Science, Technology and Society

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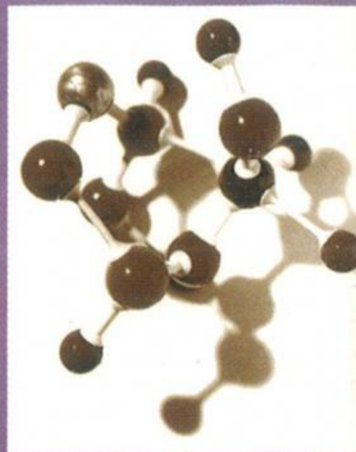

Theme Paper

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THE INDIAN INSTITUTE OF PUBLIC ADMINISTRATION

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PROLOGUE

Human civilisation owes its origin and growth to science and technology (S&T). They have been the greatest allies of mankind ever since the dawn of civilization. Creating countless pathways to progress, they have enabled man to traverse quite a long and arduous journey from his 'primitive habitat cave to moon'. Today, science and technology have become an integral part of man's life. They cover almost the entire gamut of our life. In fact, we cannot think of our existence today without the blessings and benefits of scientific and technological inventions and innovations.

The links between science and society had been recognised long ago. The *Charak Samhita*, an ancient medical treatise says, "To one who understands, knowledge of nature and love of humanity are not two things but one".[1] Nevertheless, the relevance of science for the society depends upon its applications. In fact, scientific discoveries can be used for constructive as well as destructive purposes. One of the most glaring examples of the destructive use of scientific discovery in the contemporary history of mankind was the atomic bombings of Japan's Hiroshima and Nagasaki by the United States during the World War II which killed more than two lakh innocent people and left several thousands people physically and mentally retarded for ever. This became possible through the genius of Albert Einstein whose theory of relativity led to his most famous formula, E=mc2, essential for the development of the atomic bombs. Einstein later blamed self for the world's first nuclear attacks.[2] As an eminent scientist has observed very poignantly:

Practically every scientific discovery has the potential of getting

1. Chattopadhyaya Debiprasad, *Science and Society in India*, Calcutta, Research India Pub., 1997, p.7.

2. In a letter dated June 23, 1953 Einstein wrote in German to Japanese philosopher and German-Japanese translator Seiei Shinohara: "I have always condemned the use of the

transformed into a technology which can reward mankind in the form of freedom from hunger, want, disease and discomfort. However, at the same time, there is also the possibility that the same science may turn into such applications which may cause profound harm to society. The history of our society is full of many instances of this kind where science has been tailored to be used for destructive purposes. The ancient saying, 'Fire is a good servant, but a bad master', aptly summarises the unguided use of a process leading to calamity.[3]

INDIA'S RICH HERITAGE

India, being the motherland of one of the oldest civilizations of the world, owns a very rich heritage in the domain of science and technology. It was, in fact, the "fountainhead of important foundational scientific developments and approaches".[4] Centuries ago, Said-al-Andalusi (1029-70) in his *Tabaqat-al-Uman*, probably the first work on history of science in any language, referred to India as the first nation which cultivated the sciences.[5] Ancient and medieval India was indeed far ahead of times as it made unique advances in astronomy, architecture, cosmology, chemistry, metallurgy, medicine, mathematics and various other fields of science and technology. The contributions of the great Indian *Rishis* (saints) long before the common era (BCE) and thereafter, such as Acharya Kapil (3000 BCE) in Cosmology, Acharya Kanad (600 BCE) in Atomic theory, Acharya Charak (600 BCE) in Medicine, Aryabhatt (476 CE) in Astronomy and Mathematics, Varahamihir (499 CE) in Astronomy and Bhaskaracharya (1114 CE) in Algebra and Astronomy are acknowledged in the history of sciences. In fact, the *Rishis* of India were the founding fathers of today's modern world.

Known as the father of Cosmology, Acharya Kapil threw light on the nature and the principles of the ultimate Soul, *Prakruti* (nature) and creation. He asserted that *Prakruti* with the inspiration of *Purusha* (man) is the mother of cosmic creation and all energies. Kanad, the founder of Atomic theory and the Chancellor of the famous University of Nalanda, pioneered the law of causation and the atomic theory. He classified all the objects of creation into nine elements, namely, earth, water, light, wind, ether, time, space, mind and soul, and concluded that every object of creation is made of atoms which in turn connects with each other to form molecules. This led to the foundation of the Atomic theory as far back as nearly 2500 years before John Dalton. Crowned as Father of Medicine, Charak's work titled *Charak Samhita* is widely acclaimed as an encyclopaedia of *Ayurveda*. His principles, diagnoses and treatment retain their relevance and truth even today. When the science of anatomy was confused with diverse theories in Europe, it was Acharya Charak who revealed through his innate genius, observation and contemplation the facts on human anatomy, embryology, pharmacology, blood circulation and diseases like diabetes, tuberculosis, heart ailment, etc. He was the first medical scientist who emphasized the influence of diet and activity on mind and body.

