level of investment by the private sector industry in R&D is less than 15% of the total expenditure for R&D in India. This amounts to an average company expenditure of less than 0.1% of turnover. Consequently, industrial production based wholly on indigenous R&D does not amount to more than about 5% of the total. The potential for radical change in this scenario is great. For this potential to be tapped, industry must look at technology innovation and development as a truly profit-making proposition and enhance commitment to R&D.

There are several ways by which industry can enhance their involvement in indigenous R&D: (i) in-house R&D

within the industry, (ii) partnership in joint technology projects with the economic ministries and other partners and (iii) industrial sponsorship in publicly funded laboratories as well as those managed by NGOs. For all this to happen, industry should repetitively experience the benefit of substantial gains from R&D investments. Are there, then, any success stories of sufficient magnitude?

Drugs and pharmaceuticals is an area of some success in terms of industrial research. The turnover of the drugs and pharmaceuticals industry has risen from about Rs 4 crore at the time of independence to about Rs 7000 crore currently and over 80% of the bulk drugs are indigenously manufactured. These are accomplishments made possible through R&D resorted to by the industry for developing alternative processes for drug manufacture. The pharmaceutical sector currently spends about Rs 100 crore annually on R&D and is showing signs of rapid enhancement in investments in the context of economic reforms.

The Indian entrepreneurial skills have been quite quick to grasp opportunities in certain areas of their competitive advantage. This is nowhere better seen than in the exports of some electronic items and computer services, which recorded an impressive growth rate of 47% to reach a figure of about Rs 5,000 crore in 1995–96. The setting up of the hardware and software technology parks by the Department of Electronics, with further liberalization in 1997 for their operations, helped this sector. The progress registered by Tata Consultancy Services is astonishing. The operations of Silicon Graphics in India have registered spectacular growth. Software exports are envisaged to grow at an annual rate greater than 50% through the next 5-year period and exceed a sum of Rs 35,000 crores.

Tata Research Development and Design Centre (TRDDC) marks a bright trend in industry-related R&D in the private sector. TRDDC carries out sponsored research for industry in India and abroad, so also for government agencies. Although slow to pick up (since the start in 1981), TRDDC has emerged as a viable R&D unit with business in excess of Rs 20 million and their earning exceeding expenditure.

Experienced scientists are stepping out of their laboratories, and their secure positions, into the commercial world. Karnataka Hybrid Microdevices, Bangalore Integrated System Solutions, Bangalore Genei in Bangalore, the Indian Resources Information and Management Technologies and AVRA Laboratories in Hyderabad are some of the examples of companies that have thus emerged and the trend is to see more of them in the country.

The small scale industry (SSI) in the country is a vibrant and dynamic sector of the economy. Some 2.3 million units, employing about 14 million people, produce over 7000 items, ranging from the simplest to the technologically most sophisticated. The total SSI production is valued at over Rs 2000 billion annually. This sector contributes over 40% of India's total exports. The rate of growth or production in this sector has often exceeded the growth in industry as a whole. (SSI grew at 5.6% in 1992–93 against 1.8% increase in industry.) Efforts are underway to promote links between this sector widely dispersed in the country and the equally well dispersed R&D institutions. *R&D in small scale sector is a promising growth area.*

A Technology Development and Modernization Fund of Rs 200 crore was set up in the Small Industries Development Bank of India (SIDBI) to finance quality projects aimed at strengthening the export capability of small scale industries. The latest measure approved by the Union Cabinet is to raise the investment limit in plant and machinery for the small scale sector from Rs 6 million to Rs 30 million. The National Equity Fund Scheme has been extended to tiny and small scale units.

On the whole, industry generally has begun to spend a little more on R&D during the recent years with the private sector R&D expenditure exceeding Rs 1000 crores during the last financial year.

