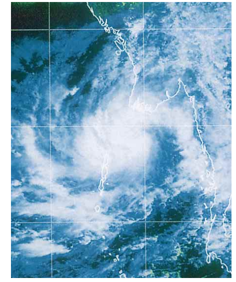
LAYING THE FOUNDATION OF RESURGENT INDIA

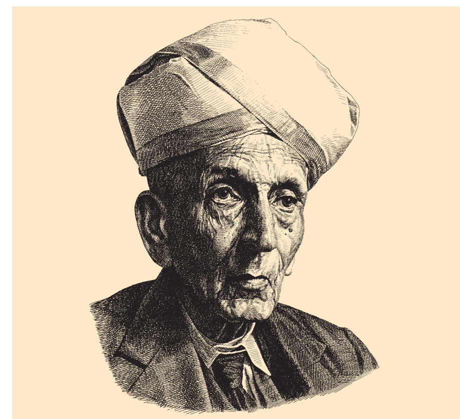
Taking the path of non-violence, Mahatma Gandhi led India to Independence. We were blessed with leaders who were determined to build a strong democratic nation free from poverty, hunger, ill-health, ignorance and fear. They recognized the value of education in general and of science and technology in particular to realize these goals. An overview of the endeavours in this direction is presented by a doyen of science. Developments in education in science, engineering and technology are traced by two eminent scientists. There is reason to feel jubilant that Indian students are winning medals in International Science Olympiads.



CHAPTER III

SCIENCE AND TECHNOLOGY SINCE INDEPENDENCE: AN OVERVIEW

In 1947, India was fortunate in having a strong foundation for science and technology (S&T) which could be regarded as among the foremost of all developing countries which had gained freedom around that time. Whilst some of this was due to traditions going back to the origins of Indian civilization, a large part of the modern base was due to the endeavours of individuals, like Mahendra Lal Sircar and Asutosh Mookerjee in Bengal and J. N. Tata in Mumbai, who were great promoters of science, and the outstanding work of many Indian scientists like J.C.Bose, P.C.Ray, Srinivasa Ramanujan, C.V.Raman, S.K.Mitra, Birbal Sahni, Meghnad Saha, P.C.Mahalanobis, S.N.Bose, Vikram Sarabhai and many more whose brief sketches have been featured as torch bearers in this volume. All these scientists worked in educational institutions, and their achievements were at par with the very best in the contemporary world -- C. V. Raman did win a Nobel Prize; some others could and should have won, considering their contributions. Their work was essentially 'small science' in today's context. There were also achievements by engineers, notably M.Visvesvaraya, which laid the foundation for self-reliance and self-confidence, in taking up large complex projects such as dams, irrigation systems, generation of electricity and the like. It is important to emphasize that these remarkable men were products of the indigenous culture, largely self-taught, and without the advantages of foreign education and guidance.

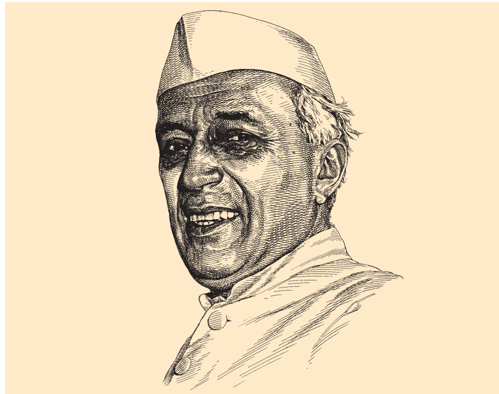


M.Visvesvaraya (1861-1962): A pioneer engineer-statesman.

At the time of Independence, however, despite the scintillating contributions that had been made to modern science, there was nothing in the economy to speak of. Growth rate in agriculture was only 0.3 per cent. The manufacturing industry was woefully small. The knowledge base was ready for a modern scientific and industrial infrastructure to be built, envisioning a future for the new nation.

THE NEHRU YEARS

In 1947, the year of Indian Independence, addressing the Indian Science Congress held in New Delhi as its President, Jawaharlal Nehru remarked: *We have to find food for them, clothing, housing, education, health and so on, all the absolute necessities of life that every human should possess. So science must think in terms of the few hundred million persons in India.*



Jawaharlal Nehru (1889-1964): Architect of modern India.

Nehru was clear in his mind about the relationship between science and society as a whole and its relevance, in the Indian context, for meeting the basic needs of large numbers. This was a recurring theme in his thought and deliberations. It was Nehru who envisioned the role of S&T to underpin and accelerate national development, science being an important element in modernizing the country to bring about what he repeatedly referred to as 'scientific temper' in society, an essential aspect of the culture of a new civilization.

