Chapter I

SCIENCE AND TECHNOLOGY IN INDIA

Innovation has been constantly adding to the progress of humankind from the day when the wheel was invented. Seeking more effective means of employing available resources has been a continuing endeavour ever since. In this, science and technology has played an important role. Science and Technology (S&T) has made tremendous contribution to the advancement of human race. Progress in science and technology has contributed to increased agricultural and industrial production, and of consumer durables, faster modes of transport and communication, variety entertainment, better access to information at the click of a mouse, and also brought live coverage of wars to millions of homes. As much as technology contributed to this once upon a time inconceivable happening, it has also influenced the implements with which wars are fought. Newton’s ‘laws of motion’ formed the basis for missiles; Einstein’s ‘theory of relativity’ made possible the ‘bomb’.

1.1 SCIENCE POLICY RESOLUTION, 1958

The government as well as the scientific community of free India realised quite early that science and technology need to be fostered and encouraged in order to contribute to the agricultural and industrial progress of the country as well as to its defence. Impressed by the efficacy of planning in bringing about economic development, Prime Minister Nehru introduced the same in India and linked the development of science to planning. For him science was a quest for ‘truth’—a truth that was neither
communist nor capitalist. He strongly advocated the inculcation of ‘scientific temper’ and ‘free inquiry’¹.

The year 1957 was the year of the Sputnik. At a time when the bullock cart was still the chief mode of transport in India the then Soviet Union sent a vehicle into space. As much as the Sputnik spurred scientific activity across the world its ripples were felt in India too. Delivering the inaugural address at the 1958 session of the Indian Science Congress, Nehru expressed his amazement at this development in science. The foundations of modern day science in India were about to be laid. The direction which science policy in India would take was outlined by Nehru during the course of his address. He said²:

"Why does science make progress? ...I suppose, because science is encouraged, science is considered important, and scientists are given importance and status, so that more and more people are attracted to science... you must consider science and the spirit and temper of science as important...Facilities should be given for the advancement of science, the scientists and the universities wherever this work is done...it is the function of the state to encourage science... because it is the right thing to do... [and also because it is] important to do so. If you do not, you get left behind, you get weak.

Two months after his address to the Science Congress, Prime Minister Nehru personally introduced the Science Policy Resolution (SPR) in Parliament on 4 March 1958. This Resolution delineates the objectives of India’s science policy.

The Resolution sought to ‘foster, promote and sustain’ science education and scientific research—both pure and applied, create a pool of scientific personnel and

¹ Baldev Singh, ed., Jawaharlal Nehru on Science [New Delhi, 1986].
encourage ‘individual initiative’ and ‘creative talent’. Importantly, and this is what concerns us—the objective was also:

- 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, agriculture, industry and defence (emphasis mine);
- ...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 efforts in the initial years after independence concentrated on laying the foundations of science. A chain of laboratories were inaugurated and science education was promoted for creating a science base in the country. As stated in the Science Policy Resolution, organising science for defence was among the stated objectives of the government. It is, of course, true that among the list of priorities defence figures last in the objectives stated in the Resolution. What is important, and rightly so, is that it is one of the objectives. Moreover, the government sought to derive every advantage that science could bestow upon its people. If one were to interpret this objective in a broader sense, implicit in the objective is a desire to employ science towards the defence needs of the country and derive the benefits that science could impart. Science has numerous applications and in various fields—one of them being in defence.

Speaking at the Third Defence Science Conference, a month after the Science Policy Resolution was moved in Parliament, and a few months after the Defence Research and Development Organisation (DRDO) was formed, the first Scientific Advisor to the Defence Minister made an impassioned presentation declaring the requirement of expanding defence research activity in the country and the need for
enhanced allocation to defence research\textsuperscript{3}. However, he quickly added that the economic condition of the country would not permit higher spending and, therefore, it was out of the question to make available ten per cent of the defence budget for defence Research and Development (R&D).

The inference that one could draw from the line of thinking of the first Prime Minister and the first Defence Science Advisor is that the development needs of the country figured more prominently than organising science for defence.

1.2 SCIENCE POLICY RESOLUTION: FOLLOW UP

In order to review the implementation of the SPR a conference of scientists was organised in 1963, five years after the SPR was moved. The meeting was addressed by Prime Minister Nehru and the then Minister for Science and Culture, Humayun Kabir. Several eminent scientists participated in the deliberations and made suggestions. The Committee on Defence was headed by the then Scientific Advisor to the Defence Minister, S. Bhagavantam, a scientist of considerable repute, who was at one time the Director of the Indian Institute of Science, Bangalore, and a former junior colleague of C. V. Raman.

1.3 THE SCIENCE COMMUNITY

The 1962 India–China War stirred the scientific community into action. The scientists expressed an intense desire to participate in the defence effort of the country. They

were, however, lacking in the knowledge of the extent to which they could associate themselves. A leading journal of those times wrote in its editorial that "...the nature and the size of research problems connected with defence are not known to scientists and technologists". Not only this, the scientists were nearly angry that the government gave no serious thought to the need for defence and on the urgency of organising the resources of the country for this purpose. This was mostly because at that time there was hardly any co-ordination between defence R&D and scientific research being conducted elsewhere in the country. The scientists honestly felt that defence R&D effort needed the active involvement of scientists outside the Defence Science Organisation. Under these circumstances it was suggested that "in this country it may be worth considering whether association of uncommitted scientists with the solution of some of our defence problems may not turn out to be fruitful." It was a time when defence R&D was conducted in a state of isolation and secrecy. Therefore, the science community suggested that the government should take a small group of scientists into confidence and discuss with them the contribution they could make.