Industry interest, involvement and investment in technology development, product innovation and globally competitive exports are vital for the robust growth of Indian economy. Routinely the expression 'GDP growth' is mentioned and discussed. The rate at which productivity is growing, say in manufactured goods, is not commonly analysed, at least not widely publicised. Unless modern technology is brought into play, the total factor productivity growth in manufacturing is unlikely to show a markedly positive trend. Improvement in quality of the product will also depend on R&D support. In a globalized regime, it will be imperative to attach values to technology elements in product manufacture. Industry will have to inevitably develop R&D approaches. Investments in R&D as well as induction of scientific personnel will have to be increasingly resorted to.

Industry hesitates to exercise technological options, often because of unfamiliarity with technologies and the methods to assess them. The result is that industry tends to persist with known technological practices, even if not entirely appropriate or seek licences for collaboration from elsewhere. Industry has to strive to enhance genuine familiarity with the world of technology. This is a central issue.

Government has been the dominant investor in R&D so far. Government has also offered fiscal incentives to industry to promote R&D in industry.* Industry, on their own, and in partnership with the Government and

**Research and Development in Industry – An Overview*, DSIR, New Delhi, 1996.

the laboratories will have to move forward in technology development and utilization with investment necessarily greater than the present level of 15% in national R&D.

Technology in society

The bulk of India's people live in rural communities. While rural poverty is declining, a large proportion continues to subsist below the poverty line. The approach paper to the 9th Five-Year Plan outlines a variety of state interventions for poverty alleviation. These include programmes for delivering seven basic services on a priority basis (drinking water, primary health care, primary education, public housing, nutritional support, road and public distribution systems). Many of these areas can be purposefully aided by technologies appropriate to the needs and conditions in specific zones, districts and blocks. For rural transformation to be engendered, the role of S&T has to shift from being a mere tool to stimulate employment towards a more encompassing responsibility of ensuring growth with equity and sustainability. Relevant technologies and product development activities have progressed in the country in one laboratory or another. What is needed is to help diffuse such developments to distant regions. The crucial element in this endeavour is technology management.

Technology management involves dissemination of relevant technology and product information, strengthening of consultancy services, development of systems around existing institutions for assessing and testing technologies and products for application, to facilitating initiation and growth of rural enterprises. Activities have to be chosen in relation to the local resources and skills. The task is stupendous because of the widely dispersed rural locations.

Various endeavours by the Departments of the Government, S&T agencies and the NGOs have so far not produced a radical change in the scenario. An outstanding exception is the National Dairy Development Board. India today is the single largest producer of milk in the world. The story of Amul Food and the other dairy products is a matter of pride. Lessons can be drawn from this success story as well as the mission-oriented approach and modern project management techniques, which have produced results in our strategic programmes, to ensure that no part of our country is isolated from the benefits of new technologies. A step in this direction is the Technology Management Programme of the Government of India – UNDP Country Cooperation Framework (CCF-1) (1997–2001). This programme will experiment with the concept of Rural Technology Development Centre (which could be a CSIR laboratory, an NGO or an industry R&D laboratory) which will serve as a mother centre in the region to cater for the technology or product development needs of the Block-level Technology Resource Centres.

Human resources for S&T

Apart from viable financial support, the most important input for R&D is manpower. While India has a large strength of S&T personnel of over 6.3 million, the number of scientists actually engaged in R&D is only about 150,000. The stock of technicians is also not large, only about 750,000. The majority of these are engaged in Governmental laboratories.

To match the rise in R&D expenditure to a level of 2% GNP by the end of the 9th Plan, the present strength of R&D personnel should be doubled to 300,000 to 400,000 by the end of the 9th Plan. A policy as well as a set of implementation measures would be needed to reach this target by the end of the 9th Plan.

The strength of R&D manpower and the stock of technicians, like expenditure, can grow rapidly if industry makes its contributions through induction of R&D personnel and technicians in substantially larger numbers than what is the situation today. These numbers are the key to wealth generation from S&T.