Nehru promoted the growth of science in every conceivable way. He travelled the length and breadth of the country to open laboratories, to attend scientific meetings, and notably the Indian Science Congress at the beginning of each year. He supported the aspirations of major players -- Homi Bhabha, to develop the Indian atomic energy programme, which later nurtured the Indian space programme; S.S.Bhatnagar, to create the chain of laboratories of the CSIR; P.C.Mahalanobis, to generate the base of statistics in terms of research, training and application as an enabling tool, particularly for planning; and D.S. Kothari to initiate work in defence research which grew into the Defence Research Development Organization. The high point of what Jawaharlal Nehru did for science was embodied in the Scientific Policy Resolution, adopted by the Government of India on March 4, 1958 (see annexure I). It was a fairly unique statement then for any country, leave alone a developing country

During the years that Nehru was Prime Minister, there was massive quantitative expansion of the educational system at all levels -- from primary schools to universities. However, a significant major initiative was the setting up of some unique institutional systems, namely, the Indian Institutes of Technology (IITs), Indian Institute of Management (IIM) and All India Institute of Medical Sciences (AIIMS) which are academic, degree-granting institutions, but set apart from the normal university system. The IITs, primarily based on the Sarkar Committee Report, were designed to be the leaders in the field of technical education. Nehru remarked: *While it is relatively easy to put up a factory or a plant or a project, it is much more difficult and it takes much more time to train the human being that will run a factory or plant*. Overall, the graduates of the IITs have been remarkably successful. The selection procedure, involving a stiff entrance examination, ensured outstanding input and the undergraduate B.Tech. programme has maintained very high standards. Today, many of the graduates from the IIT system occupy some of the most distinguished positions in business, industry and government in the country and abroad. The IIT B.Tech. has become one of the prized brand names to emerge from India. The same applies to the IIMs and AIIMS.

The Nehru period was thus characterized by massive development of an infrastructure for S&T, and for the promotion of quality and excellence. The next twenty-five years in the nation's life brought maturity in facing challenges even while reaping the successes that followed.

Confidence and Striving

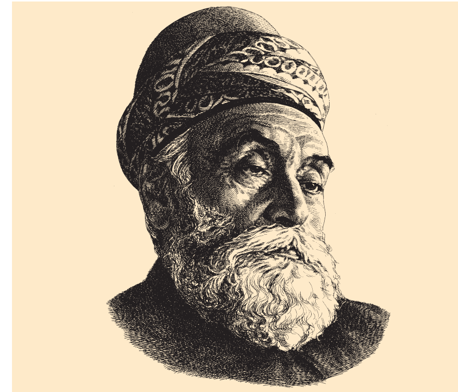
In January, 1966, Indira Gandhi became Prime Minister of India. Her approach to science was very similar to that of her father, Jawaharlal Nehru. She remarked: *Science, with its spectacular achievements, in increasing production and multiplying a thousand-fold the speed of man's movement and the range of his sight and sound, has aroused limitless expectations.*

What is more, it has the capacity to fulfill them. The challenge before leaders of science and the moulders of national and international policies is how to direct the removal of hunger, want and the diseases of privation.

The emphasis on the role that science can play in bringing about a better quality of life for humankind is obvious. But again, like her father, Indira Gandhi had a holistic view, with a deep appreciation of the interplay of the many elements that make up life: the environment from which we derive sustenance, human culture and creativity, and the development and use of capabilities to advance the well-being of society. In her own words: *Planned support for science has been one of the major commitments of governmental policy in Independent India. Jawaharlal Nehru recognized that the change of material conditions and means of production could be brought about only through a programme of scientific research and development. Science, to him, was the Bow of Shiva with which to vanquish poverty.*

The Green Revolution: One of the important areas of success in Indira Gandhi's early tenure as Prime Minister was achieved in the effort to significantly increase food production. It came about through a combination of clear-cut political decisions, good administrative support, and high quality applied research. It made the fullest use of new developments in agricultural research from abroad, which were then adapted to local conditions and blended with existing resources and cultural practices. There was good team work in extension, education and dissemination. This brought about the 'Green Revolution'. From a figure of around 50 million tonnes in the 1950s, grain production has quadrupled to around 200 million tonnes now. Not only in the case of grain, but over a wide range of agricultural products, there has been enhanced production, productivity and diversification.

The Green Revolution and related developments in agriculture, along with the potential of the new developments in biotechnology, give confidence that India can be essentially self-



Jamsetji Nussarwantji Tata (1839-1904): He nurtured science and technology in India.

sufficient in the matter of food. A number of successful missions, among them the 'White Revolution' relating to the dairy industry and milk distribution, the construction of the largest irrigation network in the world, the growth of a chemical industry, which is one of the largest in the world, achieving contemporary international levels in process systems design and catalysis, all serve to illustrate what has been accomplished in largely diverse areas, all closely related to development.

During the 1970s and '80s a wide range of new enterprises were begun in areas of great importance to the nation's future, such as electronics, environment, new and renewable energy sources, ocean development and biotechnology. These have become major spheres of activity in their own right, and will bear fruit as we have moved into the new millennium.

Strategic Areas of Self-Reliance

India's nuclear programme was envisioned by Homi Bhabha for peaceful purposes, especially large-scale production of electricity. This is unlike the major players in this field (USA, USSR, UK, France and China) who had embarked initially on nuclear weapons programmes; for them nuclear power came later. In India, nuclear electricity came first, followed much later by nuclear tests at Pokhran in 1974 and 1998. In some other countries too, for example, Japan, nuclear electricity was the prime motivation. But India's efforts preceded all of these. The entire range of technologies from prospecting for raw materials to the design, construction and operation of large power reactors is now available on a self-reliant basis.