Discussions were held between the Directors of national research laboratories and officers of the Defence Science Organisation in order to mobilise the scientific effort to defend it. What followed was the constitution of a Steering Committee. The Steering Committee had the then Director General of the Council for Scientific and Industrial Relations (CSIR) as its chairman. Besides reviewing the resource-availability in the country it recommended the creation of 'defence cells' in

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prestigious national laboratories to carry out research of relevance to defence. At this juncture it was asked by the science community if similar cells could not be formed in other research centres as well as universities.

Over the years the desirability and usefulness of marshalling all the available resources so as to employ them in defence research as and when the need was felt gained credence. A defence co-ordination unit was set up in the DRDO in 1962 to co-ordinate with the CSIR with the objective of 'joint planning of programmes' and 'co-ordinating CSIR R&D programmes with defence requirements'. The Unit is presided over by a Steering Committee, whose Chairman is the Director General of the CSIR. At the same time, the DRDO also initiated collaboration with universities and Indian Institutes of Technologies (IITs). The nature of the interaction was, and still is, in the form of conducting joint-symposia, assigning defence R&D projects to universities and IITs, mutual visits and lectures and participation by the DRDO in the summer school programmes of universities. Nonetheless, even as late as in the mid-seventies no significant degree of closer co-ordination between defence R&D and civilian R&D could be established. As if this was not bad enough the scientific and technological strength did not match the requirements of the defence R&D effort. A person of no less an authority than the incumbent Scientific Advisor to the Defence Minister expressed the opinion that:

[A] planned effort should be made, in a manner more purposeful than has been done in the past, to keep them in such a state of preparedness that all of them be

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6 For more details on the functions of the Unit see Estimates Committee (1967-68), Twelfth Report, Fourth Lok Sabha, Ministry of Defence, Defence Research and Development Organisation [New Delhi, 1967], pp. 87-88. The Estimates Committee was informed that the Unit "acts almost a focal point of scientific and technological problems of Defence Interest in which National Laboratories can render assistance".

7 Ibid., pp. 91-92.
harnessed, at short notice, to defence effort, if and when so desired. It is essential to leave them where they are during normal times and encourage them to follow their scientific avocations, but provide them with liberal support to grow fast enough and keep abreast of modern developments, so as to be useful during and keep abreast of modern developments, so as to be useful during an emergency.

What we understand is that, even at that time the invitation to scientists outside the defence laboratories was not an open one. They were expected to keep themselves in a state of 'scientific alert' so that their services could be called upon when an emergency arose. The situation did not take long to change. By 1979 defence R&D started to make fervent appeals to the science community as well as the industry to join hands with it. The then Scientific Advisor to the Defence Minister allayed the prevailing belief that defence R&D was shrouded in secrecy and went on to state thus:

Defence Science requires the help of all laboratories and industry in the country.... It should be possible for more scientists and laboratories to volunteer to play a positive role in the indigenous design and development of defence equipment for the country. This would be a great contribution to the nation and a more economic way of looking at the defence effort.

Hence, two observations would be in order. One, it was a reversal of roles for defence R&D and the science community. The science community, from having volunteered to do everything within its capability, including offering its services at no cost at all, in the aftermath of the 1962 War, had, now, to be prodded to collaborate in the defence effort of the country. Two, the appeal, including that to the industry, was sent on the early eve of the commencement of high-technology defence R&D projects.

1.4 SCIENCE AND TECHNOLOGY PLAN, 1974

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The National Committee on Science and Technology initially prepared an approach to S&T Plan in 1973 and, as a maiden venture, prepared a comprehensive S&T Plan in 1974. The Approach Paper to the Plan identified a number of thrust areas like agriculture, dairy, textiles, health and family planning, water supply and sanitation, coal, oil, power, nuclear energy, alternative sources of energy, natural resources, integrated river basin development, minerals, marine resources, iron, steel, copper and zinc, heavy engineering, chemicals, materials, transportation, cryogenics, solar energy, magneto-hydrodynamic power generation, desalination, biological control of pests and space technology, etc\(^10\).

The Plan conducted a critical examination of 24 sectors "with a view to evolving suitable programmes of research, development and design...for accomplishing time-bound targets... [The Plan was geared towards] import substitution, adaptation of imported technology, enhancement of industrial productivity, export promotion, building up capabilities in frontier areas and augmentation of R&D"\(^11\). The preparation of the Plan was a largely participatory effort, which involved the participation of more than 2,500 scientists and the sub-committees connected with its preparation having visited several parts of the country to "[discuss] at length the

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\(^{10}\) The areas mentioned here have been derived from Government of India, National Committee on Science and Technology, *An Approach to the Science and Technology Plan* [New Delhi, 1973].

\(^{11}\) See S. K. Mukherjee and B. V. Subbarayappa, eds., *Science in India: A Changing Profile* [New Delhi, 1984], p. 49
needs and the potential with producers and users of R&D... [as well as having attempted to] involve private R&D for more purposeful [ends]."12

The implementation of the Plan proceeded along three broad directions:13 encouragement to commercialisation of indigenously developed technologies and R&D by providing incentives, organisational and managerial reforms; setting up of new science and technology institutions, which included the National Remote Sensing Agency (NRSA), Germ Plasm Bank, Offshore Engineering Group, Engineers India, etc. The S&T Plan had the singular merit of being participatory in nature. Besides, the Plan sought to promote R&D and establish linkages between the laboratory and the industry. Moreover, a large number of areas were identified for promotion. However, the implementation of the Plan left much to be desired. The many areas that were identified may have, to an extent, contributed to this result, for the reason that the focus was lost and there was competition for allocations.