In about the last three decades, there have been negative as well as positive trends in the field of human resources development. In regard to higher education, the positive trend is that the annual student enrolment in various courses of study has risen consistently to add up to nearly 6.5 million at the end of 1996. However, there is a clear drop in the enrolment in basic sciences from 30.0 to 19.6% in a matter of three decades. The enrolment in engineering and technology has not increased significantly, their percentage share currently being only about 5% of the total.

However, an outstanding development, since independence, is the setting up of the five IITs (Indian Institutes of Technology) starting with the first IIT at Kharagpur in the fifties and adding four more (at Kanpur, Bombay, Delhi and Madras) in the sixties. The sixth IIT has just now come into being at Guwahati. IITs have proved themselves to be islands of excellence in the area of higher education in engineering and technology. Hordes of IIT graduates have attracted opportunities in large numbers in USA.

In the field of post-graduate education and research in engineering and technology the following trends are worrisome. (i) The average turnout of Master's Degree holders in engineering technology is only around 5000 per year and this is against the capacity of more than 15,000. (ii) The loss of engineering graduates to software industry is taking place on a large scale with consequences to post-graduate programmes. On account of these negative developments there is an acute shortage of teachers with post-graduate qualifications in engineering and technology. The situation is becoming one of concern as expansion in engineering education will have to go hand in hand with economic growth. (iii) The number of doctorates in engineering and technology being produced annually now is only about 400 and 90% of them come from only a dozen institutions.

Several measures are needed to help improve the situation in regard to availability of post-graduate engineers and technologists for technology intensive projects and programmes.

A most successful strategy for ensuring the availability of scientific and technical manpower in a continual fashion for a high technology programme is the one used by Homi J. Bhabha. The Department of Atomic Energy inducts candidates from a variety of disciplines first into their training school. The graduates entering the training school go through an year long coaching in advanced fields (nearly up to the post-graduate level) before they take up their regular jobs. The superb idea here is that the training school inductees are assured of a job.

The concept of an *assured placement scheme* is extremely relevant today. The Government, as well as the industry investment, in new technologies, have to be supported with trained manpower. Educational programmes at advanced levels are not merely the responsibility of the Ministry of Human Resource Development. Major economic ministries, science departments and industries will have to, henceforth, actively participate to ensure adequate rate of growth of trained manpower.

When biotechnology was emerging as a new field, the Department of Biotechnology took the initiative to promote M.Sc. courses in biotechnology. This has naturally provided trained manpower in this new field as more and more biotechnologists were needed in the country. The pace of development of communication and information technologies is mind-boggling. The country has to rise to the demands of these emerging fields by actively promoting educational programmes and institutes in this area.

The Department of Space and the Department of Defence Research & Development have funded a few major research centres in academic institutions in fields relevant to them. Such initiatives will have to be expanded rapidly to include educational programmes in some of the high technology areas. Ocean development is another emerging area which in future will require trained manpower in abundant numbers. Department of Ocean Development has recently supported a post-graduate course in Coastal Aqua Culture and Marine Biotechnology in Andhra University and a Unit for Ocean Technology in IIT Madras. A reference has been made to manufacturing technology. Advanced degree courses in such fields are yet to take adequate shape in the country.

Improvement in the availability of trained manpower in all these fields will be possible only when the respective stake holders in the Government and industry initiate measures to support advanced teaching and training programmes in our institutions. An example of a successful link between the industry and a technology teaching institution is the University Department of Chemical Technology in Mumbai.

The training of technicians is equally important. Advanced countries speak of different levels (e.g. Japan's supertechnicians for micro electronics industry) of training for technicians in specific fields. Industry as well as professional associations have to do much more to cope with the demands for trained, and higher-level trained technicians.

There is a need to set up a National Centre of Engineering Information (on the lines of National Science Information at Bangalore). In this age of information super highways, software and other resources are available on the Internet. In order to use these extensively in teaching and research, we need to set up several committed groups to download, suitably reorient, package and disseminate the software for use in educational institutions.