The space programme, started by Vikram Sarabhai, was again for wholly peaceful developmental purposes like telecommunications, broadcasting, and remote sensing. Over a period of 40 years, capabilities have been developed to build operational satellite systems for all the above application areas. The launch of orbiting operational remote sensing satellites is now carried out on a routine basis. Launchers for orbiting operational geostationary satellites have also been tested. India's satellites, whether low orbiting ones for remote sensing or geostationary ones for telecommunications, broadcasting and meteorology, have performed at contemporary international levels. These are designed and built in India.

Defence research, whilst initially dealing largely with improvements to imported equipment and minor adaptations and modifications, rapidly moved forward to import-substitution. Over the last quarter of the century, it has taken on wholly a new range of manufacturing such as battle tanks, advanced guns, electronic warfare and guided missile systems, radar and communication systems, combat aircraft and the like. There is significant self-reliant, indigenous input in all of these and strong linkages are continually being established with the national research systems, as well as the industrial production systems.

Department of Science & Technology (DST): To provide a nodal point for science and technology in the broadest sense, apart from specific areas such as atomic energy, space, and electronics, Indira Gandhi set up the DST. It was this Department which created the first effective institutional framework for advice to Government on matters relating to science and technology by setting up the National Committee on Science and Technology in 1971. Many initiatives were taken by this body and its successors, the Science Advisory Committee to the Cabinet, which functioned from 1981 to 1986, followed by the Science Advisory Council to the Prime Minister, 1986 to 1990. It was the DST which provided the base for nucleating activities in the areas of ocean science and technology, new and renewable sources of energy, large-scale remote sensing, and of biotechnology. It has also provided broad-based support for research in a variety of disciplines in S&T.

Environment and Ecology: Environment and ecology gained international importance with the UN Conference on Human Environment held in Stockholm in 1972. From the local issues of air, water, and industrial pollution, going on to regional and trans-boundary impacts, and to environment in relation to health, discussions have now progressed to global issues such as ozone depletion and increase of carbon dioxide concentration in the atmosphere, and the consequent implications for climate change. The great importance of the earth's biodiversity, something that has come down through a large and complex process of evolution, as a rich resource for the future is an issue that has also come to the forefront. India has a good scientific base (including one in the use of powerful techniques of modern biology) to deal with this area.

Indira Gandhi was always deeply interested in the cause of the environment. She was one of the two Heads of Government who attended the 1972 UN Conference in Stockholm. It was there that she made her famous statement: *Are not poverty and need the greatest polluters? The environment cannot be improved in conditions of poverty. Nor can poverty be eradicated without the use of science and technology.* She was the first world leader to explicitly relate environment to poverty eradication. In 1972, she established the National Committee on Environment Planning and Co-ordination, which set the tone and ambience for such work in India. In 1981, the Department (now Ministry) of Environment and Forests, came into being.

Indira Gandhi (1917-1984).

Renewable Energies: Indira Gandhi set up a Commission on Additional Sources of Energy that became the base for establishing the Department (and now Ministry) of New Energy Sources. It is clear that this is a pursuit of utmost importance for India, as we search for all possible ways to meet our energy needs, particularly in the vast rural hinterland where electrical transmission and distribution systems are rudimentary or absent. To set up the conventional systems in these regions would call for very large investments and long time scales besides other costs. Renewable energy systems would ensure sustainable development, while reducing usage of fossil fuels at the same time. This is clearly an area for thrust and emphasis, in this century.

Electronics and Information Technology: After the hostilities with China in late 1962, Homi Bhabha pointed out to the Government of India that research as well as production in various sectors of electronics, particularly in strategic areas, was not in a satisfactory state. Thereafter, a Committee was set up under his chairmanship, whose report he finalized but it was actually presented to Prime Minister Indira Gandhi a few weeks after he died in a tragic air crash in 1966. Initially, the Government tried to implement the recommendations of this Report through another committee. Five years later, when Indira Gandhi discovered that this had not worked, she set up a separate Department of Electronics and an Electronics Commission.

Whilst the Department of Electronics had to deal with the usual areas of industrial licensing, clearance of imports and the like, as called for by the country's laws, its principal focus was on promoting areas of high technology in terms of research and production. Two major programmes were implemented for the defence services. One was the Adges Plan for the Air Force, in which it was necessary to integrate and operationalize radar systems set up to monitor incoming threats, with communication systems which transmit this information to ground bases, along with computer hardware and software capable of analysing the threat and setting in motion necessary counter measures. This was done successfully on an indigenous basis.

The other programme was the Aren Plan which was a complete communication network for the Indian Army, from field levels to headquarters. Through these plans, very significant capabilities were built up relating to static and mobile radar systems, mobile and wireless communication networks and associated computer systems. This was the first major effort in which electronic switching was introduced in a networking mode linking wired and wireless systems. The automatic electronic switch developed for Plan Aren along with the work at the Telecommunication Research Centre of the Ministry of Communications on digital electronic switching, became the base, in the '80s, for setting up the Centre for Development of Telematics. This Centre was responsible for the development and induction of indigenous electronic switching on a very large-scale into the national communication system, particularly for the rural areas.