Aryabhatt's genius and intellectual brilliance remapped the boundaries of mathematics and astronomy. At the age of 23, he wrote a text on astronomy and unparalleled treatise on mathematics called *Aryabhatiyam*. He formulated the process of calculating the motion of planets and the time of eclipses. He was the first scientist to proclaim that the earth is round, it rotates on its axis, orbits the sun and is suspended in space, 1000 years before Copernicus published his heliocentric theory. His most spectacular contribution lies in the concept of zero without which modern computer technology would have been non-existent. Varahamihir's work called *Panchsiddhant* holds prominent place in the realm of astronomy. He was the first to proclaim that the moon and planets are lustrous not because of their own light but due to sunlight. In *Bruhad Samhita* and *Bruhad Jatak*, he had revealed his discoveries in the domains of geography, constellation science, botany and animal science. Bhaskaracharya's renowned work called *Lilavati* and *Bijaganita* bear testimony of his profound intelligence. In his treatise *Siddhant Shiromani* he wrote on planetary positions, eclipses, cosmography, mathematical techniques and astronomical equipment. He was the first scientist to discover gravity, 500 years before Sir Isaac Newton.[6]

Even in the domains of technology and architecture, ancient and medieval India was far ahead of its time. The planning of our ancient cities and water and drainage systems dating as far back as the Mohenjodaro and Harappan civilizations, and the architectural designs of our medieval palaces and forts bear ample evidence of ancient and medieval India's supremacy

3. Qasim S. Z, "Sea: Store-house of Renewable Energy", *Yojana*, Vol.35 (1&2), January 26, 1991, p.12.

4. Government of India, Ministry of Science & Technology, *Science and Technology Policy, 2003*, p.6.

5. Khan M. S, "Qadi Said-al-Andalusi's Account of Ancient Indian Sciences and Culture", *Journal of the Pakistan Historical Society*, Vol.XLV, 1997, pp.1-31. Also see, Kumar Deepak, "Science and Society in Colonial India: Exploring an Agenda", *Man & Development*.

6. The contributions of Indian *Rishis* in S & T are drawn from the compilation on

in the knowledge of science and technology. Unfortunately, due to external invasions and colonization, "all advancement in scientific knowledge and even technical progress got arrested."[7]

IMPACT OF COLONISATION

The Indian Reawakening in the 19th Century was, in a sense, the successor of the European Renaissance. Modern science as well as the rational thinking and ideals of the European Renaissance were brought to the static society of feudal India by the enlightened European Missionaries, Western educationists, social workers, journalists, scientists and others, namely, William Carey, Joshua Marshman, David Hare, Derejeo, Sister Nivedita, Father Lafont, P. Tachini, Alphonse de Penaranda, alongwith Indian social reformers like Raja Rammohun Roy, Ishwarchandra Vidyasagar, Sir Syed Ahmed Khan, Mirza Ghulam Ahmed, Ranade, Phule and eminent Indian scientists such as P.C. Ray, J.C. Bose, C.V. Raman, M.L. Sircar, M.N. Saha, Ashutosh Mukherjee and Visvesvaraya. In fact, the long process of transformation of India from feudalism to modernity was initiated by these enlightened reformers and scientists who often came into conflict with the imperial British rulers who put several obstacles in the way of spreading modern science and education out of fear and apprehension. Nevertheless, modern science and education grew, albeit slowly and unevenly, as a logical process of history. To quote an eminent historian, "Emergence of modern science along with its industrial and commercial applications coincided with colonial explorations and understandings. This was no coincidence. Both had an intimate, though complex, cause and effect relationship. Science, modernization and domination, all marched together. This lay in the logic of history and was to change human knowledge and relationship in every conceivable way."[8]

If the notion of ***science for profit*** was dominant in the early stage of colonialism in India, ***the applications of modern science and technology to facilitate private capital investment from Britain for commercial penetration*** became the guiding principle of colonial rule since the second half of the 19th Century. However, the process of British capitalist investment in India, or so-called "export of capital", observes the noted Marxist thinker, Rajani Palme Dutt very poignantly, "did not by any means imply a

7. Heptulla Najma, "Science and Technology for National Development", *Yojana*, vol.35 (1 & 2), January 26, 1991, p.18.

development of modern industry in India. Nintyseven per cent of the British capital invested in India before the war of 1914 was devoted to purposes of Government, transport, plantations and finance – that is to say, to purposes auxiliary to the commercial penetration of India, its exploitation as a source of raw materials and markets for British goods, and in no way connected with industrial development."[9] Consequently, the British introduced ***technology projects***, like telegraph, metalled roads and railways to develop means of communication, but these could not develop into a ***technology system***.

Let us take, for example, the railways which were indeed a great technological experiment. The British capital investment on railway construction, like other investments, was covered under the Public Debt, a favourite device already applied by the oligarchy in Britain to establish its stranglehold. Until the end of the 19th Century, revealed Dutt, £ 226 million were spent on railways, resulting in a loss of £ 40 million, which fell on the Indian Budget. After the turn of the century a profit was made out of the railways. However, till 1943-44, when the sterling debt due to railways was repatriated, nearly £ 10 million a year have been transmitted from India to England for railway debt.[10] Thus, India had to bear the entire costs of railway construction. But what did she actually get out of it? As a renowned scholar in History has observed very forthrightly:

> The vast and diverse terrains of India served as a 'laboratory', in which the railway engineers 'tested their skills and adapted their practice'. But these could not stimulate new industries. Asia's first railway workshop was established at Jamalpur in 1864, but no technological spin-off could emerge. The railways remained import-oriented and 'enclavist'. In fact it was 'a colony', within the colony.[11]

As in the other fields, the British colonial policy of discrimination was evident in the domain of science and technology too. Based on social stratification among scientists and technologists and their orientations, one can identify *three categories* of scientific and technical personnel and associated institutions from about the third quarter of the 18th Century.[12]

9 Dutt Rajani Palme, "The Exploitation of India: A Marxist View" in Lewis Martin Deming (ed.), *The British in India: Imperialism or Trusteeship*?, Boston, D.C. Heath & Co, 1962, p.51.

10. *Ibid*., p.50.