1.5 TECHNOLOGY POLICY STATEMENT, 1983

The then National Council for Science and Technology prepared a Technology Policy Statement in the late seventies for the consideration of the Cabinet. However, due to political uncertainty in India at that time a decision was not taken in this regard.14 After the Congress came to power in 1980 the matter once again came up before the Cabinet. Finally, in January 1983, the government issued the Technology Policy Statement (TPS). Though the TPS was issued the question of formulating a

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12 C. Subramaniam, "Whither Science and Technology in India—II", The Hindu (Madras), 29 February 1996. The author was the chairman of the committee that drafted the Plan, in his capacity as the Minister for Science and Technology, incidentally the first full–fledged Minister of this Ministry.


14 Government of India, Department of Science and Technology (henceforth DST), Science Advisory Committee to the Cabinet, Annual Report, 1981-82 [New Delhi, 1982], p. 6.
mechanism for its implementation remained. Subsequently a high level Technology Policy Implementation Committee was constituted.

The TPS aimed at developing indigenous technology and efficiently absorbing and adapting imported technology. It sought to correct regional imbalances in development, serve the needs of the underprivileged sections of the society and help India achieve technological self-reliance. The TPS also aimed at fostering linkages between the various S&T institutions in order to generate technology which would impart economic benefit.

The TPS laid ‘special emphasis on agriculture, including dryland farming, optimum utilisation of water resources, pulses and oils seeds, drinking water, nutrition, reduction of blindness eradication of communicable diseases, low-cost housing, renewable non-conventional energy resources and industrial development. The TPS declared that ‘full support’ would be given to the development of indigenous technologies, especially in critical and vulnerable areas and in high-value added items. The TPS recognised the advantages of being self-reliant in technology.

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15 See DST, Technology Policy Statement [New Delhi, 1983]. The text of the Technology Policy Statement says, “Government will evolve instruments for the implementation of this technology Policy and spell out detail guidelines...”.


17 DST, Technology Policy Statement, n.15.

18 Quoting a statement released by the Indian Physics Association, a provocative editorial “Undeclared Embargo” was written by Patriot (New Delhi), 19 October 1982, when the United States declined to deliver equipment meant for basic research, which included computer systems and their peripherals, microprocessor development systems, data collection and data presentation equipment, remote terminals, laser systems and their components, balloons for high altitude equipment, etc. The attention given in the TPS to the development of critical and frontier technologies with a view to achieving self-reliance in technology should be understood in this background.
1.6 AFTER THE 1983 TECHNOLOGY POLICY STATEMENT

In order to disseminate the advantages of the application of technology to a wider section of the society the government had set up National Technology Missions between 1985 and 1989 in the areas of rural drinking water; immunisation of pregnant women and children; adult literacy; self-sufficiency in edible oils; improving telecommunication networks; dairy development; and wasteland development.

Unlike in the seventies when indigenous initiative, expansion and modernisation were pursued indigenous efforts in S&T seem to have received a setback during the eighties, even though the TPS sought to support the development of indigenous technology. This trend was not only questioned but made one commentator to remark that the launching of the Agni missile was a lesson for indigenous effort and that it was all the more relevant for all areas of S&T. The general trend was for a preference for foreign collaboration rather than on indigenous development.

Even after the TPS was issued, it was realised that something was amiss. During a meeting of the Parliamentary Consultative on Science and Technology in 1988, it was stated that “there was a need to clearly define the S&T objectives of the country for the next ten to fifteen years, besides identifying select R&D areas and establishing technology missions.”

With this in view, in July 1988 the Science Advisory Council to the Prime Minister (SACC) prepared *An Approach to a Perspective Plan for 2001 A. D.: Role of Science and Technology* (APP). The Approach to a Perspective Plan (APP) hoped to achieve deceleration in population growth, a two-fold increase in food production, health for all, literacy for a vast majority, better management of energy and transportation, better communication facilities in rural as well as urban areas, reversal in erosion of ecology, address problems of rural housing and selective habitat, excellence in selected frontiers of S&T and reduce poverty and

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21 Reported in *Hindustan Times* (New Delhi), 18 February 1988. These technology missions were in the field of frontier technologies. They are different from the technology missions established earlier, which were meant to cater to basic needs.
22 It is understood that initiatives on science and technology from this time onwards are based on the DST, SACC, *An Approach to a Perspective Plan for 2001 A. D., Role of Science and Technology* [New Delhi, 1988] and the suggestions given by the SACC from time to time.
unemployment\textsuperscript{23}. From the objectives of the APP one could gauge that the planners of the day laid stress on removing the shortcomings that were confronting the country by providing S&T inputs. While on the one hand improving the general living conditions of the people needed to be addressed in a systematic manner it was also recognised that a concerted effort should be made to pursue R&D in frontiers areas of technology with a view to achieving self-reliance in these areas.

