

CMS Communication Colloquium National Lecture

**The New Millennium Challenges for
Indian Science and Technology**

by

**Dr. R.A. Mashelkar
Director General
Council of Scientific and Industrial Research
New Delhi – 110 001**

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**Centre for Media Studies
New Delhi**

I consider it to be a special privilege and a great honour that the Centre for Media Studies deemed it appropriate to invite me to deliver this prestigious National Lecture under the CMS Communication Colloquium Series on Challenges and Opportunities of the New Millennium. I am grateful for this invitation and accept it with great humility and pride.

We await the dawn of the next millennium with excitement and anticipation. Around the world today, there is a discussion and debate on designing the future of societies and nations in the new context that is going to emerge. However, dreaming about the next few centuries ahead of us is a very difficult task; indeed an impossible one. As you know, the knowledge is doubling in approximately 10 years now. The ability to speculate on the future is more difficult now than ever before. Even when the pace of change was nowhere near, what it is today, the forecasts made by some of the brightest minds went so wrong.

Let me recall one such effort. In 1937, the American National Academy of Science organized a study aimed at predicting breakthroughs of the future. Several wise statements about agriculture, synthetic rubber etc. were made. They were essentially based on an imaginative extrapolation of the present. But it missed all the things that happened. It was amusing that in their predication, there was no mention of nuclear energy, no antibiotic (although it was just 8 years after Fleming), no jet aircraft, no rocketry, nor any use of space! And these are precisely the technologies that have dominated our lives in the last few decades.

Forecasting always is a hazardous task and how often have people gone wrong in forecasting. Let us look at some of the nineteenth century predictions. 'Heavier than air flying machines are impossible' said Lord Kelvin, the President of Royal Society in 1895. Airlinkage is the lifeline of global connectivity today. Sometimes, leaders can be limited by the vision. 'Everything that can be invented has been invented' said Charles Duell,

Commissioner of the US Office of Patent in 1899. After this statement, around forty million patents have been filed!

That was the nineteenth century. Did our ability to forecast improve in the twentieth century? I am afraid it did not. 'I think there is no world market for many be more than 5 computers' said Thomas Watson, Chairman of IBM in 1943. I need not comment on this. 'There is no reason anyone would want a computer in their home' said Ken Olson, President of DEC, 1977. We can see how personal computers have dominated our life. '640K ought to be enough computer memory for anyone'. Said someone in 1981. And how wrong he was as we move from kilobytes to megabytes to gigabytes to terrabytes. Did you know, who said this? It was Mr. Bill Gates.

This long preamble is just to emphasize the point that to really think of the problems of the next millenium is a difficult task. With some sense of humility, and by seeing the embarrassment caused to some of the best minds of our time due to these failures that I have cited above, I would only like to focus on what could be the challenges in the early part of the next millennium; indeed, the early part of the new century. My emphasis will be, of course, on science and technology as a powerful instrument that will propel the future. The lecture is going to focus more on strategy, policy and the direction that S&T as an innovative problem solving tool in the early part of the next century rather than a comprehensive account of the areas that we need to focus on.

Looking back

Let me begin by looking back a little bit. As we look back, one finds that Indian gains in the post-independent India are sizeable. We have functioned as a nation in spite of the cultural, social, political, economic and religious diversities and integration of states. We have a vibrant democracy, an independent judiciary, and a diversified and widespread industry. We lacked

economic or military clout, yet we contributed significantly to the establishment of an equitable world order.

In spite of all that we have achieved, several formidable challenges remain: exploding population, widespread poverty, illiteracy, squalor, ruptures & cleavages based on region, religion, language and gender threatening the social fabric, urban congestion, wounded ecosystems, critical power and energy situation. Almost as many Indians are below the poverty line and illiterate as the entire population of India in 1950. Another dimension to the challenge has been added by globalization in terms of both economy and geopolitics. Never before in the history of mankind, did a country with democratic dispensation had to feed so many poor and teach so many illiterates and also simultaneously compete with the most advanced countries for a place under the sun. We enter the next millennium, therefore, with a great challenge.