11. Kumar Deepak, *Supra*. n.5, p.91

12. Krishna V.V, "The Emergence of the Indian Scientific Community", *Sociological*

The *first* category includes the transplanted or settler scientific and technical personnel employed by the British government. They were basically the 'gate keepers' of colonial science who not only controlled and regulated research strategies to serve colonial ends, but also promoted discrimination against native scientists and technologists. In the *second* category were 'scientific soldiers' who were called upon by the colonial government to execute specific tasks. They usually did not have any commitment to the promotion of scientific disciplines or scientific societies. In the *third* category were a few hundreds of nationalist Indian scientists led by Ray, Bose, Raman and other eminent scientists of their time, and supported by a small group of Western settler scientists, missionaries and Jesuits, who relentlessly worked towards the 'professionalisation of science' in India despite infrastructural, financial and other handicaps. They had to struggle hard and sacrifice their self for the promotion of science in our country during the critical period of colonial subjugation. Acknowledging the contributions of this third category of scientists, an eminent scientist working in the realm of Sociology of Science has observed very aptly:

> While scientists in the first two categories were part and parcel of the colonial scientific enterprise and shared with and benefited from the colonial structures in science, the third category struggled against these structures... At the national level, however, these scientists widely shared the national obligation to transform colonial structures of science and create alternative support structures with the necessary autonomy to embark on an independent scientific status.[13]

With the objective of professionalizing science in India within a national perspective, the nationalist Indian scientists in collaboration with a small group of their European friends and supporters made sincere efforts to develop institutional support structures. Such efforts resulted in the creation of the Indian Association for the Cultivation of Science in 1876, followed by other institutions such as the Indian Institute of Science (1909), University College of Science, Calcutta University (1913) and Bose Research Institute (1917). There is no denying that these institutions made laudable contributions in advancing modern science and had produced great mathematicians and scientists of our country, namely, S.N. Bose, famous for Bose-Einstein statistics, Meghnad Saha, whose Saha theory of thermal ionization is crucial to our understanding of spectra observed in astrophysics, Ramanujam and his singular contributions to Number theory. Nevertheless, these institutional

support structures were not enough to ensure widespread applications of S & T to serve the greater needs of the Indian society. Consequently, science and technology were, by and large, alienated from society during the long period of colonial British rule in India. Jawaharlal Nehru, while serving his ninth term of imprisonment in a British Jail in India, wrote in 1944:

> The independence of the United States of America is more or less contemporaneous with the loss of freedom by India. Surveying the past century and a half, an Indian looks somewhat wistfully and longingly at the vast progress made by the United States during this period and compares it with what has been done in his own country. It is true no doubt that the Americans have many virtues and we have many failings, ... And yet perhaps it is not inconceivable that if Britain had not undertaken this great burden in India and, as she tells us, endeavoured for so long to teach us the difficult art of self-government, of which we had been so ignorant, India might not only have been freer and more prosperous but also *far more advanced in science and art* and all that makes life worth living.[14]

POST-INDEPENDENCE SCENARIO

Since 1947, with the transformation of the country from a colony of the British Raj to a sovereign, democratic republic, India continues to vigorously pursue a comprehensive programme of employing modern science and technology for national development. The founding fathers of our republic, and in particular, Jawaharlal Nehru, the architect of modern India, "laid great emphasis on building up a viable framework for science and technology policy as an integral part of planning for national development."[15] Consequently, ever since Independence, development of science and technology has been given a high priority by the Central Government, with the Prime Minister himself being the Cabinet Minister in-charge of science and technology. Scientific organizations which had existed in some form before Independence, were converted soon after Independence into 'umbrella organizations', and assigned the responsibility of promoting research and development (R&D) in their respective disciplines. These organizations included Indian Council of Agricultural Research, Indian

14. Nehru Jawaharlal, "The British Rule in India" in Lewis Martin Deming (ed.), *Supra*. n.9, p.26 (emphasis added).

Council of Medical Research and the Council for Scientific and Industrial Research. Subsequently, new structures and organisations were created to cater to new fields of scientific and technological research. These included the creation of the Department of Atomic Energy in 1954, the Defence Research and Development Organisation in 1958, the Department of Electronics in 1971, the Department of Space in 1972, the Department of Non-Conventional Energy Sources, the Department of Ocean Development, and the Department of Biotechnology in 1982. While these central structures function as independent entities, the Department of Science and Technology, created in 1971, has continued to play the key role in policy formulation and coordination in matters relating to science and technology.[16]

Over the years, these organisations have not only been developed in terms of skilled manpower and R & D infrastructure with the generous support from the Central Government, but also playing significant role in fulfilling the basic human needs of our vast population. For instance, the Indian Council of Agricultural Research, which is credited for having placed the country amongst the self-reliant food secure Nations, has emerged today as one of the largest agricultural research organizations in the world with over 6,000 scientists, 26,000 personnel, 48 institutes, 5 National Bureaux, 31 National Research Centres, 11 Project Directorates, 91 All-India Coordinated Research Projects, 38 State Agricultural Universities, 1 Central Agricultural University and 485 Krishi Vigyan Kendras (KVKs). The council has been actively involved in cutting edge research for developing technologies and tools for sustainable agriculture, and also in technology transfer through KVKs to improve economic return to the farmer.