An area to which the Electronics Commission devoted considerable attention was that of computers. Major computer systems were inducted into the country for use as stand-alone systems at regional and national centres. Two major national centres were set up: one was a National Centre for Software Development and Computing Techniques (which has since become the advanced National Centre for Software Technology); and the other was the National Informatics Centre which brought in large-scale database management into Government systems and established a network for information gathering, storage, accessing and communication, across the country at all levels, from the village *Panchayat*, to District, State and up to the Centre.

When restrictions were imposed by the United States on import of supercomputers by India, even though these were meant for meteorological long range weather forecasting and for scientific research of a broad nature, India mounted an effort to develop supercomputers working on parallel processing. Whilst work on this project was carried on independently in the atomic energy, defence and industrial research systems, the main national effort was concentrated at the Centre for Development of Automatic Computing which successfully developed parallel computing which could effectively do what the systems earlier planned for import were meant for.

In order to be part of the global electronic system relating to exports/imports, export processing zones were set up; the first was at Santa Cruz in Mumbai in the early '70s and Software Technology Parks established in the '90s; the latter was the basis on which Indian software companies were able to establish themselves in the country to embark upon major software export tasks.

An important initiative taken up by the Electronics Commission in the early '70s was to establish facilities for the production of semi-conductor devices with a resolution of a few microns, which would have been contemporary then. However, unfortunately, for a variety of reasons, largely related to administrative decision making in Government, this programme did not progress.

Whilst software development and exports started to grow on a significant basis towards the latter part of the 1990s, particularly with the IT boom that was taking place globally, the Government took a decision in 1998 to set up a National Task Force on Information Technology and Software Development. This body has submitted several reports to the Government during the short period that it functioned. These deal with the large-scale growth of information technology in the country including generation of human resources, e-governance, software development and exports, development of a content industry, promotion of hardware manufacture in the country and many such related issues.

Micro-electronics enabled the computer revolution: we are now into the age of informatics -- with computers and communications merging into a single stream, bringing together all types of media relating to information storage, access, dissemination, computation and analysis. Information Technology (IT) represents a revolutionary tool, which promises to transform every facet of human life and usher in a knowledge-based society in the next century; it will bring about connectivity of each human being on earth to all others. There has been increasing recognition in India of the importance of IT in national development. In a variety of ways, India now has a base to embark on an IT programme that will enable it to emerge as a major global player. The new National Informatics Policy can bring this about. The wide ranging and rapidly growing capabilities in IT are the result of efforts in strategic areas such as defence, nuclear and space research, as well as other government initiatives relating to software development and database management, parallel computing, digital communication systems, and the rapid growth of the private sector in the field of software, particularly for exports.

Institutional Framework for Advice to the Government at High Level on Matters Relating to Science and Technology

There has always been an apex level structure for advising the Government on policy issues relating to all aspects of S&T. Some of these structures in the past were: (a) Advisory Committee for Co-ordinating Scientific Work - 1948; (b) Scientific Advisory Committee (SAC) - 1956; (c) Committee on Science & Technology (COST) - 1968; (d) National Committee on Science & Technology (NCST) - 1971; (e) Science

Advisory Committee to the Cabinet (SACC) - 1981-1986, and (f) Science Advisory Committee to the Prime Minister 1986-1990.

In addition, a Cabinet Committee on Science and Technology was set up in 1981, under the chairmanship of the then Prime Minister, to oversee and provide policy guidance for the development of the S&T sector. In 1986, a Scientific Adviser to the PM was appointed in addition to a Science Advisory Council to the Prime Minister (SAC-PM), largely consisting of scientists and technologists from outside the Government system.

NCST (1971-1980): The National Committee on Science & Technology (NCST), particularly when it was first constituted in 1971, performed an important role in trying to link science and technology development to the planning process for which it produced an S&T plan. It also devised means to promote science and technology promoted by the State Governments through appropriately constituted bodies.

SACC (1981-1986): Important developments that arose out of deliberations of the Scientific Advisory Committee to the Cabinet (SACC) during its tenure from 1981-1986 were:

- Setting up of a National Science and Technology Entrepreneurship Development Board (NSTEBD) so that scientific capabilities, financial resources, as well as local natural resources and needs, could all be integrated with significant employment potential.
- Recognition of the spectacular advances taking place in the life sciences and in their application through biotechnology which, in time, would be of great importance in areas of food and health, apart from their deep significance for many other aspects of human life. To take care of this area, a National Biotechnology Board was initially set up, which has now evolved into the highly active and promotional Department of Biotechnology.
- The National Council for S&T Communication (NCSTC) was set up in 1982, and it continues to function and organize a variety of activities that relate to science communication and aspects relating to promotion of scientific temper in the society.
- A scheme referred to as COSIST was established to ensure further support through the University Grants Commission for groups and departments in educational institutions that had established their credibility for high quality teaching and research in S&T.
- By analogy with the Indian Council of Agricultural Research (ICAR), a new set-up was created for the sector of forestry, in the Indian Council of Forestry Research & Education (ICFRE).
- Considerable efforts were put in to strengthen the areas of S&T in forensic activities under the Ministry of Home Affairs.

