THE STATE OF INDIAN SCIENCE

Today we observe National Science Day, commemorating what is perhaps the greatest scientific event that has occurred in India in this century: namely the discovery of the Raman effect. Working with simple equipment but great skill, imagination and dedication, Raman could establish, on 28 February 1928, that there was a "new radiation", as he called it in his lecture at Bangalore two weeks later. The anniversary of this discovery seems an appropriate occasion on which to reflect on the state of Indian science, as I have been asked to do.

A great deal has changed in the seven decades since Raman made his discovery. An independent India laid much greater stress on science and technology than the imperial government had ever done, and a rapid expansion in the number of scientific institutions and of scientific personnel took place in the first 25 years of the new republic. Some of the more egregious difficulties encountered by Raman, such as having to dip into his own pockets to support his students or for buying equipment, seem mercifully in the past. On the other hand, science elsewhere in the world has also changed dramatically since the Second World War. A well-known American scholar, Prof Philip Altbach, has pointed out how centralized world science has become today: its complex and expensive infrastructures are located in a small number of industrialized countries - and, within each of them, in a similarly small number of universities and national laboratories. To break into the "world knowledge system", as he calls it, and to become a major player there, calls for an investment that is so enormous that he thought even India and China would find it difficult to afford it for some time to come at least.

So are we back to square one 50 years after independence? To answer this question, let us first see what today are the most prominent features of the Indian scene.

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In attempting this task I shall look at science, engineering and technology all together - not because they are all the same - they are not - but because they are inextricably inter-connected, in the public mind as in an ambitious nation's agenda.

Perhaps the most remarkable development in the last five years is the emergence of the software services business as a major creator of wealth, vying with leather, jewellery and such other traditional products as a major item of export from India. At the recent meeting in Davos, Bill Gates - chief of Microsoft and the world's richest man - is reported to have asked the Prime Minister why Bangalore produced the world's finest software engineers. A distinguished British scientist visiting me two months ago called Bangalore "the engine-room of the international software industry". Although there may be some exaggeration in these assessments, and we are really providing *services* rather than our own software products or packages, what is striking is that in an area of technology that is so current the products of our better educational institutions seem to be able to hold their own. And this growth of Indian strength in a sector of information technology is highly decentralised; it has occurred without a deep or direct involvement of the government, and appears to have a dynamics of its own.

The other development that is remarkable is the emergence of Indian space technology at the international market place. We can now launch our own one-tonne class satellites on our own launch vehicles from our own launch-pads - and should be able to launch even bigger satellites before long. Indian satellites are some of the best in the world, and their high-resolution imagery is in demand in many advanced countries. *Aviation Week & Space Technology*, perhaps the most widely read technical magazine in the field, recently lauded India's space successes, achieved on what it called a "shoe-string budget". Other international journals have expressed similar views. There is no doubt that the country's space programme presents a most remarkable example of advanced technology development in the public sector. And wherever the much-maligned public sector has invested in technology development, it seems actually to be faring quite well, while much of the private sector keeps grumbling about the dangers of the recent globalization programmes supported by the Government.

In contrast to the software business, space technology has been a strongly directed programme, with the deep involvement of the Union government; its carefully crafted plans have obtained sustained public support for over three decades.

There are other areas like chemical technology that have also done well. But the two examples I have quoted should convince us that there are methods by which India can use technology development for the creation of wealth - whether in the public or in the private sector.

In the basic sciences, the best Indian scientists are highly respected all over the world. This is all the more remarkable because so much of the finest Indian talent has migrated abroad (and continues to do so), seeking a prosperity and patronage that it cannot find at home. From one point of view it is surprising that as many committed scientists and engineers remain here as they do, and, what is more, that the best of them are doing so well against all the odds that their friends and colleagues who have fled overseas find so irksome. Indeed, even with this exodus, it is striking that more Indian scientists working in India have been elected to prestigious foreign academies than Indians working abroad.

It is therefore clear beyond doubt that India's intellectual resources are very considerable, and we may confidently assume that they are second to none in the world. Indeed a strong case can be made for the proposition that the only areas in which India is internationally competitive are all *intellectual*: the best of our human resources and their intellectual products, in science, engineering and the arts and letters, stand out anywhere in the world, unlike any artefact made by any Indian industry. This incidentally shows up the large gap between intellect and artefact - between hardware and software - in India (the remarkable thing about Indian space technology being that this is one field in which the gap might have begun to be closed).

But we must admit that Indian S&T as a whole is not yet a force to reckon with in the world: we account for no more than the odd entry in foreign data bases, and a few respected papers or interesting footnotes in their journals. The big question therefore is this: how is it that we have done so well in some fields but so poorly in most? how is it that some scientists - like Raman - have brought such credit to the country, but, collectively, we are still a minor force on the periphery of the "world knowledge system" I mentioned earlier?