In order to achieve the objectives stated in the APP the SACC recommended the launching of ‘national programmes’. Following the recommendation three such programmes were launched between 1989 and 1993\textsuperscript{24}: ‘New Fibres and Composites Programme’, ‘National Superconductivity Programme’ and ‘National Laser Programme’\textsuperscript{25}. The National Superconductivity Programme supported 67 projects in basic research, technology development and applications\textsuperscript{26}. During the same time Technology Missions were created in the areas of parallel processing systems, biosensors and erasable disk\textsuperscript{27}. Subsequently, a ‘massive’ exercise for launching Mission Programmes was planned. These were planned in the fields of sugar production technology, advanced composites, next generation massively parallel supercomputer, new electronics materials and components, micro-electronics and photonics, information technology and future air navigation systems, etc\textsuperscript{28}.

Another programme that has been launched recently is the ‘Critical Technologies Programme’. Under this programme, the Department of Science and Technology supports research in a number of areas including sensors, fuzzy logic–based systems, intelligent processing of materials, etc\textsuperscript{29}. In view of the various programmes launched in many areas of advanced technologies in the recent past, it could be seen that the efforts aimed at achieving self-reliance in technology development have gained momentum. Exhorting scientists to strive hard for developing advanced technologies, the then Prime Minister, H. D. Deve Gowda, asked scientists to “accept the

\textsuperscript{23} Ibid., p. 6.
\textsuperscript{25} These programmes were launched after having recognised the immense potential that fibres and composites, lasers and superconductors hold for the future. They are being implemented in various institutions.
\textsuperscript{27} Ibid., p. 31.
\textsuperscript{29} DST, Annual Report, 1994–95 [New Delhi, 1995], p. 39.
challenge posed by the reluctance of advanced countries to transfer sophisticated technology in the frontier areas of science and technology.\footnote{See excerpts of the Prime Ministers address to the 84\textsuperscript{th} Session of the Indian Science Congress, 24 January 1997, New Delhi, reported in \textit{The Hindu}, 25 January 1997.}

The development of strategic technologies is one of the chief aims of India, as it approaches the next millennium. Recently, a panel of the Technology Information and Forecasting Council (TIFAC), Department of Science and Technology, identified areas that are critical to the growth of strategic industries in India. In fact, the TIFAC itself was created upon the recommendation of the SACC\footnote{TIFAC is a registered society. It is involved in the generation of technology forecasting, technology assessment and techno-market survey documents. Besides, it also runs an on-line information system, promotes the development of technology, evolves mechanisms for testing technologies and helps in the commercialisation of technologies.}. The \textit{raison d'etre} for identifying areas that are critical to the growth of strategic technologies is that the industrially advance countries have already established themselves in these areas, derived economic prosperity and have begun to impose various control regimes on those countries that were attempting to establish an indigenous base in strategic areas; the six broad areas identified include:\footnote{DST, TIFAC, \textit{Strategic Technologies} [New Delhi, 1996], pp. 5-7.}

- **Aviation**: aircraft, propulsion/airframe technology, avionics and communication;
- **Electronics**: Micro electronics, wireless technology, displays;
- **Sensors**;
- **Space communication and remote sensing**: Communication, remote sensing, meteorology;
- **Critical materials and processing**: Critical materials, structures, processing; and
- **Robotics and artificial intelligence**.

The proposal is to develop various technologies in the broad areas listed above within a time span of twenty five years. The target periods have been classified as short, medium and long term—year 2000, year 2010 and year 2020 respectively. The Panel recommended a shift from know–how to know–why, alliances for realising the development of critical technologies, a time–bound mission–mode programmes, encouragement and increased allocation for R&D, policies aimed at greater
partnership between government and industry, etc\textsuperscript{33}. Partnership with national laboratories and defence laboratories would, the industry has been told, facilitate quicker acquisition of technologies and less investment in R\&D\textsuperscript{34}.

Whereas the specific areas identified by the Panel are those that merit special attention, and on which the future of strategic industries of the country is dependent, work has already been commenced on a vast number of areas, which would fit into the broader areas listed above. An interesting exercise was conducted by a senior defence scientist wherein the areas that the U. S. considered critical and in which India has an abiding interest were listed which include\textsuperscript{35}.

- Microelectronic circuits and their application
- Parallel computer architectures
- Fibre optics
- Automatic target recognition
- Signature control
- High power microwaves
- Preparation of gallium arsenide and other compound semiconductors
- Machine intelligence /robotics
- Sensitive radars
- Phased arrays
- Computational fluid dynamics
- Hyper velocity projectiles
- Software productivity
- Simulation and modelling
- Passive sensors
- Data fusion
- Air breathing propulsion
- High–temperature and high–strength composite materials;
- Super-conductivity

1.7 R\&D ACTIVITY

The initial planners of S&T in India attached immense significance to R\&D. The idea was to utilise technology developed through indigenous R\&D to make up for lack of

\textsuperscript{33} Ibid., p. 8

\textsuperscript{34} See Abdul Kalam's speech at a seminar reported in The Hindu, 18 September 1995.

resources. The imperative of conducting R&D was best stated by one of India's well-known scientists in these words\textsuperscript{36}.

Most developing countries do not have much to sell except agricultural products, raw material, arts, crafts and clothes. If their industries have to [be competitive] they have to do R&D of a high calibre and produce technologies comparable to those from the advanced countries. [This is especially true of India].

India today has a vast R&D network and a large pool of manpower. The CSIR is the principal body that is charged with the task of creating an R&D base in the country. Over the years, a chain of 200 national laboratories, an almost equal number of R&D institutions in the central sector and about 1,000 R&D units in the industrial sector have been established\textsuperscript{37}. Besides, R&D activity is conducted by the Department of Atomic Energy (DAE), Department of Space (DoS), Department of Electronics (DoE), Indian Council for agricultural Research (ICAR), Indian Council for Medical Research (ICMR), public sector undertakings and private industry.