SAC-PM (1986-1990): In 1986, Prime Minister, Rajiv Gandhi decided to replace SACC by a smaller committee consisting of only non-official working scientists to advise him on major issues of S&T, its health and the direction in which it should move. This committee was designated Science Advisory Council to the Prime Minister (SAC-PM). It was expected to examine certain matters concerned with the scientific departments, priorities in research and development and monitor the technology missions initiated in 1985. In addition, it was to prepare a perspective plan for AD 2001. The Council got in-depth studies carried out by experts drawn from all parts of the country on major issues of societal concern, e.g. food security, watershed management, population control and improvement of human health, protection of environment etc. At the same time it commissioned studies on frontier areas of S&T like advanced materials, photonics, parallel computing, lasers, robotics and manufacturing automation.

The Council presented its recommendations to the Prime Minister at regular intervals.

An empowered committee headed by the Cabinet Secretary was charged with the responsibility of implementing any programmes emanating from these deliberations. This often required coordination of activities of several departments and agencies of the Government. The Council reviewed some of the recommendations of the SACC and in consulation with the Scientific Adviser to the Prime Minister ensured their implementation. Some of the major outcomes of Council's efforts were the creation of C-DAC which developed supercomputers strengthening of activities in the field of telecommunications, laser and robotics and superconductivity research. The Council also made recommendations on the use of S&T in planning, its integration with economic planning and planning for S&T *per se*. Those interested may consult the Council's publication, *Perspective in Science & Technology*, published in two volumes by the DST in 1990.

A Scientific Advisory Committee to the Cabinet (SACC) was constituted in June, 1997. This was an Advisory Committee to the Cabinet and the terms of reference were: rendering advice on the implementation of S&T policy of the Government; identifying and recommending measures to enhance the country's technological self-reliance and also foreign collaboration; and considering policy issues for the development and application of science and technology and organizational aspects of S&T institutions. The Committee also looked into the issues relating to filling critical gaps in national competitiveness, promoting technological co-operation amongst developing countries, emerging changes from international competitiveness in S&T and other international matters.

The tenure of the Committee was for two years. The SACC had considered various issues relating to autonomy of scientific institutions, guidelines for technology transfer, modernization of patent office, revision of fellowships for research students, special incentives for women scientists and strengthening of infrastructure and improvement in the universities and related S&T institutions.

The SAC (C) was reconstituted in March, 2000. The terms of reference were almost same as the earlier SACC. This Committee has also held two meetings to discuss simplification of administrative and financial procedures, human resource development, especially women scientists, core competence of the nation, among other matters.

There is also a Consultative Group of Government departments and agencies on S&T. The terms of reference are to evolve mission and action plans for implementation of S&T policy, to review the scientific and technological progress of missions, to suggest schemes to nurture a scientific environment and other important matters for development and application of S&T in different sectors. An Expert Committee of Senior Scientists has also been set up.

The Technology Policy Statement

Perhaps, the most important conceptual initiative of SACC was in the drafting of the Technology Policy Statement (TPS, see annexure II) adopted by the Government in 1983; this was announced by the Prime Minister, Indira Gandhi, in her inaugural address at the annual session of the Indian Science Congress in Tirupati in January 1983.

The fundamental approach of the Technology Policy Statement was to ensure that S&T is applied in a manner relevant to country's development. It focused on aspects of efficiency, employment, environment and energy. The essence of the Technology Policy is: *In a country of India's size and endowments, self-reliance is inescapable and must be at the very heart of technological development. We must aim at major technological breakthroughs in the shortest possible time for the development of indigenous technology appropriate to national priorities and resources.*

A Technology Policy Implementation Committee (TPIC) examined the TPS in detail to spell out measures needed for its implementation. Two of the measures worked out by TPIC have since been implemented. One is the setting up of a Technology Information Forecasting and Assessment Council (TIFAC) to ensure the availability of full information on the technology scenario in the world and within India as also to ascertain developments that are likely to occur and the capability to assess and choose the technologies most relevant for the nation's needs. Another recommendation was the setting up of the Technology Development Fund, which would support all proposals considered *prima facie* suitable for the development of advanced and relevant technologies. Today these are being implemented by bodies under the purview of the DST.

Science, Technology and Planning

The Planning Commission of India has had an important role to play in matching various national objectives with S&T programmes, reconciling: differing priorities and viewpoints; resource availability and investment priorities; allocation of responsibility between the Centre and the States, and between public and private sectors; and bringing about integration between various sectors of the economy. As a result of concerted efforts of the Planning Commission and the DST (particularly through the initiatives of NCST and SACC), the States and Union Territories have also set up their own S&T Councils and/or Departments of Science and Technology. For identification and formulation of the S&T component in the socio-economic sectors, the larger Ministries and Departments have created their respective Research Advisory Committees (RAC) and Science & Technology Advisory Committees (STACs) with the DST organizing interdepartmental coordinating meetings for STACs.