The government has introduced a number of fiscal measures to encourage industry to invest in R&D. A governmental innovation in terms of fiscal incentives to private industry for inducting scientists as well as trained technicians is needed. In the same way, industry could be encouraged by the government to support post-graduate technical education by offering tax incentives for the expenditure incurred solely on this account. These measures would be in line with the expectation that industry should come forward to supplement government efforts in an all-round fashion, not only to promote R&D investment but also to enlarge the base of utilization of R&D personnel.

International R&D

Generally, large domestic markets attract R&D investment from abroad. Although overseas institutions have not yet come into the country substantially for joint R&D, this should be expected to happen. Domestic markets in India are huge in agriculture and health-related products. So far, notable R&D initiatives from abroad have not been many. Roche Scientific Company (India), Mumbai and Astra Biochemicals, Bangalore are recent in the area of pharmaceuticals. Astra are not altogether new to this country. Astra have been operating a research centre for more than seven years in Bangalore, funded totally by Astra AB (funding presently is approximately Rs 100 million). The objective of the centre has been to develop novel, highly selective therapeutics for treating diseases such as malaria and tuberculosis. Astra Biochemicals is expected to be a business wing of their research centre. Imperial Chemical Industry's new research laboratory is being envisaged as a centre for worldwide research, and not merely research for the Indian market. Recent additions to this list are Cray

Research Limited, a wholly owned subsidiary of Cray (Computers) Research Inc., USA and Uniliver International Research Centre as part of their international research station network. A few others are on the anvil.

International Advanced Centre for Powder Metallurgy and New Materials is a large and promising technology development centre, recently set up by the Department of Science and Technology in Hyderabad with participation of five former CIS countries, namely Russia, Ukraine, Byelorussia, Moldova and Uzbekhistan. Investments by the CIS countries have been made through contributions by way of equipment and technology for the projects. This Centre is an outcome of the Integrated Long Term Programme of Cooperation in Science and Technology (ILTP) between India and Russia. ILTP covers many disciplines and has been underway for a decade with the help of a joint science council. International Centre for Genetic Engineering and Biotechnology (ICGEB) in New Delhi has come into existence through UNIDO with support on the Indian side by the Department of Biotechnology.

Cooperation between the Indian and the US academic communities has a happy history with several successes to its credit. In terms of formal arrangements, the largest joint science collaboration until recently has been between India and the US. The collaboration agreement benefited from the US India Fund (USIF) was instituted through the PL 480 scheme. However, with the expiry of the scheme, new initiatives will have to take shape. A joint Indo-US S&T Forum has just been agreed upon. Department of Science & Technology (India) and National Science Foundation (USA) will cooperate through a joint arrangement. Another recent agreement with US pertains to cooperation in earth and atmospheric sciences.

The Indo-French, Indo-Japan and Indo-Israel joint science collaborations have a formal structure in the shape of joint science councils, so also the Indo-German and Indo-UK cooperative science programmes, all of which are growing. In the case of Indo-French collaboration, the setting up of a Indo-French Centre for the Promotion of Advanced Research has been an effective mechanism and has successfully functioned for ten years now.

The partnerships being entered into by corporate entities with overseas companies to take up joint R&D is a new trend. Ranbaxy has teamed up with Eli-lily to take up R&D jointly in India for discovering new drug molecules. Novo Nordisk A/S of Denmark have a joint R&D venture with Reddy's Laboratory in Hyderabad to develop a series of molecules for anti-diabetic application. Reddy's Laboratory has a joint R&D programme with Debiopharm of Switzerland for developing anti-cancer drugs.

R&D is an expensive proposition. Different countries have differing strengths and weaknesses. While research hardware is not easy to come by in India, manpower in western countries is a more expensive commodity. With the available research skills in this country, the cost effectiveness of R&D in India is a well-recognized advantage. *Joint R&D provides an effective mechanism to exchange knowledge and to intermesh the advantages and weaknesses of the participating countries for the benefit of accelerating the pace of progress in R&D. International R&D is therefore bound to become popular.* India should design methodologies and strategies to profit from this trend.