In spite of the problems, we have all the pre-requisites to convert them into opportunities. For this, we need a fresh thinking. We need a new vision of India. This vision cannot merely be a derivative of the past. It has to be, of course, based on the reality of the present, but it has to have a boldness, ambition and hope, which is commensurate with the aspiration of this great nation. I am confident that Indian S&T can play a vital role in setting up the new vision and also making it happen.

Indian S&T in the past

One might ask, as to what gives us this confidence? The strong S&T base of India, in my judgement, gives us this confidence. We go back to the great architect of this base, namely, Pandit Jawaharlal Nehru. To Pandit Nehru, science was not only a tool for economic development but also a means of emancipation of man and qualitative transformation of a stagnant society. The 1958 science policy resolution reflected his own belief beautifully. "It is

an inherent obligation of a great country like India with its tradition of scholarship and original thinking, and its great cultural heritage, to participate fully in the march of science, which is probably mankind's greatest enterprise today".

It was this vision, which spurred the Indian scientists on. If we look back on our achievements, we can say with confidence that the Indian science and technology in the post-independent India has done us proud. Thanks to the '*green revolution*', India is able not only to feed its millions but has enough to spare and export. The '*white revolution*' has made India the largest milk producer in the world last year.

With a comprehensive defence R&D infrastructure, India is among the few countries of the world, which makes the most sophisticated weapons and weapons systems, including missiles of various descriptions and multi-barrel rocket systems. It has developed low-level tracking radar, night vision devices, and sophisticated ship sonar systems. An indigenous light combat and a remotely piloted vehicle are at an advanced stage of development. Today, India ranks among the few nations of the world that have a credible capability in space science and technology, including design and construction of satellites and launch vehicle technology. India's capability in nuclear science and technology including nuclear fast breeder reactors has been the result of indigenous efforts. The entire range of technologies from prospecting of raw materials to the design and construction of large nuclear reactors is now available on a self-reliant basis.

There have been other proud moments in Indian science and technology. We had path-breaking developments in parallel computing, breaking into the export market for supercomputers, and India has unveiled the new, PARAM 10000 supercomputer, with a capability of 100 Gigaflops (100,000,000,000 mathematical operations per second). The open frame architecture of C-DAC's PARAM 10000 places India in the League of Nations, which are

expanding the frontiers of supercomputing to teraflop range. Presently, only USA, Europe and Japan have such technological capability. Further, India has the status of a world leader in the development of software-based language translation, which finds application in pagers and computers for non-English speaking users. Our software exports are growing with over 50% annual compounded growth rate over the past few years and India has already unravelled the plans to become a software superpower.

In the industrial R&D sector, India has achieved success in some areas. The Indian pharmaceutical industry, which was practically non-existent at the time of independence, has emerged as one of the most competitive producers of therapeutics in the world. It has contributed greatly to improving the standards of healthcare in the country and making modern medicine available to the people at affordable price. India is a net exporter of pharmaceuticals, meeting more than three quarters of its requirements of bulk drugs and almost all its requirement of formulations. Agro-chemicals is yet another area of success for Indian S&T. The industry, which was predominantly dependent on imports till the early seventies, is today self-sufficient in all matters of technology and production, thanks to the contribution of the indigenous know-how. In the area of petroleum refining and petrochemicals, the country has made some impressive strides. In the area of industrial catalysis, India counts among the top few countries possessing world class capability for catalyst development and manufacture.

The Indian leather industry has been transformed from a mere exporter of raw hides and skins a few decades ago to a vibrant, modern industry that ranks among the top five export earners. R&D has contributed to the entire range of technical activities from leather processing technologies for curing, dehairing, tanning and finishing (all environmentally clean), to process automation and modernisation of tannery operations, and novel product design.

This is all a good news, but there is a plenty of bad news too. It must be acknowledged that Indian performance in industrial R&D is nowhere near its potential. Reverse engineering has dominated the scenario barring a few honourable exceptions. World class technology and products have been an exception rather than a rule. It must be admitted that industrial R&D strives and grows in a competitive environment. Such an environment is beginning to be created in the post-liberalisation era and therefore there is a hope that competition will evoke the innovative instinct of our industry and that will make the difference. A recent example of this is the auto industry, where we can proudly say that Tatas have introduced a world class product, namely Indica. Who knows, this may be the beginning of the revival of the technopreneurship in Indian industry!