There is in fact a widely expressed sense of unease about the state of Indian science today. Indeed, a favourite pastime, within the community of scientists as well as outside, is to debate "what ails Indian science" - as most of the debaters put it. There are many reasons for this unease, but the one most frequently proffered is that, with whatever investment we have made in S&T today, the so-called "common man" has not seen visible benefits. This perception must be questioned. At the least, the country has abolished famines, and our people are certainly better fed and clothed now than they ever were during the British raj. Nevertheless, innumerable problems remain: there is never enough power or water, plague and cholera keep breaking out every now and then, our cities are becoming highly polluted, and so on. If there is any improvement here, the pace of change is clearly too slow to catch the public imagination. And science and technology appear to get blamed for this state of affairs. Perhaps scientists have not given enough attention to these problems, and have erred in propagating the notion that, given enough support, they will solve *any* problem; the sociological and administrative limits to change have certainly not been sufficiently appreciated. Surely many problems have not been solved because there is no political will to do so (for where the will is evident solutions *have* been found, as e.g. in food production and missile technology). Perhaps the many problems that scientists often offer or undertake to solve are more easily and naturally tackled through changes in *economic* policy.

Whatever the reasons, these feelings of unease are fed by the perception that huge investments have been made in science and that they have not paid off. But what *is* the Indian investment in science? The truth is that our annual S&T budget is about US $ 1.5 billion in all fields put together (including space, defence, agriculture etc.), which is less than that of single major industries in the west, and is e.g. typical of development costs for a *single* new aircraft type at Boeing. Our investments are low not only in absolute terms (in rupees or dollars), but even in relation to our own (rather low) gross national product. Thus, the fraction of g.n.p. invested in Indian S&T now stands at less than 1% and is *declining*. Here we are not only behind the advanced nations (who put in 2.5-3%), but even our neighbours like China (1.5%) and Korea (2.0%). Other countries wonder how we can run our space programme on only $ 300 million a year! Foreign visitors are often puzzled how *any* good science gets done at all in India, when not even power and water can be taken for granted. Certainly, from a global view-point, the investment in science in India is minuscule. So what successes we have had suggest that good Indian science is inexpensive - and I predict that more and more foreign businesses will realize it and begin to get their R&D done here - that is, if we have not killed or disabled Indian science before then by starving it.

Any argument for greater investment is often countered by the doubt whether Indian science can "absorb" any more money now, assuming it were available. The sceptics ask what the chances are that society can reap any benefit from greater support. We must admit that money by itself cannot make our S&T more effective, and many other changes will be needed. Among these I would list: a wider national commitment to *both* equity *and* excellence, a less bureaucratic approach to sponsoring science, a greater appreciation of daring and innovative projects, quick support to young scientists of promise, a closer involvement of private wealth and non-governmental support, and more handsome rewards to successful scientists and technologists. In fact, we badly need an internal liberalization of S&T, like the one being attempted (however haltingly) in economics - but one which keeps overall national and social interests uppermost in mind.

The most striking proof of the need for such changes is that we still keep losing such a large fraction of our most valuable human resources: the vast majority of bright young Indians hanker after the prosperity and patronage that the West offers them. Clearly such large scale import of talent by the West has taken place only because of its economic value to *them;* why are *we* not in a position to exploit the same talent? Talent has always been mobile, and has become dramatically more so with the spectacular development of information technology and aviation; it will seek the environment it feels most wanted in. Till now we have managed with those scientists who have decided to remain in the country; the best of such people, in my view, are among the true unsung heros of our land. But is it prudent to depend so much on such heroism?

So, if I may summarise, the state of science in India today is that (a) our intellectual resources are world class (as Raman always realized), but (b) we are unable to encourage, support and manage them well enough for national profit. My own unease about the state of Indian science is not that it has not delivered - for the pittance it has got it has done quite well. Rather, the unease stems from the fear that lack of appreciation of the enormous potential of Indian science, and lack of imaginative skill in managing it for national development, may condemn the country permanently into the fringes of the world knowledge system. And by the word "management" I mean not only the way that a scientific institution harnesses the skills, capabilities and resources in its possession, but macro-management at the national level that sets up appropriate goals and reward systems. It is not widely realized that knowledge creation is a surprisingly fragile enterprise. And science is in fact a rather delicate plant that will wilt with alarming speed on signs of mismanagement or neglect - witness what happened in Germany after Hitler, or in the former Soviet Union as it started to break up.

I submit that what we do now depends on our vision of the future for India. And, as a society, we appear to be confused by two competing candidates for that vision vying for our minds and hearts. One vision is of an India that prefers to be left alone, that is self-sufficient, that is content with what little it has, that will maintain - with such minor modifications as may be forced upon it at various times, by internal or external pressures - the kind of social equilibrium that has been so carefully crafted over the last millennium. This cautious vision has a certain attraction for many thinking minds in the country. One major and compelling difficulty with it is that we will never be left alone, even if we wish to be, and even if we were willing to leave the others alone: surely that is the lesson from our history of the last thousand years (if not longer)?

The other vision is of an India that is strong, prosperous, healthy, creative, out-going - and a major force in the world - for good, we should hope; and caring, we should also hope. If our vision is the first, then we should be content with business as usual, with minor increments now and then; and we will never break into the "world knowledge system". But if our vision is the latter - as I submit it must be - and we wish to get out of the present rut to a higher equilibrium, then clearly we are doing far too little for science - not just in terms of money, but attention, analysis and integration into our national agenda. We have about 150 scientists and engineers per million in our country. South Korea has ten times as many, and Japan 30 times. If we go back to the millennium *before* the one that is shortly going to end, to an age when Indian science could boast of such names as Aryabhatta, Bhaskara, Caraka and so forth, and was greatly respected all over the world - when the Arab historian of science Said al-Andalusi called India "the premier nation among those that cultivate science" - there is no doubt that we should opt for the second vision. Anything less would be a betrayal of our heritage.

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