Nation's scientific data

The subject of scientific data information is not discussed often. Every nation generates a vast amount of data on a whole range of parameters at a great cost. In the modern age, this subject has acquired considerable significance.

We have many organizations in the country today engaged in producing relevant data in a wide spectrum of fields: topographic maps, meteorological data, geological resources data, forest surveys, data concerning various life forms, both plant and animal, oceanographic data, seismological data, public health data, data pertaining to water resources such as river basins, rainfall and irrigation. The gathering of these data is a colossal exercise involving several thousand scientists, whose painstaking work generally goes unnoticed. Satellite-based techniques are a recent development catering for the purpose. Data of this type are important for national economy and the social relevance arises from the fact that some of the areas mentioned above affect disadvantaged populations.

There are many issues associated with the scientific data system as a whole. There are also ramifications. Scientifically speaking, techniques for measurement are getting progressively updated. Deployment of advanced techniques, higher resolution in data surveys, precision and validation of measured data, use of improved computing techniques for documentation are some of the issues demanding attention.

Further, new developments in science demand altogether fresh endeavours and new skills. For example, the area of genetic information, which is basically information about families. The new genetics has serious implications for the legal system, for insurance and employment practices. A very large programme would be necessary to handle new knowledge and the rapidly developing technologies in this field.

Data of various types are needed for scientific analysis, research, forecasting and risk assessment (based on data associated with natural disasters).

An example of data inputs for risk management is the project of Department of Ocean Development on sea level monitoring and modelling. Part of the activity relates to preparation of 0.5 metre contour interval coastal maps of the stretch from Nellore to Machilipatnam using aerial photography in the scale of 1 : 25,000. This has cost Rs 20 million!. This coastal stretch of the Andhra coast is prone to frequent tidal wave attacks. The digitized data collected during the mapping activities are being used to develop an inundation model, so important for risk management. Hopefully financial resources will be found to extend this programme to other coastal stretches, especially along the east coast of India.

Scientific data are of economic value as they are often required for commercial purposes. For example, meteorological data have implications to agriculture, power, air conditioning industry, tourism, sports, aviation, climatic changes and so on. The importance of atmospheric studies is exemplified by what happened following the discovery of the ozone hole during an expedition to Antarctica. Within two years of that discovery, the whole world was sensitized through the Montreal Protocol in 1986 and everywhere there is now awareness of the importance of air quality. Comprehensive atmospheric analyses with respect to pollutants such as carbon dioxide and methane have national and international implications. International scientific efforts at measurement and analysis to confirm or discard notions about global warming and sea level rise are well known.

Therefore, the realm of scientific data pertaining to a range of systems, land, sea and atmosphere, and life forms, constitute a national issue of public importance. In any given aspect of these systems, data gathering itself is a massive and time-consuming job. It is a large endeavour also to take stock of the availability of such scientific data, the quality of the data archived and the adequacy of the methods and the techniques adopted for ensuring the required standards of data quality. *The use of such data bases for the benefit of the public and the national scientific effort calls for a re-examination of the current policies governing access to such data to ensure informed public opinion and encourage value-addition to the acquired data through both public and private enterprise without jeopardizing national security interests.*

Emerging pressures

Presently, the trend in every field is towards globalization – in politics, economy, culture and S&T. The key factors are interdependence and the aspiration to harness human intellect for common good. Declarations have been made to move towards universal principles of equality, liberty and democracy.

Earth Summit of 1992 in Rio-de-Janeiro was a major event. Nearly the entire world came together to establish a new global partnership. Agenda 21 commits all states to engage in a continuous and constructive dialogue, keeping in view the increasing interdependence of the community of nations and calls for sustainable development to become a priority item on the Agenda of the international community.