The VI, VII and VIII Five Year Plans did have a strong focus on development of capabilities in S&T and on areas of strategic applications, but they also made the effort to relate these to the priorities of national development, particularly for the upliftment of the rural people, weaker sections and ecospecific regional issues. Accordingly, the Planning Commission conducted detailed studies of the Island territories of Andaman and Nicobar and Lakshadweep and prepared plans for ecospecific development in these parts with S&T based approach to energy, employment, fishing, water harvesting and the like.

Another important aspect of the interaction between the Indian planning process and the scientific development sector has been their remarkable mutual responsiveness. While the Planning Commission related to national needs at a given time, the scientific sector focused its R&D efforts to match it.

An analysis of the principal objectives of each of the Five Year Plans and corresponding scientific efforts illustrates the above. The II Plan dealt with the setting up of heavy industries and raising the low savings rate; this was conceived principally by Mahalanobis. The III Plan focused on import substitution because of the problem of balance of payments faced by the country, with falling international prices of primary products. The IV Plan followed a period of devastating droughts with consequent food shortages, food imports and devaluation; this clearly called for efforts to ensure food security. The V Plan recognized that reduction of poverty by the trickle-down process through industrialization had not worked, and there was need for positive anti-poverty programmes and a strong effort to meet the minimum needs of vast numbers. The VII Plan recognized the excess capacities in heavy industry generated through the success of the II Plan, and the need to deal with infrastructure. The VIII Plan was directed towards the creation of infrastructure, relating particularly to sectors such as energy, support of sunrise industries and the like. The VIII Plan took place with the opening up of the economy to the global winds of change, bringing about a market orientation through liberalization and economic reforms. The IX Plan has laid emphasis again on agriculture.

When one looks at each of these thrust areas of a given Plan period, determined by national needs at that time, one also discerns a trend in the scientific effort of that period and support provided, particularly where applications are concerned. There was a focusing of scientific effort to ensure that the basic objectives of that Plan period were met. In addition, long horizon programmes in the strategic sectors of atomic energy, space and defence research were supported in fulfillment of their original objectives.

The Mission Approach

Several new mechanisms were evolved by the Planning Commission, particularly in the VII Five-Year Plan period, to ensure that S&T capabilities are brought to bear appropriately on problems clearly defined on the basis of national objectives and needs. In particular, the following four are important: (a) the mission approach, (b) integration of S&T in the socio-economic sectors, (c) application of S&T for rural development and poverty alleviation, (d) S&T for societal development (to benefit specific beneficiary segments).

The mission approach was conceived, for the first time, and initiated during the VII Five-Year Plan period. The approach was to first define the total task to be accomplished and identify all the components needed for this purpose, including the S&T component. The latter would be undertaken by scientists who would then expect to see the fruition of their work in achieving the end results through the effective establishment of live and organic linkages between various organizational structures. These linkages would include administrative ministries, financial aspects, and the coordination between various scientific components along with the institutions concerned with them, and the actual field work. A mission oriented ethos, it was felt, would introduce a sense of urgency with clear-cut time and cost schedules, monitoring mechanisms and a new management approach. This is what was done in the case of the atomic energy and space programmes, and was being implemented for defence projects.

Six National Technology Missions, in areas of direct relevance to society and envisaging entirely new management approaches, were launched. These covered: increase of oilseed production; mass immunization; better communications; improving clean drinking water supply; raising milk production; and reduction of illiteracy. Similarly, nine S&T projects in the Mission Mode were taken up during the same Plan, with emphasis on an end-to-end approach with a significant research and development component, but connected with the financial, administrative and management aspects. These included missions such as cattle-herd improvement, bio-environmental control of vector borne diseases and so on.

The Future

The development of S&T in India since Independence has been essentially based on visionary support by political leadership at the highest level, namely, Jawaharlal Nehru and Indira Gandhi; and, to some extent, Rajiv Gandhi, who unfortunately did not live to have the necessary time span. The other driving force behind the development of technology in India has been the presence of visionaries of science, such as Homi Bhabha for the atomic energy programme, Vikram Sarabhai for the space programme, S.S. Bhatnagar for CSIR and B.P. Pal for agricultural research. There were also others, such as D.S. Kothari in the field of higher education and defence research, and P.C. Mahalanobis in the area of statistics. Many of these visionaries not only conceived of programmes with long time horizons, but generated leadership, often of their own calibre, to continue these.

From what was only small science of very high quality, the newly emerging nation, devoid of modern technology on any relevant scale, has moved significantly forward over the past five decades. There is now an industrial base to be reckoned with. In S&T, there is a major infrastructure and extensive coverage of a wider spectrum of disciplines than most countries in the world. Not only is it a matter of infrastructure and capabilities but also accomplishment of a high order.

There has, however, been a major change both, on the international scene as well as in India, over the past decade, as a result of advances in S&T, particularly in respect of IT and in transportation of goods and people. We now live in a highly interconnected interdependent world. This has led to globalization of markets which tend to look for resources, including financial, from all over the world, and bring these together at points where production is most cost effective and efficient, and then move the goods to markets everywhere. This calls for a seamless or borderless world for movement of goods and of people. In recent years, India has embarked on a significant process of reform to move towards this globalization. It has to be remembered that India is endowed with highly competent trained human resources in a variety of fields and the cost of living in India is relatively low. Using current and developing information technology, it should be possible to shift a great deal of work to India from elsewhere in the world: in research, design systems engineering, software product development and applications.