The meagre resources made available to science in the country prompted leading science luminaries, as well as those interested in science, to debate on how best to employ these resources. In order achieve to rapid progress, S&T was seen as a useful tool. With this in view, efforts began in several areas. These also included areas in 'big science' such as atomic energy and space. Under these circumstances, there was a widespread criticism of the choice of the areas that received funding and encouragement.

\textsuperscript{36} See a thought provoking article by C. N. R. Rao, "Role of Science and Technology in Society", \textit{National Herald} (New Delhi), 10 January 1992.

\textsuperscript{37} \textit{The Hindu}, 12 November 1994.
Table 1: R&D Expenditure by Major Scientific Agencies, 1976 to 1983

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<tr>
<td>DAE</td>
<td>2445.63</td>
<td>5831.74</td>
<td>6082.32</td>
<td>6781.46</td>
<td>7623.24</td>
<td>8826.06</td>
<td>10563.13</td>
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<td>CSIR</td>
<td>2500.77</td>
<td>4125.71</td>
<td>5592.39</td>
<td>5918.99</td>
<td>7281.79</td>
<td>7877.08</td>
<td>10081.50</td>
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<td>DRDO</td>
<td>3428.97</td>
<td>5065.00</td>
<td>6678.61</td>
<td>9662.91</td>
<td>7970.00</td>
<td>10483.36</td>
<td>12199.96</td>
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<td>ICAR</td>
<td>2408.42</td>
<td>3739.24</td>
<td>5603.56</td>
<td>7739.81</td>
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<td>ICMR</td>
<td>170.00</td>
<td>423.00</td>
<td>533.54</td>
<td>598.50</td>
<td>842.08</td>
<td>1195.13</td>
<td>1423.15</td>
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<tr>
<td>DST</td>
<td>213.67</td>
<td>1121.20</td>
<td>2389.83</td>
<td>2603.56</td>
<td>3573.30</td>
<td>4608.01</td>
<td>6051.06</td>
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<tr>
<td>DoS</td>
<td>1909.22</td>
<td>3892.45</td>
<td>4553.74</td>
<td>4421.13</td>
<td>5270.85</td>
<td>7503.44</td>
<td>8605.17</td>
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<tr>
<td>DoE</td>
<td>97.53</td>
<td>422.01</td>
<td>511.47</td>
<td>750.25</td>
<td>431.35</td>
<td>751.11</td>
<td>847.55</td>
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<tr>
<td>Total</td>
<td>13174.21</td>
<td>24620.35</td>
<td>31945.46</td>
<td>38476.61</td>
<td>39555.88</td>
<td>52393.69</td>
<td>62892.32</td>
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Notes: All figures in rupees lakhs.


One section felt that excessive importance was being given to big science at the cost of more socially useful areas like food, textiles, housing, etc. As the R&D work began to focus on market-oriented research with the unveiling of the New Economic Policy (NEP) in 1991, it was pointed that it would be more prudent to conduct research that had ‘an autonomous justification’ and relevance to a greater majority of the people than to ‘anchor’ it on “market principles and neo–liberal ideology”38. One reputed scientist strongly favoured investing in ‘technologies, processes and products’ in a mission mode, as this would yield more dividends39.

The following table presents the data on the growth of R&D manpower in India. As can be seen from the table, the total number of those connected with KoGD work nearly tripled in a span of twenty years, between 1974 and 1994. The number of those involved directly in R&D activity rose by more than two times during the same period.

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From table 1.3 and table 1.4 it can be noticed that the central sector spends an overwhelming amount on R&D while the contribution to R&D by the state sector and the private sector is quite low. The contribution of the private sector to R&D is distressing. The private sector contributes no more than two per cent of the total R&D expenditure in the country, though in the number of R&D units functioning, it far surpasses that of the public sector. The SACC felt that in most cases the private industry ran R&D units to take advantage of tax concessions and "in the name of R&D, only the mundane functions of quality control and analytical functions are carried out". Agreeing with the opinion expressed by the SACC, an anonymous author felt that "most of the activity that passes for R&D seems to be more for tax avoidance than purposive research".

Table 1.2: R&D Manpower in India

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<tbody>
<tr>
<td>R&amp;D</td>
<td>48,328</td>
<td>54,105</td>
<td>64,875</td>
<td>78,036</td>
<td>85,309</td>
<td>96,927</td>
<td>105,936</td>
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<td>Auxiliary</td>
<td>27,882</td>
<td>41,753</td>
<td>51,842</td>
<td>72,233</td>
<td>70,233</td>
<td>80,956</td>
<td>96,737</td>
<td>98,202</td>
<td>98,769</td>
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<td>Administration</td>
<td>33,556</td>
<td>51,965</td>
<td>61,079</td>
<td>71,680</td>
<td>79,093</td>
<td>86,398</td>
<td>98,204</td>
<td>99,660</td>
<td>101,317</td>
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<tr>
<td>Others*</td>
<td></td>
<td></td>
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<td>6,062</td>
<td>3,335</td>
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<tr>
<td>Total</td>
<td>109,766</td>
<td>147,823</td>
<td>184,096</td>
<td>221,949</td>
<td>240,697</td>
<td>267,616</td>
<td>300,887</td>
<td>293,348</td>
<td>314,489</td>
</tr>
</tbody>
</table>