In certain areas of technology requiring massive funds and multiple inputs (e.g. high energy physics, fusion energy) cooperative R&D between nations is becoming the only way for the efforts to be viable. Even in less demanding areas, as pointed out earlier, international cooperation is growing because of advantages arising from complementarity. India's joint science programmes with other countries have been a rewarding experience.

Despite the declarations about global partnership and notwithstanding cooperative scientific endeavours, transfer of technology across the seas does not always occur. India's attempts to acquire technologies have often met with obstacles, even in instances where the goal was to introduce clean technologies which is of international interest.

Before the Second World War, embargoes existed only in times of war. Strangely, during the 50 years of relative peace, technology control regimes have been evolved in several areas to deny countries such as India the fruits of S&T in a universal and nondiscriminatory manner. *Leading edge technologies are sought to be denied, not so much in exercise of the profit motive of individual companies, which is understandable. The denial sometimes seems to be governed by arbitrary political considerations and this is not only in high technology areas. The problem is compounded by disparate views of applying free trade in some areas and control regimes in others.*

All this is as inexplicable as it is illogical. Independent India has always been a highly responsible member of the comity of nations. India's position on all issues of international importance has been constructive, be that on chemical weapons, or narcotic drugs, or nuclear proliferation or what have you. We have never asked for anything more than fairness and a level playing field. And yet efforts continue to be made to deny India the opportunities for growth, opportunities to undo some of the wrongs done to it by history.

There are now pressures arising from WTO and other multilateral arrangements where intellectual property rights are actively discussed. A case in point is the recent grant of a US patent for the use of turmeric powder as a wound-healing agent. CSIR took this up and has succeeded in having the patent nullified. This is a significant event for the protection of traditional Indian knowledge base. The lesson is to mount efforts to acquire capabilities to deal with the complexities of external attitudes and the challenges under regimes such as WTO.

Indian research capabilities have to be geared to contend with the inevitable pressures of a competitive world and aim definitively at securing gains for the country through innovations. This may seem unfamiliar ground now but cannot remain so for long, once we decide to equip ourselves appropriately.

It has become all the more imperative for us to get our S&T act together. Debates like basic science versus applied science, strategic science versus societal science have to be put aside. Existing capabilities have to be consolidated and new ones have to be acquired. All-round progress is essential to cope with the demands that will continue to be made on our scientific resources and technological developments.

Concluding remarks

In retrospect, it is clear that the country has taken many strides in S&T in the last fifty years. Considering the situation that prevailed in 1947, the progress that has been made in several areas since then does us proud. The Government has so far been a dominant supporter of S&T. We owe this to the political leadership, regardless of the party in power. Presently several urgent measures are needed to revitalize our science infrastructure for which interventions are required.

Looking forward to the future, bold new approaches are needed to harness S&T for faster economic growth. Government has a role in facilitating this, not industry alone, as is generally believed.

We need to strengthen existing mechanisms, and create new structures where necessary, to promote indigenous technology, to protect it from foreign competition until it stabilizes and to acquire technologies from elsewhere, if possible. We also have to absorb the imported technologies and build complementary strengths. The Government and its agencies have to help provide bridging inputs and cover, in reasonable measure, the risk element. However, it is industry which is best placed to commercialize technologies. For all these, visionary policies are necessary. I fervently hope that the pointed suggestions made in this article will receive favourable consideration.

As behoves a great country, India has pursued a policy of self-reliance since independence. When we are today subject to competition and controls, we only need to strengthen this fibre of self-reliance. The foundations that we have laid in S&T, along with our strong democratic polity, have ensured India's stability through vicissitudes of the developmental process. These are bound to stand us in good stead in the face of multifarious pressures as we move into the next millennium to build a strong India. India's large size, abundant natural resources and vast human skills bear the potential to make India a prominent world power and a force for good. Our goal must be to realize this potential.

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