Science and technology in free India

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India achieved independence on 15 August 1947. On that day, the British colonial power finally and formally quit India. The period of foreign domination lasted nearly 190 years, if we count from the Battle of Plassey in 1757. After nearly two centuries of subjugation by a foreign power, we have been a free nation for more than a half-century now [1]. What are our achievements in the domain of science, technology, education and industry in these past 55 years? And what are our failures?

Science and technology in Ancient India

Before we take stock of the 1947-2002 period, it will be useful to take a quick look at the S&T scenario in ancient India. This is needed as a background for evaluation. Let us enumerate only the salient contributions:

- The invention of the decimal system of numbers.

This was truly a great breakthrough in Mathematics. The Arabs got this idea from India. An Arab chronicler of the 10th century AD exclaimed: " It is mind-boggling to see how the Hindus (Indians) are able to represent any number, however big it may be, by using just 10 symbols!".

The Europeans came to know of this system from the Arabs. So, they called the numerals " Arabic numerals"! It is interesting to note that the Arabs themselves call them "Raqm al-Hind" (Hindu numerals) [2]

- The invention of ZERO as a number.

This can be described only as a giant leap forward in the domains of Mathematics and all sciences.

- Great schools of Mathematics flourished in the Kerala region of India. Madhava discovered the mathematical series called the Gregory series (now renamed as Madhava-Gregory series). In the Malayalam text "Yuktibhasha", we find statement like

"Ekadyekothara pada sankalitam samam padavargathinte pakuti", which , when translated into modern mathematical language would read as

"The integral of x dx is equal to $x^2 / 2$" . Remember that this book was written before the times of Newton!

The Parahita system of astronomical calculations was improved and revised by Paramesuaran Namboodiri in the 9th century. Paramesuaran devised the Drigganita system. His house was situated at the "confluence of Bharatha Puzha (river) and the Arabian Sea. He is said to have practiced meditation (dhyana) for 55 years during which time his sole major interest was Mathematics and Astronomy.

- The realization of the global nature of planet earth by Varahamihira(5th century BC)

He also calculated the circumference of the earth at the equator to be 40,350 km and the radius to be 12,845. How close these values are to the presently accepted data!

[According to a data source, the presently accepted values for circumference and diameter are, respectively 40,075 km and 12714 km (polar diameter) and 12756 km (equatorial diameter)].

- Aryabhata (5th century B.C) knew that the earth rotated towards the east and that it revolved around the sun. [Copernicus more or less re-invented this independently in the 15th century A.D!]

- Mohanjo Daro and Harappan civilizations were aware of the applications of metals (copper, bronze) and ceramics.

- The iron pillar of Delhi (5th century A.D) still remains free of rust after more than 1500 years!

- The huge Buddha statue at Sultanganj in Bihar(5th Century AD) made entirely of copper is another testimony to the metallurgical skill of the ancient Indians.

- Ayurveda was a well-developed discipline by the 6th century BC.

... The list could go on..., and go on!

S&T Renaissance in Modern Times

Modern science is only about 400 years old, if we reckon from the time of Isaac Newton. It was born and nurtured mainly in Europe. Its ripples gradually spread over the entire earth. India too benefited from this, thanks to the spread of the English language in India. Among the different regions of India, Bengal led the way in this respect also, as in many other areas.

The establishment of the Indian Association for the Cultivation of Science (IACS) in 1876 in Calcutta by Professor Mahendra Lal Sarkar was a landmark in the annals of S & T in India. The legendary Sir C.V.Raman carried out his early research work at the IACS. Among the other archetypal figures in Indian science, let us remember professors J.C. Bose, Sreenivasa Ramanujan, P.C.Ray, M.N.Saha, P.C. Mahalanobis, and S.N.Bose as the early titans.

Another great institution was the Indian Institute of Science (IISc) established at Bangalore, through the beneficence of J.N. Tata and the largesse of the Maharaja of Mysore. The IISC remains aloft as the great citadel of Indian science to this date.

Other landmarks were : The establishment of Universities at Madras, Bombay and Calcutta around 1857; the founding of Bengal Chemical & Pharmaceutical s in 1900; the discovery of oil in Assam in 186o; the setting up of

Tata Iron and Steel Co. At Jamshedpur in 1907; the establishment of the Council of Scientific and Industrial research (CSIR) in 1942 etc.

Post - Independence Scenario

Independence brought a new elan to S & T in India. We are largely indebted for this to our early leaders , above all Pandit Jawaharlal Nehru.