INDIA's S & T POLICY FOR THE 21ST CENTURY

The late 20th Century globalisation and economic liberalisation reinforced by Information and Communication Technology (ICT) revolution have indeed been posing new challenges as well as providing new opportunities for science and technology of developing countries as ours. In response to the emerging needs of liberalised and competitive economy, the Government of India's *Science and Technology Policy 2003* reiterates the country's "commitment to participate as an equal and vigorous global player in generating and harnessing advances in science and technology for the benefit of all humankind."[17] Recognising the changing context of the scientific

16. Singh Manmohan, *op. cit.*

17. Government of India, Ministry of Science and Technology, *Science and Technology*

enterprise, and to meet present national needs in the new era of globalisation, our new S & T Policy has laid down fifteen broad objectives, namely:

- To ensure that the message of science reaches every citizen of India, man and woman, young and old, so that we advance scientific temper, emerge as a progressive and enlightened society…
- To ensure food, agricultural, nutritional, environmental, water, health and energy security of the people on a sustainable basis.
- To vigorously foster scientific research in universities and other academic, scientific and engineering institutions; and attract the brightest young persons to careers in science and technology…
- To provide necessary autonomy and freedom of functioning for all academic and R &D institutions so that an ambience for truly creative work is encouraged…
- To accomplish national strategic and security-related objectives, by using the latest advances in science and technology.
- To encourage research and innovation in areas of relevance for the economy and society, particularly by promoting close and productive interaction between private and public institutions in science and technology. Sectors such as agriculture…, water, health, education, industry, energy including renewable energy, communication and transportation would be accorded highest priority.
- To establish an Intellectual Property Rights (IPR) regime which maximizes the incentives for the generation and protection of intellectual property by all types of inventors…
- To ensure, in an era in which information is key to the development of science and technology, that all efforts are made to have high-speed access to information, both in quality and quantity, at affordable costs; and also create digitized, valid and usable content of Indian origin.
- To encourage research and application for forecasting, prevention and mitigation of natural hazards, particularly, floods, cyclones, earthquakes, drought and landslides.[18]

With a view to fulfilling these broad objectives, the S & T Policy 2003 has also spelt out a viable implementation strategy.[19] Keeping in view the achievements and advancement in the domain of science and technology in our country during the past over five and half decades after Independence, one may reasonably expect that this new policy will be implemented in true spirit for building up a new and resurgent India.

APPLICATIONS OF S&T FOR NATIONAL DEVELOPMENT AND SOCIETAL TRANSFORMATION: RETROSPECT AND PROSPECT

There is no denying that science and technology become relevant for the society as and when scientific and technological advancement is based on human needs, and the vast treasure of scientific and technological knowledge is used to address social problems. The symbiotic relationship between science, technology and society has been explained very succinctly by our Scientist-President, A.P.J. Abdul Kalam, in the following words:

> Technology is a non-linear tool available to humanity which can affect fundamental changes in the ground rules of economic competitiveness. Science is linked to technology through applications. Technology is linked to economy and environment through manufacture. Economy and environment linked to technology promotes prosperity in society.[20]

Keeping in view the symbiotic relationship between science, technology and society, let us now make an evaluation as to how science and technology are being used to meet some of our major social concerns and needs.

(i) Food and Agricultural Security

It is most unfortunate that in spite of technological breakthrough in the field of agriculture, provision of food for the ever-increasing population continues to be the main problem for developing countries of Asia, Africa and Latin America. In fact, one of the most critical problems bequeathed to us by our colonial ruler was hunger and famine. It needs to be recalled that the export of food grains, especially rice and wheat, from starving India under the British rule rose from £ 858,000 in 1849 to £ 19.3 million in 1914, or an increase of over twenty-two times, resulted in the number and intensity of famines in the second half of the 19th Century. Thus, in the first half of the 19th century there were *seven* famines, with an estimated total of *1.5 million deaths* from famine, whereas in the second half of the 19th Century there were *twenty-four* famines with an estimated total of *20 million deaths* as per official records.[21]

After Independence, we have been able to stop *famine* but not *hunger*

20. Kalam A.P.J. Abdul, "India in 2020: A Wishlist" (Excerpts from the President's address at the 92nd Indian Science Congress, 2005, at Ahmedabad), *Outlook*, Vol.XLV (28), July 18, 2005, p.34.

altogether, nor the reported incidents of *deaths by starvation* in some parts of the country. It is really deplorable that at a time when India has not only emerged as *a self-reliant food secure nation*, but is also earning foreign exchange through export of food grains to other countries, some of our own people would die out of starvation or, a large chunk of our children, women and men would be denied of food security, that is, 'physical and economic access to food at all times'. Does this not reflect the poor quality of governance in our country? What should then be the role of our agricultural scientists and public policy makers in regard to food and agricultural security? Suggesting that only "green" or environmentally friendly technologies be used for raising food productivity, M.S. Swaminathan, a noted agricultural scientist has emphasized that what a population-rich but land-hungry country like ours needs is land-saving agriculture and grain-saving animal husbandry. He also advocates continuous improvement in the productivity and profitability of rice farming as it is very vital for our food security. "If some of the postulated changes in precipitation, temperature, ultraviolet-B radiation and sea levels do take place", observes Swaminathan, "the importance of rice in our national food security system will grow. This is because of the wide range of variability occurring in rice strains with regard to tolerance to temperature, precipitation and flood levels. We must, therefore, conserve the biological wealth in rice…" As for public policy makers, Swaminathan suggests that they should lose no further time in preventing the diversion of good farm land for non-agricultural purposes through carefully developed National Food Security Act designed to facilitate both greater production by resource poor farm and fishermen families and greater consumption by the economically under-privileged sections of the community, based on ecological ground rules.[22]

It is now being emphasized that there is need for a *Second Green Revolution* in our country. This implies greater application of S & T in agriculture as well as increase in investments, both public and private, in such application.