Note: * Details on break-up not available


Table 1.3: National Expenditure on R&D, 1974-83

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cent. Sector</td>
<td>231.14</td>
<td>300.54</td>
<td>343.92</td>
<td>41.49</td>
<td>500.36</td>
<td>545.31</td>
<td>721.94</td>
<td>908.67</td>
</tr>
<tr>
<td>State Sector</td>
<td>24.00</td>
<td>25.20</td>
<td>28.50</td>
<td>40.24</td>
<td>51.95</td>
<td>71.79</td>
<td>88.62</td>
<td></td>
</tr>
<tr>
<td>Pvt. Sector</td>
<td>36.46</td>
<td>48.42</td>
<td>58.20</td>
<td>75.87</td>
<td>92.14</td>
<td>103.93</td>
<td>147.00</td>
<td>161.38</td>
</tr>
<tr>
<td>Total</td>
<td>291.60</td>
<td>374.16</td>
<td>430.62</td>
<td>528.60</td>
<td>638.54</td>
<td>701.19</td>
<td>940.73</td>
<td>1158.67</td>
</tr>
</tbody>
</table>

Notes: All figures in rupees crores.

Source: Government of India, Department of Science and Technology, R&D Statistics, 1982-83.

The government levies an ‘R&D Cess’ on the import of technologies on all industrial concerns for any foreign collaboration agreement approved in accordance with the Industrial Policy of the government, on payments made for the import of technology; cost of drawings and designs in terms of any foreign collaboration agreement; and deputation of technical personnel to India in terms of any foreign collaboration agreement. Besides, evading industries can also be brought to book and charged penalties; the maximum penalty that can be imposed is ten times the amount of evasion. The Technology Policy Implementation Committee, which was constituted to implement the Technology Policy Statement, recommended the creation of a Technology Development Fund.\textsuperscript{42} A Technology Development Board was constituted in September 1996 to “enable the placing of the proceeds of the R&D Cess into the Fund for technology development and application.”\textsuperscript{43}

<table>
<thead>
<tr>
<th>Table 1.4: National Expenditure on R&amp;D, 1985-94</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>1985-86</td>
</tr>
<tr>
<td>1988-89</td>
</tr>
<tr>
<td>1989-90</td>
</tr>
<tr>
<td>1990-91</td>
</tr>
<tr>
<td>1991-92</td>
</tr>
<tr>
<td>1992-93</td>
</tr>
<tr>
<td>1993-94</td>
</tr>
</tbody>
</table>

Notes: All figures in rupees crores.
Source: GOI, Department of Science and Technology, R&D Statistics, 1992-93.

In order to encourage the industry to invest in R&D, annual awards are being given for achieving ‘excellence in in-house R&D’. However, it is noticed that the amount spent on R&D as a percentage of turnover among these winners had in most cases decreased and in some cases it is seen that though the percentage decreased initially it recovered later. The data in table 1.5 reveals this.

\textsuperscript{42} DST, \textit{Annual Report, 1989-90}, n. 16, p.40. To start with the Fund was created with a sum of Rs. fifty lakhs.

\textsuperscript{43} DST, \textit{Annual Report, 1997-98} [New Delhi, 1998], p. 55.
R&D activity in the country suffered to an extent due to the bureaucratisation of science. This lead to a state of affairs where some scientists donned the mantle of bureaucrats more than they functioned as leaders of science, and, hence, failed to generate enthusiasm among their junior peers\textsuperscript{44}. Moreover, the interaction between the universities and research laboratories diminished\textsuperscript{45}. Addressing the Platinum Jubilee Session of the Indian Science Congress, one renowned scientist remarked that scientists themselves were found to be less motivated and, hence, were not able to enthuse the younger generation. Therefore, the scientists shall have to shoulder the responsibility of ‘providing the right atmosphere’ and set an example in promoting excellence\textsuperscript{46}.

\textbf{Table 1.5: Decline in R&D Spending among Award Winning R&D Units}

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Madras refiners Limited</td>
<td>0.17</td>
<td>0.14</td>
<td>0.09</td>
</tr>
<tr>
<td>Sponge Iron India</td>
<td>1.88</td>
<td>1.00</td>
<td>0.79</td>
</tr>
<tr>
<td>Sol Pharmaceuticals</td>
<td>1.79</td>
<td>1.63</td>
<td>0.86</td>
</tr>
<tr>
<td>Anupam Machine Tools</td>
<td>4.90</td>
<td>3.15</td>
<td>3.03</td>
</tr>
<tr>
<td>Bharat Electronics</td>
<td>4.60</td>
<td>6.60</td>
<td>3.90</td>
</tr>
<tr>
<td>Kirloskar Electric Co.</td>
<td>0.41</td>
<td>0.48</td>
<td>0.40</td>
</tr>
<tr>
<td>ELICO</td>
<td>2.13</td>
<td>2.39</td>
<td>2.10</td>
</tr>
<tr>
<td>BHEL, Ranipet</td>
<td>0.27</td>
<td>0.19</td>
<td>0.20</td>
</tr>
<tr>
<td>Wockhardt</td>
<td>1.80</td>
<td>1.73</td>
<td>4.40</td>
</tr>
<tr>
<td>Indo-Am'cn Hybrid Seeds</td>
<td>14.76</td>
<td>12.33</td>
<td>18.22</td>
</tr>
<tr>
<td>Cosmo Films</td>
<td>1.26</td>
<td>0.42</td>
<td>0.67</td>
</tr>
<tr>
<td>Peninsula Polymers</td>
<td>2.03</td>
<td>1.60</td>
<td>1.89</td>
</tr>
<tr>
<td>MPR Refractories</td>
<td>0.30</td>
<td>4.29</td>
<td>17.12</td>
</tr>
<tr>
<td>Secure Meters</td>
<td>11.30</td>
<td>12.3</td>
<td>14.61</td>
</tr>
<tr>
<td>Jain Plast. and Chem.</td>
<td>1.50</td>
<td>1.70</td>
<td>1.80</td>
</tr>
</tbody>
</table>

\textit{Source: The Hindu, 2 December 1995.}

\textsuperscript{44} See B. S. Raghavan, “S&T Policy Planning: Charting a New Course”, \textit{The Hindu}, 8 March 1990.