Jawaharlal Nehru and J. J. Bhabha

Atomic Energy

The atomic age was heralded in 1945, under tragic circumstances. (One remembers Hiroshima and Nagasaki here.) Mankind has crossed the Rubicon; there cannot be any turning back now. All that is needed now is the wisdom to use this enormous power for the good of all, and never, ever for war.

The father of atomic research in India, Dr. Homi Bhabha had planned a programme of the developing of nuclear power in India as early as 1958. Bhabha's closeness with Nehru helped greatly. Today, India is a *de facto* nuclear power [3]. The Pokhran implosions (1976 and 1998) should leave no one in doubt.

More important, we have gone some way in harnessing nuclear energy for peaceful purposes. We now have nuclear power stations at Tarapore, Kota, Kalpakkam, Arora, Kaiga etc. Our power stations are second to none in safety, we are told. Credit is due to our nuclear scientists, and for our institutions like BARC, TIFR and IGCAR for all this.

The vast deposits of Monazite (an ore of Thorium) in the mineral sands of southwest India would ensure our self-sufficiency as regards nuclear fuel for a very long time.

Space research

Our space programme started in 1963 under the stewardship of another great pioneer, Dr. Vikram Sarabhai. On one occasion, Sarabhai said "The question is not whether India can afford to spend money for space research, the question is whether India can afford *not* to spend money for it!"

The first Indian satellite was launched in 1975 (Aryabhata). This was followed by several other successful launches (Bhaskara, INSAT series, Rohini, IRS series etc). As regards launching vehicles, we have success stories about SLV,ASLV and PSLV. Soon we would have our GSLV. The ISRO and its various centres (VSSC at Thiruvananthapuram, the centres art Sri Harikota, Bangalore, Hassan, Ahmedabad etc.), have all done us proud.

Defence research

Our Defence Research and Development Organization (DRDO) has made giant strides under the able leadership of Dr. A.P.J. Abdul Kalam [4]. We are fast progressing in Missile Technology and have developed missiles like Agni, Prithvi, Akash, Nag , Trisul etc.

Petroleum

After striking oil in Assam in 1860, our oil exploration has gone a long way, and we have struck oil in Bombay High, Krishna-Godavari basin, Tripura, Arunachal, Rajastan etc. The petroleum production has increased from a mere 0.25 million tons in 1947 to 3o million tons in 1997.

This amounts to a saving of Rupees Ten Thousand crores!

Green, White and Blue Revolutions

Thanks to the Green Revolution efforts, pioneered by Dr. M.S.Swaminathan, we are now self-sufficient in food grains. Let us remember that, even as late as 1960, we had depended on food grain imports (Remember the PL 480 days!). We now produce enough food grains for our nearly 1000 million people. This is no mean achievement, by any yardstick!

Similarly, the white revolution, stewarded by the genius of Dr. Varghese Kurien, has now made India a land of milk (and honey!). A Blue Revolution is under way to exploit our vast oceanic resources, especially fisheries wealth, with our long coastline and our tropical oceans.

Pure and applied research

India now boasts of having the third largest reservoir of trained S & T personnel in the world. Some of our Universities have made their mark in the global research scenario by the quality and quantity of our research output. Our Indian Institutes of Technology (IITs) and the IISc in Bangalore count among the reputed research institutions of the world.

The CSIR, fathered by Dr. S.S.Bhatnagar, now has more than 42 national/ regional laboratories under its umbrella. The ICAR, ICMR and other Councils also have extensive network of research centres all over India

Factories, irrigation, power

Independence saw a blossoming in the Indian industrial scene. Once again, we owe a lot to the vision of our first Prime Minister Nehru for his. He actively encouraged industry and technology and science. The Hindustan Steels at Bhilai, Durgapur, etc, were his pet projects. Although the HAL at Bangalore had been established before independence, its phenomenal growth took place only after India became a free country. Other great industries such as HMTs, BHEL, ITI. BEL, HLL, FACT, Oil Refineries, Locomotive factories, etc have all come of age.

The hydroelectric and irrigation

projects such as Bhakra-Nangal, DVC , Nagarjunasagar etc have all contributed immensely to the welfare of the people. Not for nothing did Nehru call factories and dams "the new temples of India"!

Telephones, radio, television, communication, computers

India now has a really vast telephone network, thanks to dynamic leaders like Dr.Sam Pitroda. Radio and television net work has reached even remote villages. Let me quote Pitroda here:

"It is not wealth that creates technology; it is technology that creates wealth!'