(ii) Water Security

Since the dawn of civilization, water has been one of the basic elements of the life support system on our planet. According to the Hindu mythological concept of the *Panchbhutas*, water, along with land, fire, the sky and air, constitute the most fundamental set of divine forces.[23] Unfortunately, India's

22. Swaminathan M.S., "Science and Agriculture", *Yojana*, Vol.35 (1&2), January 26, 1991, p.11.

23. Kanda Mohan, "Land Resource Management in India" in Mohan Kanda(ed.), *Vasundhara: An Anthology of Land Resources in India*, Government of India, Department

water resources are now in *a state of deep crisis.* People in all parts of the country, from hills to plains, suffer from scarcity of water due to extensive deforestation, exorbitant use of groundwater for irrigation, erosion of the catchment areas caused by short-sighted developmental plans and projects, and various other factors.

Forests are primarily producers of water and only secondarily, of wood. Yet, these forests have been subjected to a net denudation of more than one million hectares per year.[24] The government's policy of building industrial townships in forest areas, big dams, growing urbanization, and a high market demand for timber are the major factors responsible for excessive denudation of forests. These apart, "the forest scientist's concept of clear felling in favour of quick-growing high revenue yielding plantations", observes a scholar very poignantly, "has also been denuding forests and creating favourable conditions for the introduction and spread of exotic weeds and diseases. These are matters as much of science policy as of political policy."[25]

Another important sources of water in our country is rainfall. The 'temporal and spatial variations' in the occurrence of rainfall lead to 'drought-flood-drought syndrome' affecting about one-third of the country to droughts and about one-eighth part to floods. Both droughts and floods result in huge losses to human lives, habitats, properties, and above all, our national economy. There is, therefore, the need for massive conservation of water through its storage and scientific use to meet the increasing requirements for irrigation, drinking and industrial use. Application of science and technology can help in efficient water resource management in many ways, namely:

- Adoption of scientific methods of leveling and shaping of the field to increase the efficiency of water application;
- Use of drip, sprinkler and injection system to increase the efficiency of irrigation;
- Systematic management of water based on scientific measurement of the flows; and
- Effective use of ground water through the scientific development of durable tubewells (now possible) with the use of bore hole camera and provision of better types of strainers made out of polymers which can resist rusting and provide a long-term clogging free operation.[26]

24. Ghosh Sailendranath, "'Modern Science' vs Society," *Seminar*, No.334, June 1987, p.18.
25. *Ibid*
26. Chitale M.A., "Scientific Use of Water Resources", *Yojana*, Vol.35 (1&2), January

Mountain glaciers are also a very important source of water. However, global warming is now shrinking glaciers the world over. With 33,000 sq km of glaciers, the Himalayas is aptly called the 'water tower of Asia', ensuring round-the-year supply to billions of people. But recent research shows that 67 per cent of the Himalayan glaciers are retreating much faster in the last three decades than they did in the last 200 years.[27] A march 2005 report by the World Wide Fund (WWF) for Nature which was a collaborative effort between India, China and Nepal reveals that in the Ganga, the loss of glacier-melt water will reduce July-September flows to two-thirds, causing water shortage for 500 million people and 37 per cent of India's irrigated land. Although accelerated melting of glaciers will raise river water levels over the next few decades initially, leading to higher flooding and landslides, in the long term, as the volume of ice available for melting diminishes, a reduction in glacial run-off and river flows can be expected. The emerging scenario will have serious implications for our country's economy since all of agriculture in North India is highly vulnerable to any change of stream flow.[28]

As of now, little research has been carried out on the subject, and hence, our scientists and glaciologists are handicapped due to non-availability of adequate data. According to Dr. Renoj J. Thayyen, a glaciologist at the Wadia Institute of Himalayan Geology, "All these years, this was a relatively neglected issue. We lack long years of data and research across different climate zones in the Himalayas. Now it's become a knowledge game between the developed countries (who have the database) and developing ones (who lack it) because of which there is a tendency among international agencies to force their point of view and influence water resources management strategies at the highest level on the basis of studies reported from other mountain regions of the world."[29] Hence, the need of hour, emphasizes Thayyen very forthrightly, is to strengthen our knowledge base on hydrology and hydrometeorology of mountain catchments.

CARTOSAT-I, which was injected in a polar orbit of 618 km from the Satish Dhawan Space Centre at Sriharikota on May 5 this year, has become 'a world-class earth mapper', and will find applications in the domains of land, water and environment management. It will facilitate the generation of large-scale base maps, thematic maps, a national level digital elevation

27. Dogra Chander Suta, "High Water, Then Hell", *Outlook*, Vol.XLV (29), July 25, 2005, p.63.
28. For further details, see *Ibid.*, pp.63-68.

model, a digital terrain model, and contour interval mapping to the extent of about 10 meters. "Data from CARTOSAT-I in conjunction with other IRS satellite data", observes our Scientist-President, A.P.J. Abdul Kalam, "will be useful in applications such as mapping of settlements,…and delineation of watershed. The digital terrain model with improved accuracies will find applications in inter-river basin studies pertaining to interlinking of rivers and urban and rural infrastructure development…"[30]

(iii) Health Security

A serious challenge before the scientific community, especially medical scientists in our country is to find ways for effective prevention, treatment, containment or total eradication of diseases including deadly ones like cancer and AIDS. In fact, our scientists and technologists have made significant contributions in the fields of bio-technology, pharmaceuticals, nuclear medicine and health technology. New researches in advanced health technology must aim at helping the poor and needy people. Explaining his vision of developed India in 2020 and his perception of the mission of the scientific community, A.P.J. Abdul Kalam wished that developed India should be "a nation where the best of healthcare is available to the population."[31]

Advancement in *stem cell research* in our country, as Kalam points out, has now enabled our expert doctors to carry out its clinical application in heart, eye, pancreas, liver, kidney diseases and spinal injury. Citing an example of such application, Kalam has said that drawing on thousands of stem cells, capable of transforming themselves into almost any kind of tissue, from the suffering patients and injecting them into the heart to stimulate heart restoration has already been practiced.[32] Further advancement in stem cell research and its application will help in near future in the treatment of many diseases in a cost-effective way.