While India has considerable industrial activity, it is still an agricultural country in terms of deployment of its population. The shift towards a greater role for industrialization, and from rural to urban centres is taking place in parallel with the IT revolution. There will also be a rapid move to a knowledge-based society. Hitherto, there has been some lack of coherence and interaction between India's scientific research and capabilities and its sectors of production and services. The situation is changing rapidly. The World Trade Organization and the new patent regime have created an awareness of the importance of Intellectual Property Rights and their role in the new world order.

There is enormous latent innovative capability in the Indian scientific system which could easily fructify into competence of value. This calls for support from other areas such as patent attorneys, patent offices and the financial sector. With the emphasis on experts and global competitiveness, the production sectors in India will increasingly turn to the scientific competence in the country, which is also liked with the global scientific enterprise.

As India develops and increasing numbers become well-to-do, they will move into the market economy on a scale that will fuel further growth. India represents a giant system, functioning as a democracy, moving from a conservative hierarchical society to a flexible, modern knowledge-based one. The foundations laid in creating its present wide-based competence in science and technology will stand it in good stead in this transformation.

Scientific Policy Resolution Annexure – I

New Delhi, the 4th March 1958/13th Phalguna, 1879

- No.131/CF/57- The key to national prosperity, apart from the spirit of the people, lies, in the modern age, in the effective combination of three factors, technology, raw materials and capital, of which the first is perhaps the most important, since the creation and adoption of new scientific techniques can, in fact, make up for a deficiency in natural resources, and reduce the demands on capital. But technology can only grow out of the study of science and its application.
- The dominating feature of the contemporary world is the intense cultivation of science on a large scale, and its application to meet a country's requirements. It is this, which, for the first time in man's history, has given to the common in countries advanced in science, a standard of living and social and cultural amenities, which were once confined to a very small privileged minority of the population. Science has led to the growth and diffusion of culture to an extent never possible before. It has not only radically altered man's material environment, but, what is of still deeper significance, it has provided new tools of thought and has extended man's mental horizon. It has thus influenced even the basic values of life, and given to civilization a new vitality and a new dynamism.
- It is only through the scientific approach and method and the use of scientific knowledge that reasonable material and cultural amenities and services can be provided for every member of the community, and it is out of a recognition of this possibility that the idea of a welfare state has grown. It is characteristic of the present world that the progress towards the practical realization of a welfare state differs widely from

country to country in direct relation to the extent of industrialization and the effort and resources applied in the pursuit of science.

- The wealth and prosperity of a nation depend on the effective utilization of its human and material resources through industrialization. The use of human material for industrialization demands its education in science and training in technical skills. Industry opens up possibilities of greater fulfillment for the individual. India's enormous resources of manpower can only become an asset in the modern world when trained and educated.
- Science and technology can make up for deficiencies in raw materials by providing substitutes, or, indeed, by providing skills which can be exported in return for raw materials. In industrializing a country, a heavy price has to be paid in importing S&T in the form of plant and machinery, highly paid personnel and technical consultants. An early and large scale development of S&T in the country could therefore greatly reduce the drain on capital during the early and critical stages of industrialization.
- Science has developed at an ever-increasing pace since the beginning of the country, so that the gap between the advanced and backward countries has widened more and more. It is only by adopting the most vigorous measures and by putting forward our utmost effort into the development of science that we can bridge the gap. It is an inherent obligation of a great country like India, with its traditions of scholarship and original thinking and its great cultural heritage, to participate fully in the march of science, which is probably mankind's greatest enterprise today.
- The Government of India have accordingly decided that the aims of their scientific policy will be:

❋ to foster, promote, and sustain, by all appropriate means, the cultivation of science and scientific research in all its aspects -- pure, applied and educational;

❋ to ensure an adequate supply, within the country, of research scientists of the highest quality, and to recognize their work as an important component of the strength of the nation;

❋ to encourage, and initiate, with all possible speed, programmes for the training of scientific and technical personnel, on a scale adequate to fulfil the country's needs in science and education, agriculture and industry, and defence;

❋ to ensure that the creative talent of men and women is encouraged and finds full scope in scientific activity;

❋ to encourage individual initiative for the acquisition and dissemination of knowledge, and for the discovery of new knowledge, in an atmosphere of academic freedom;

❋ and, in general, to secure for the people of the country all the benefits that can accrue from the acquisition and application of scientific knowledge.

The Government of India have decided to pursue and accomplish these aims by offering good conditions of service to scientists and according them an honoured position, by associating scientists with the formulation of policies, and by taking such other measures as may be deemed necessary from time to time.

Extract from Technology Policy Statement Annexure – II

Preamble: Political freedom must lead to economic independence and the alleviation of the burden of poverty. We have regarded S&T as the basis of economic progress. As a result of three decades of planning, and the Scientific Policy Resolution of 1958, we now have a strong agricultural and industrial base and a scientific manpower impressive in quality, numbers and range of skills. Given clear-cut objectives and the necessary support, our science has shown its capacity to solve problems.