Indeed! Let us try to understand the full implications of this inspired opinion!

Computers have become ubiquitous now. The PC will soon become as familiar a household thing as theTV. When the developed countries wanted to put obstacles in the way of our technological achievements, we developed our own supercomputers like *Param, Anurag, Flosolver* etc.

Transport

We have one of the biggest railway networks in the world. Our factories like Chitaranjan Locomotives, Integral Coach Factory etc have made us self-sufficient in this area. We are an aerospace power too. The various factories under the umbrella of HAL make a variety of planes and helicopters.. The recent achievements include Light Combat Aircraft (LCA), Advanced Light Helicopter(ALH) etc.

Criteria of success

Here are other criteria of success too. Let us compile a list of the essential items and consumer items which India had to import in 1947 and compare it with an updated list of 1998. We find that most of the items are now made in India itself. Compare this with the plight of several African countries, which even after years of freedom from their colonial yokes, still import items such as match boxes, postage stamps and distilled water!

In the early years after independence, we used to import foodgrains. Now we are the seventh largest exporter of food grains to the needy world!

And let us not forget that we have the third largest reservoir of trained S & T personnel in the world. [Critics might say, what about the quality? Yes, that is a relevant question. But history says that quantity will eventually lead to quality.]

Is it then Roses, Roses, all the way?

Alas! It is not! We have had our failures, our deficiencies. Some of our major weak points are:

- We did not pay enough attention to he environment, in our enthusiastic pursuit for development.

Luckily, a new awareness of the urgent need to protect and preserve our precious environment has now pervaded all strata of society. Let us hope then, that this lacuna will soon be taken care of.

- Our power sector has to develop further. We have to tap renewable and ecofriendly energy to the maximum.
- Have we succeeded to reach the benefits of S & T to the common man? Certainly, much more attention and dedication is called for here.
- We still have the tendency to give undue respect to the foreign scientist! The "white skin" complex still lingers in our collective psyche! We have to exorcise this!

Summing up, I would say that our achievements are not poor, by any standard. We have not done badly indeed. However, much more could have been done; it should have been done much faster too! But our signal achievements in some selected highly specific areas (such as space, atomic energy, food sector and communication) show that, if we set our targets properly and clearly, and if we choose the leaders of S& T judiciously, based on their merit and competence and sense of dedication, and if we then give them freedom of action in congenial ambience, then, we can achieve anything! We live in the age of S & T. Progress can now come only through S & T.

Let us hope that India will soon be a great S & T power in the world. Only then can our country be that "heaven of freedom" dreamed by Tagore, "where the mind is without fear and where the head is held high"!

Notes:

(1).It is interesting to recall an anecdote here. During a cocktail dinner, an English professor(— who had had a fair share of drinks—) wanted to dress down a newly arrived visiting professor from India. He said: " You Indians now think you are a great scientific nation. But remember, we ruled you for 200 years!"

The unruffled Indian professor kept his cool and said pleasantly: " You are right. The British ruled India for about 200 years. But , if I remember my British history correctly, the Romans ruled you for 500 years!". Everybody laughed. Another English professor confided in the ears of the Indian: " Served him right!"

(2). An international group was discussing ancient Mathematics. There were Frenchmen, Arabs, Indians and Russians in the group. When an Indian professor said that the Arabic numerals were really invented by Indians, an Arab professor said: " Of course!. But why do you Indians still call them Arabic numerals? We in Iraq, call them "Raqm al-Hind" , i.e, Hindu numerals!"

(3) At an international symposium, during a recess, there was the usual " small talk". A Western scientist said: " Isn't it a pity that India, with its big problems of poverty and unemployment wastes time and energy and resources to embark upon projects like atomic energy and space? Leave it to the developed countries and you concentrate on traditional areas of science only.". Hearing this harangue an Indian professor said:. " Shall I pose a question for your consideration?. Suppose writers in a language decide that they shall confine their activity to novels and short stories only and discourage and neglect poetry and drama. What kind of literature will they have?". The westerner: " Well, literature is an integral thing. You cannot compartmentalize it!".

The Indian: " Science too is an integral thing!" The westerner (grudgingly): " You do have a point there."

(4) Dr. Abdul Kalam is now (2004) the President of India. His book, " India 2020—Vision for the new millennium" must be compulsory reading for every patriotic Indian. In it, Dr. Kalam gives us a roadmap to development. ■