Recently, the experts of the nuclear medicine department of All-India Institute of Medical Sciences (AIIMS) have reportedly invented a new machine called the Positron Emission Tomography (PET/CT) which will accurately detect cancer in just over an hour at an estimated cost of only Rs.7,500. The technology has already been tested on three patients with 10 trial runs, all of which proved successful. The Bhabha Atomic Research Centre (BARC) in Mumbai has finally given the AIIMS the go-ahead to use this new machine. This will go a long way in providing quick and cost-

30. Kalam A.P.J. Abdul, "Technologies for Societal Transformation" (an article based on the President's Technology Day 2005 address over All India Radio and Doordarshan), *The Hindu*, Hyderabad, May 16, 2005, p.10.

31. Supra, p.20, p.22

effective cancer detection facility in a country like ours where as many as 8 lakh new patients are diagnosed with cancer every year.[33]

Our 'best minds' in science must also engage themselves in the discovery of low-cost drugs to cater to the needs of the poor. In his inaugural address to the 92nd session of the Indian Science Congress at New Delhi on January 3 this year, Prime Minister, Manmohan Singh has emphasized the need for creating *alternative paths of drug discovery*. As he observes very forthrightly:

> New drug discovery research is becoming increasingly expensive. It now takes upto 15 years and upto 1.5 billion dollars to move a molecule to the market. Let alone the poor in India, even the rich in the developed world will not be able to afford such drugs! India cannot just emulate these models and hope to win. We must create alternative paths of drug discovery, where India has distinct comparative advantage and a chance to win.[34]

It is heartening to observe that our scientists, scientific institutions and pharmaceutical industry are aware of their social responsibilities. The Central Drug Research Institute, for instance, has recently produced a drug to treat cerebral malaria, which is being sold internationally by Themis, an Indian pharma company under the brand name *E-Mal* to as many as 48 countries world over including countries in Sub-Saharan Africa, at affordable prices. Another good example is India's Santha Biotech which produced a recombinant DNA vaccine named *Shanvac* on Hepatitis B. Before Shanvac's entry to the international market, this vaccine was being sold at a very high price of US$ 15 per dose, while its prices have now come down to less than a dollar per dose. This spectacular reduction in price bears convincing evidence of India's unique S & T capacity of manufacturing low-cost life saving drugs which can benefit India as well as the whole world.[35]

(iv) Energy Security

Energy is, and has to be, another area of major concern for our scientific community. In fact, the demand for energy will continue to increase in view of our ambitious 'developmental goals' and 'the expected increase in per capita consumption'. Since our existing sources of energy as well as existing technologies in the energy sector are not adequate to meet the growing

33. *The Times of India*, Delhi, July 24, 2005, pp.1&22.

34. Singh Manmohan, "Science Needs a New Boost",(Prime Minister's inaugural address to the 92nd Indian Science Congress at New Delhi on January 03, 2005), Delhi, DAVP, February, 2005, p.6

demand for energy, we now require a 'technological revolution' aiming at developing and utilizing different sources of energy including renewable sources, such as solar energy, bio energy, wind energy, wave energy and even energy of the ocean. These conventional and renewable energy sources have immense potential to supplement the increasing energy and power demands. The technical and economic viability of these energy sources have been proved over the decades. They are also recognized as ecologically acceptable sources.

Solar energy is a glaring example of a renewable source of energy which is being increasingly used not only for producing low grade heat for applications such as cooking, water heating, air heating, water desalination, drying of food grains, vegetables, timber etc., but also to generate electric power. With the use of latest technology of silicon-based photo-voltaic cell, it will now be possible for us to install highly efficient and cost-effective 100 MW solar electric power plants in different regions of the country. As compared to highly expensive nuclear electric power plant, the cost-effective solar electric power plant is vital for our country's energy security and promises better quality of life for the people.

The renewable capacity of solar energy is extremely high since its supply is abundant. To quote an eminent scientist, "Sun is the biggest fusion reactor known to mankind which supplies to the earth daily free of charge about 10,000 times energy needed by the world population. Apart from being the sources of life Sun happens to be the source of all energies except nuclear energy and geothermal energy. Even the energy of the fossil fuels is a form of solar energy acquired by plant life several thousands of years ago and buried underground for centuries."[36]

Oceans are also a vast 'store-house' of renewable energy. There are at least *eight* sources of energy which could be extracted from the oceans through various ingenious methods. These are: (i) ocean waves, (ii) ocean tides, (iii) ocean thermal energy conversion (OTEC), (iv) ocean currents, (v) ocean winds, (vi) salinity gradient, (vii) ocean geothermal, and (viii) bioconversion of seaweeds.[37] Though the appropriate technology for extraction of energy from the sea has been a serious constraint, our scientific community are gradually overcoming it, and consequently, the new technologies are being developed now for the generation of power from the sea in an efficient and cost-effective manner.