\textsuperscript{45} Bidwai, n. 38, p. 97.

\textsuperscript{46} C. N. R. Rao, “Frontiers of science and Technology: The Indian Context”, General Presidential Address, 75\textsuperscript{th} Science Congress, Pune, January 1988 [Calcutta, n.d.], p. 17.
1.8 SOME IMPORTANT SCIENCE AND TECHNOLOGY AREAS

An attempt is made in this section to explain the significance of space, lasers, information technology, materials and electronics and to briefly capture the progress that India has achieved in these areas, as they have a more direct relevance, than others, to defence R&D effort.

1.8.1 Space Technology

*Satellites*

The efforts beginning in the early sixties, when a sound infrastructure and technical expertise was established in a focussed manner, bore fruit during the eighties, with the successful and successive launching of a series of communication and remote sensing satellites, enabling the provision of communication and meteorological services. The first generation of communication satellites was called INSAT-I series and the second, INSAT-II. The INSAT series satellites have been the medium for business, administrative and computer communication, remote area business management, disaster warning, facsimile transmission, etc. After gaining experience with the launching of experimental remote sensing satellites, a series of remote sensing satellites of the IRS series have been launched. Whereas the IRS-1A and IRS-1B provided a resolution of 30 m in the multi-spectral bands, the later satellites—IRS-1C and IRS-1D—provide 5.8 m resolution in the panchromatic and 20 m resolution multispectral imageries. The country is poised to launch the next generation of remote sensing satellites.
**Launch Vehicles**

In the area of launch vehicles, the progress achieved has been quite impressive. India is now in a position to place satellites with the help of its own launch vehicles. The country has been able to develop the Augmented Satellite Launch Vehicle (ASLV), the Polar Satellite Launch Vehicle (PSLV) and is nearing the completion of developing the Geostationary Satellite Launch Vehicle (GSLV). The first satellite launch vehicle was the SLV–III, which placed a 35 k. g. satellite into a Low Earth Orbit (LEO) in 1980. The leader of the project was Abdul Kalam, who later came to direct the Integrated Guided Missiles Development Programme (IGMDP). The ASLV was designed to place a 150 k. g. satellite into 100 k. m. orbit. The next generation of launch vehicle was the PSLV. It was designed to place a 1,000 k. g. satellite into a 900 k. m. polar sun-synchronous orbit. India, soon, plans to launch its satellites into orbit employing the third generation GSLV. The early completion of work on the crucial cryogenic engine for the launch vehicle would determine the first flight of the GSLV.

**1.8.2 Advanced Materials**

**Composites**

The advantage that the composites offered in terms of reducing the weight of aerospace systems provided the necessary motivation for their development. In this, in the United States, "the military have led the way, sponsoring research, development and structures demonstration programmes in the early 1960s".\(^\text{47}\) A lot of advance has been made in composites research over the years. The F-14 and F-15 used

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boron/epoxy composites while the F-16, for the first time, made use of graphite/epoxy composites; composites form nearly a quarter of the F-18’s structural weight.

**Super Conductors**

Superconductivity can be understood as a property of some pure metals and metallic alloys of having negligible resistance to the flow of an electric current at low temperatures. Metals and metallic alloys that possess the property of superconductivity are called superconductors. One such material is maraging steel. It has a variety of applications and is especially of relevance to the defence sector. It is not only used in the centrifuges of uranium enrichment plants and the landing gear of aircraft but has also a wide variety of industrial use, and can be employed in the making of outer casing for rockets, missiles and cluster bombs.

The year 1987 was a landmark in the field of materials in India. The Madras Group, together with the Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam, shattered the monopoly of the industrially advanced countries when they developed what is called maraging steel. Work in this area began in the eighties, elsewhere in the world. The uniqueness of maraging steel is that it is light in weight, has a high strength and is four times stronger than conventional steel. Facilities were subsequently set up to produce it at MIDHANI, Hyderabad. The Madras Group has developed more than 50 materials.

**Fibre Optics**

A wide range of work is being conducted on materials and systems on optical communication. This includes optical fibres, splicing and connecting techniques,

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48 *Ibid.* Also see J. P. Agarwal, *Composite Materials* [New Delhi, 1990].
modulation and demodulation techniques, multiplexing and de-multiplexing techniques and systems studies. Optical fibres enable a larger transmission of signals, owing to their property of higher refractive index and total internal reflection, and hence, are more efficient and secure means of communication, than metals like copper. Moreover, they are more compact thereby facilitating higher rates of transmission. Research work is being conducted in the country on glass fibres, gallium arsenide lasers, silica fibres, etc.