The frontiers of knowledge are being extended at incredible speed, opening up wholly new areas and introducing new concepts. Technological advances are influencing lifestyles as well as societal expectations.

The use and development of technology must relate to the people's aspirations. Our own immediate needs in India are the attainment of technological self-reliance, a swift and tangible improvement in the conditions of the weakest sections of the population and the speedy development of backward regions. India is known for its diversity. Technology must suit local needs and to make an impact on the lives of ordinary citizens, must give constant thought to even small improvements which could make better and more cost-effective use of existing materials and methods of work. Our development must be based on our own culture and personality. Our future depends on our ability to resist the imposition of technology which is obsolete or unrelated to our specific requirements and of policies which tie us to systems which serve the purpose of others rather than our own, and on our success in dealing with vested interests in our organization: governmental, economic, social and even intellectual, which bind us to outmoded systems and institutions.

Technology must be viewed in the broadest sense, covering the agricultural and the services sectors along with the obvious manufacturing sector. The latter stretches over a wide spectrum ranging from village, small-scale and cottage industries (often based on traditional skills) to medium, heavy and sophisticated industries. Our philosophy of a mixed economy involves the operation of the private, public and joint sectors, including those with foreign equity participation.

Our directives must clearly define systems for the choice of technology, taking into account economic, social and cultural factors along with technical considerations; indigenous development and support to technical, and utilization of such technology; acquisition of technology through import and its subsequent absorption, adaptation and upgradation; ensuring competitiveness at international levels in all necessary areas; and establishing links between the various elements concerned with generation of technology, its transformation into economically utilizable form, the sector responsible for production (which is the user of such technology), financial institutions concerned with the resources needed for these activities, and the promotional and regulating arms of the Government.

This Technology Policy Statement is in response to the need for guidelines to cover this wide-ranging and complex set of inter-related areas. Keeping in mind the capital-scarce character of a developing economy it aims at ensuring that our available natural endowments, especially human resources, are optimally utilized for a continuing increase in the well-being of all sections of our people.

We seek technological advancement not for prestige or aggrandizement but to solve our multifarious problems and to be able to safeguard our Independence and our unity. Our modernization, far from diminishing the enormous diversity of our regional traditions should help to enrich them and to make the ancient wisdom of our nation more meaningful to our people.

Our task is gigantic and calls for close coordination between the different departments of the Central and State Governments and also of those concerned, at all levels, with any sector of economic, scientific or technological activity, and, not least, the understanding and involvement of the entire Indian people. We look particularly to young people to bring a scientific attitude of mind to bear on all our problems.

Aims And Objectives

Aims: The basic objectives of the Technology Policy will be the development of indigenous technology and efficient absorption and adaptation of imported technology appropriate to national priorities and resources. Its aims are to:

- attain technological competence and self-reliance, to reduce vulnerability, particularly in strategic and critical areas, making the maximum use of indigenous resources;
- provide the maximum gainful and satisfying

employment to all strata of society, with emphasis on the employment of women and weaker sections of society;

- use traditional skills and capabilities, making them commercially competitive;
- ensure the correct mix between mass production technologies and production by masses;
- ensure maximum development with minimum capital outlay;
- identify obsolescence of technology in use and arrange for modernization of both equipment and technology;
- develop technologies which are internationally competitive, particularly those with export potential;
- improve production speedily through greater efficiency and fuller utilization of existing capabilities, and enhance the quality and reliability of performance and output;
- reduce demands on energy, particularly energy from non-renewable sources;
- ensure harmony with the environment , preserve the ecological balance and improve the quality of the habitat; and
- recycle waste material and make full utilization of by-products.

Self-Reliance: In a country of India's size and endownments, self-reliance is inescapable and must be at the very heart of technological development. We must aim at major technological breakthroughs in the shortest possible time for the development of indigenous technology appropriate to national priorities and resources. For this, the role of different agencies will be identified, responsibilities assigned and the necessary linkages established.

Strengthening the Technology Base: Research and Development, together with S&T education and training of a high order, will be accorded pride of place. The base of science and technology consists of trained and skilled manpower at various levels, covering a wide range of disciplines, and an appropriate institutional, legal and fiscal infrastructure. Consolidation of the existing scientific base and selective strengthening of thrust area in it are essential. Special attention will be given to the promotion and strengthening of the technology base in newly emerging and frontier areas such as information and materials sciences, electronics and biotechnology. Education and training to upgrade skills are also of utmost importance. Basic research and the building of centres of excellence will be encouraged.

Skills and skilled workers will be accorded special recognition. The quality and efficiency of the technology generation and delivery systems will be continuously monitored and upgraded. All of this calls for substantial financial investments and also strengthening of the linkages between various sectors (educational institutions, R&D establishments, industry and governmental machinery).

Sketchs of M. Visvesvaraya, Jawaharlal Nehru, and J.N. Tata in this chapter have been prepared by V.N. O'Key, published in Architects of Modern India.