36. Sootha G.D., "Renewable Energy Sources and their Social Relevance", *Yojana*, Vol. 35 (1&2), January 26, 1991, p.69.

(v) Disaster Management

Man's struggle against nature's fury is as old as civilization. Historically, most of the scientific and technological innovations have emerged in times of crisis. Time and again, it appeared that 'unexpected' crisis became the 'incentive to innovate'. However, it has been realized now that instead of wasting valuable time awaiting a crisis to occur, it would be rather wise if our scientific community utilize such time as an opportunity to leverage the technology and prepare for the worst. The recent tragedy of unexpected Tsunami is a case in example. As Union Minister of State for Science and Technology, Kapil Sibal, has observed very poignantly during his address for the Technolog Day function in New Delhi on 11th May this year, "*We were caught totally unaware, sitting in comforts of the belief that it was Pacific Ocean phenomenon and we need not bother about it. But we learnt our lesson albeit the hard way.*" [38]

Taking cue from the Tsunami lesson, the Department of Ocean Development, announced the Minister in that function, is now in the process of setting up a Tsunami and Storm Surge Early Warning System, and it is expected to be in place by 2007. The National Centre for Medium Range Weather Forecasting (NCMRWF) will also soon dedicate a scientific team to work on predicting the extent of damages by floods, storm surge, impacts of climate change, etc., once its super computing abilities are enhanced. "Since the science of the earth systems", observes the Minister further "is still suffering from uncertainties, we need to make more vigorous efforts by honing our skills in modeling different scenarios. A lot more is to be done and we hope to do that soon."[39]

It needs to be noted in this context that the combined findings and calculations of the American and Japanese researchers have proven that a devastating tsunami swept ashore in what is now the Pacific Northwest state of Washington way back in January 1700. The discoveries of paleoseismologists – those who study earthquakes of the past – are shedding new light on the risks that the region faces for future earthquakes and tsunamis, and the devastation that could come with them. Hundreds of bridges and tall buildings in the metropolitan areas of Seattle, Washington and Portland, Oregon could be at risk if a quake of similar magnitude were to occur again.[40] Though scientists are finding that earthquakes defy

38. *Vide* Minister's address for the Technology Day on May 11, 2005 (hardcopy), Courtesy: Government of India, Department of Science and Technology.

39. *Ibid.*

40. For further details, see Krajick Kevin, "Future Shocks: Modern Science, Ancient Catastrophes, and the Endless Quest to Predict Earthquakes", *Smithsonian*, March 2005

predictability, they are learning much more about their likelihood from clues that seismic events left behind centuries ago. Such information is invaluable for urban planners and engineers to assess construction safety requirements and emergency planning more accurately.

The scientific community in India which has the required talent and competence to grasp the recent developments in paleoseismology and other related disciplines, is expected to rise to the challenge and develop indigenous and economically viable technology for predicting as well as meeting emergencies arising from cyclones, earthquakes, floods, droughts, tsunamis, avalanches and landslides. Our 'best minds' in science and technology must play a significant and useful role in the nation's endeavour to address the problems of prevention, mitigation and management of impact of natural disasters.

(vi) Linking ICT Revolution to Social Ends

The Information and Communication Technology (ICT) revolution of the present age breaks the barriers of national boundaries, and makes every individual a 'global participant' and every place in the world a part of global village. With its ability to link information resources world-wide the ICT has profound implications for the future of education. This emerging technology is fast demonstrating that schools are one of the many places where learning can and will take place due to ready access to information beyond the classroom walls. It is also increasingly blurring, to quote a Varginia based educational consultant, "the distinction between learner and teacher through the capability of giving all users rapid and simultaneous access to information at decreasing cost… Schools are already beginning to evolve toward Learner – Centered complexes that will take advantage of global resources both during and after regular school hours. What constitutes schoolwork and homework will become less clear as a result of emerging communications technology."[41]

It needs to be mentioned in this context that Indian Space Research Organisation (ISRO)'s EDUSAT (Educational Satellite) programme is designed to support education through low-cost ground segments so as to reach the un-reached people of India. EDUSAT, when fully operational, will have a capacity of 30 uplinks and about 5,000 remote terminals per uplink. Thus it will provide as many as 1,50,000 ground terminals in its full capacity. It brings two-way interactivity and collaboration. Coupled with

41. Exline Joseph, "Science, Technology and Society", *Science Professional Development/*

the broadband, it will form "a heterogeneous network in taking quality education to all parts of the country".[42]

In the existing socio-economic context of India, 'knowledge connectivity' through ICT is fundamental to bridging the rich-poor as well as urban-rural divide not merely in education but other sectors as well. It may even save people in times of crisis. For example, the *information center,* set up to empower the villagers of Veerapattinam along the coast of Pondicherry with knowledge through communication tools like the internet, turned into the *lifeline* of residents when the tsunami waves struck on December 26, 2004. The villagers who saw the first wave rising rushed to the lone information center and used the public address system installed therein to let the villagers know that they were in danger. Several lives were reportedly saved due to this one announcement in a village having a population of about 6,500 persons. Even after the tsunami disaster, this center collected information through the internet on the wave height and the weather and informed villagers, and these updates helped reduce their anxiety.[43]

It is heartening to note that *Mission 2007: Every Village a Knowledge Centre* is a nationwide initiative to facilitate setting up of such centers by the National Alliance of voluntary organizations led by M.S. Swaminathan Research Foundation in each of India's 600,000 villages by the year 2007. The Government of India is a partner in the alliance. The knowledge center is equipped with communication tools like the internet to provide information to the people in the context of the lifestyle and local needs of a particular village. Taking cue from the Veerapattinam experience, it has been felt that information centers need to be set up in many more villages along the sea coast. Mission 2007 is indeed a glaring example of public-private partnership in information and communication sector which could be emulated in other sectors as well.