**Metals and Alloys**
Metals and alloys have a wide use in industry and defence. For instance, titanium and its alloys possess high strength, low weight, high toughness, and are resistant to erosion and corrosion\(^49\). Magnesium and lithium too fall in the category of light metals. Aluminium–lithium alloys have application in aeronautics industry\(^50\). 30 per cent of the Light Combat Aircraft’s structure is made of this alloy.

### 1.8.3 Electronics

Electronics is “a branch of science and technology relating to the conduction of electricity through gases or vacuum or semiconducting materials... and is concerned with the design, manufacture and application of electron tubes and solid state devices”\(^51\). Electronics finds its application in radios, televisions, broadcasting equipment, telecommunication, switching and transmission equipment, earth stations, nuclear reactor control power and in defence applications such as radar (as in *Indra*).

\(^50\) Ibid.
and Rajendra,), remotely piloted vehicles (RPVs) (as in Nishant), underwater systems and drones.

A variety of electronics equipment have been developed in India. These include, strategic microwave components, UHF and microwave communication equipment, liquid crystal displays, industrial control and instrumentation for industries, safety equipment for the railways, automatic test equipment, wind finding and weather analysis radar, route surveillance radar, etc.

1.8.4 Computers

Computers development has come a long way. The first computer was developed in the 1950s. Beginning then, advances in the electronics industry have influenced the evolution of computer technology. The development of microprocessors has revolutionised computer technology. Super Computers today are capable of performing more than 13000 million floating point operations per second. These are mainly used in weather forecasting, nuclear physic and computational fluid dynamics. Computers are widely used for military applications. Computers are being used in artillery gun instrumentation (as in the Arjun), night vision equipment, tracked vehicles, fly-by-wire system (as in the Light Combat Aircraft), missiles—in navigation and guidance (as in the onboard computers in the strapdown inertial navigation system of Agni and Prithvi), image processing for homing in on the target (as in the Nag), designing and testing of missiles, in surveillance and communication, simulation and wargaming (as in Shatranj, Chaturbhuj), and in management information systems. 52.

The Centre for Development of Advanced Computing (CDAC) is a dedicated centre for the development of super computers. It has developed the Param-10000, of a 100-gigaflop capability. Besides, the National Aerospace laboratory has developed the Flosover—the country’s first supercomputer, the BAARC has developed Anupam, C-Dot has developed a high-performance parallel processor and the DRDO the PACE computer.

With a view to enhancing the country’s information technology (IT) strengths, a panel was formed in 1998 to recommend an IT Policy.

1.8.5 Lasers

"Laser is a device that uses the maser principle of amplification of electromagnetic waves by stimulated emission of radiation." The properties of laser include coherence, monocromaticity, directionality and energy density. The broad categories of lasers are solid-state lasers, liquid lasers, gas lasers, free electron lasers, X-Ray lasers and chemical lasers.

Laser research in India encompasses a wide range of sub-fields. These include Helium-Neon laser, CO₂ laser, pulsed TEA CO₂ laser, gas dynamic CO₂ laser, nitrogen laser, copper vapour laser, Helium–Cadmium laser, dye laser, ruby, Nd:YAG and Nd:YAG glass. The SACC recommended that the indigenous development of those critical components required for laser research that are not being developed in India. These include grating, ZnSe, mirrors for CO₂ laser, thyatron and krytron.

54 SACC, n. 49, pp. 251-56.
Lasers have found application in medical surgery, engineering—welding, drilling cutting, surveying, meteorology, communications, holography, data storage, and in defence. The defence-related applications of laser include laser range finder (as used in the \textit{Arjun} tank), underwater laser for naval application, laser-guided anti-tank guided missiles, radar, ring laser gyroscope in the inertial navigation of medium and long-range missiles (as in \textit{Prithvi} and \textit{Agni}), secretive illuminators in air reconnaissance, military communication, anti-missile defence system, proximity fuse for missile warheads, firing simulators for training tank gunners, etc\textsuperscript{56}.

To sum up, in India the foundations of science in modern times were laid in 1958 with the adoption of the Science Policy Resolution in Parliament. With this began the creation of a science base in the country and a vast pool of manpower. Besides, a large network of national laboratories and R&D units in the central and industrial sector emerged, with the CSIR being the principal body for R&D. Thereafter, impetus to technology was given in 1974 when the Science and Technology Plan was prepared. A further concerted effort at fostering technology development was made in 1983 when the Technology Policy Statement was unveiled.

Indian S&T had to reckon with conflicting views. The arguments in this context include big science versus science targeted towards the larger societal interest; basic science versus applied science; autonomous scientific research versus market-oriented research; and diverse research areas versus mission-oriented research. One of the reasons for the inability of the country in being able to formulate and

\textsuperscript{56} K. V. Narasimhan, \textit{Laser and its Applications} [New Delhi, 1993].
implement an effective science and technology policy is the lack of an understanding of the field by the public, the bureaucracy and the politicians\textsuperscript{57}. The SPR had as one of its objectives the training and encouragement of scientific and technical personnel in order to cater to the defence needs of the country. The S&I Plan and the Technology Policy Statement do not seem to have a specific defence orientation. To the extent that there is a collaboration between the defence R&D effort and the national laboratories and academic institutes, these contribute to defence R&D. Though efforts were made to establish linkages between civilian and defence R&D, these floundered. There now is a renewed effort to forge stronger bonds between the National Laboratories, academia, and additionally the Indian industry.

Such an initiative suits the present context, more than ever before, though this should have all along been the course that India followed.

\textsuperscript{57} See Raghavan, n. 44.