(vii) Convergence of Nano and Bio Technologies

The convergence of nano and bio technologies today promises to revolutionize the way we live and will be the *propeller of growth* in near future. We need to accelerate our work on these technologies to be in the *driver's seat* to contribute towards this *societal change*. "A nation that is alert", to quote India's Scientist-President, A.P.J. Abdul Kalam, "should be sensitive to the changes in the technological fabric of world and prepare

42. *Supra*, n.20, p.34.

43. Pandit Ambika/TNN, "Tsunami villages reach out, via ICT" (a report), *The Times of*

itself for the arrival of newer changes in the horizon. If we take an appropriate and timely action, we can become one of the important technological nations in the world."[44]

The global market for nano materials, nano tools and nano-biotechnology put together is now worth over $100 billion, of which nano-biotechnology is the fastest growing area. Carbon nano tubes and its composites will give rise to *super-strong, smart and intelligent structures* in the realm of material science, while nano-biomedical sensors will play a major role in *glucose detection* and *endoscopic implants*, and revolutionize healthcare to a great extent. Molecular switches and circuits along with nano cells will also pave the way for the *next generation of computers*.[45] Thus, the process of convergence is not restricted to nano and bio-technologies, but extended to information and communication technology as well. Together, these technologies will make huge contribution towards ushering in of a new era of societal transformation.

(viii) Meeting Societal Needs: Challenges and Response

There is no gainsaying the fact that in a developing country like India, the scientific community is required to play a catalytic role in providing S & T based solutions to various societal problems, especially poverty and unemployment, and facilitating socio-economic upliftment of the millions of our poor and needy people. It is heartening to mention that the Government of India's Department of Science and Technology (DST) has already launched a unique programme called *Science and Society Programme* which aims at applying S & T based solutions to need based problems for socio-economic upliftment of the weaker sections of the community. This programme supports S & T based institutions, NGOs, Universities and Colleges throughout the country to take up innovative grant-in-aid projects in challenging areas at the grassroot level with various schemes targeted for different sections of the society to address location and occupation specific problems with a view to enhancing livelihood options. The major focus of the programme is to catalyze and support research, development and adaptation of relevant and appropriate technologies for empowering and improving quality of life of Artisans, Landless labour, women and other needy people in rural areas with a number of programmes, namely:

- ***Science and Technology Application for Rural Development (STARD):*** It extends core support to S & T based field groups and individual projects for development of micro-watershed, low cost bio-control and bio-fertilizer production, computerized village information support system, rural engineering, health and sanitation, improved agricultural practices, etc.
- ***Science and Technology Application for the Weaker Sections (STAWS):*** This programme aims at deriving benefits from S & T experience and skills vis-à-vis needs of the people particularly weaker sections of the population in order to develop *sustainable replicative models*. It includes various projects such as floriculture and nursery training for income generation, small scale enterprise for weaker sections for production of precast concrete door and window with lower production cost and higher quality of output, demonstration and standardization of pearl culture technology to create scientific and technical expert manpower in weaker sections of the society, low cost technology application for integrated village development in terms soil, water and energy conservation, safe drinking water and sanitation facilities, etc.
- ***Tribal Sub-Plan (TSP):*** Under this scheme, location specific and need-based projects are supported for socio-economic upliftment of tribal communities. These projects include conservation and scientific tapping of sterculia urens for better quality of gum, value additions to local horticultural produce and sustainable livelihood creation for tribal women, socio-economic empowerment of tribals through state-of-art technologies in sericulture, etc.
- ***Special Component Plan for the Development of Scheduled Caste Population (SCP):*** Its objective is to apply S & T for the benefit of Scheduled Caste population. Areas of S & T intervention include improving skills and efficiency of traditional occupations like handloom, jute, etc., functional capability development, skill upgradation through training, etc.[46]

There is no doubt that these programmes have been very well conceived. However, their success in achieving the desired outcome would ultimately depend on the active participation of S & T based institutions, NGOs, Colleges and Universities, and above all, the local population.

EPILOGUE

India is probably the first country in the world to recognize the links between science and society many centuries ago. Being the motherland of one of the oldest civilizations in the history of mankind, she owns a very rich heritage in the domain of science and technology. The contribution of our great *Rishis* in various fields of science and technology long before the common era (BCE) and thereafter, have been duly acknowledged in the history of sciences. Medieval India was also far ahead of its time in the spheres of technology and architecture. Unfortunately, due to external invasions and colonization, all advancement in science and technology was halted in our country for a considerable period of time.

During the long period of colonial British rule, the nationalist Indian scientists in collaboration with a small group of progressive European missionaries and scientists made laudable contributions in developing institutional support structures for scientific research as well as in advancing modern science in this country. Nevertheless, science and technology were, by and large, alienated from society due to colonial policy of the *British Raj*. This dim scenario began to change with the advent of freedom in 1947. Since then the independent India continues to vigorously pursue a comprehensive programme of employing modern science and technology for national development and societal transformation as discussed elaborately in this paper. It is heartening to mention that during the past over five and half decades the scientific community in India has time and again demonstrated its competence and commitment in meeting the multi-pronged and stupendous challenges before it in the fields of food and agriculture, water resource management, health care, development and utilization of conventional and renewable energy sources, disaster management, knowledge connectivity through ICT, and convergence of nano and bio technologies. The Government of India's commitment to science and technology and their applications for solutions of need based problems for socio-economic upliftment of the weaker sections of the community is reflected from the aims, objectives and contents of various schemes under Science and Society Programme launched by its Department of Science and Technology. While public-private partnership is the key to the success of these programmes in achieving the desired outcome, the quality of governance is also required to be improved to facilitate the ongoing process of societal transformation with the applications of modern science and technology. There is no doubt that the collective and committed efforts of our scientific community, civil society organizations, government agencies and