The Way Ahead

Our policy on science and technology would have to be directed along five lines. The first priority will be to use the great powers of science and technology to meet the basic human needs particularly taking note of locale-specific situations; these would relate to food, health, water, energy, employment, shelter etc. The second would be to use science and technology to create wealth, both by enterprises as well as by individual Indian entrepreneurs. The third would be to embark on a major thrust in emerging knowledge based areas such as informatics, biotechnology, new and renewable energy sources, new materials and environment-related programmes. In all of these, India can make a major headway and surge ahead of the rest of the world and use this position to its advantage in the global technological scenario. The fourth relates to strategic areas, where for love or for money, technologies will not be available to us. This would involve nuclear energy, defence research and space science and technology. Fortunately, we have built self-reliance and enormous capabilities over the past few decades in all these areas.

What is our stock-in-trade? The world acknowledges the high calibre of Indian scientists, engineers and technologists. The obvious proof of this is the fact that while products of few other Indian enterprises command international prestige and price, the products of our higher educational institutions are in great demand internationally. The contribution of Indians to the growth of science and technology in developed countries has been widely appreciated. Can we not then garner all these energies and contribute to building the new India in a TEAM INDIA spirit? We certainly can. But for this to happen will also need to ensure that the finest minds, who seek to work on what excites them most, are provided with the environment and opportunity to pursue their interests with the fullest zeal. The government has the prime responsibility to create a great leveraging by using the large base of highly trained manpower created by its institutions of higher learning. The Indian hopes of the next millenium will have to be pinned on this rich resource.

New Strategies and Models

We might have succeeded in the past by following certain models, but the challenges ahead will mean developing new models. After all the context decides the content. The new context has to create a new content and therefore a new model. Let me illustrate this by taking 'green revolution' as an example. At a point of time in our history, we went to the western world with a begging bowl for food. Then came the green revolution. It was not merely the innovation by agricultural scientists. Innovative extension models, participation of farmers in the innovation movement and so on were responsible for its success. Indeed a positive policy support, liberal public funding for agricultural research and development and dedicated work of farmers contributed to its success. But what about the future? We have the daunting task of feeding almost 1.5 billion people with about 350 millions tons of foodgrains by 2040. The increased production has to be attained with minimal ecological damage, falling per capita arable land, less irrigation water and less fossil fuel based energy sources. This needs an innovative blending

of technology and experience. Here, on the one hand, we will need to deploy cutting-edge advances in modern biotechnology, space technology, information technology and renewable energy technology; on the other hand, we will need to take cognizance of the best in India's traditional agricultural wisdom and prudence.

Let me dwell on this a bit further. It is only through the blending of the "gene revolution" with our experience in the 'green revolution', that we can reach our goal of 'evergreen revolution' and also 'nutritional revolution'. The advantage of the gene revolution is that it is relatively scale neutral, and therefore, in principle, it should benefit the big and small farmers alike. It can also reduce a farmer's dependency on chemical inputs such as pesticides and fertilizers.

Sir Francis Bacon had once said: *"It would be an unsound fancy to expect that things which have never yet been done can be done except by methods which have never been tried"*. We therefore require a new approach, and modern biotechnology offers that approach. Indeed, modern biotechnology will offer great opportunity for enhancing genetic potential of crops and other commodities, management of biotic and abiotic stresses, bio-remediation, waste management and organic recycling. India is one of the main centres of agricultural biodiversity and its gene richness can greatly complement the developments in modern biotechnology. Likewise, new developments in GIS, remote sensing and crop modelling provide new opportunities for integrated management of natural resources.

The new challenge will be posed due to the fact that the people need to be taken into confidence, before some of the technologies can be used, since there are several concerns that need to be addressed. This was something that was not a central issue when the first 'green revolution' took place. There are concerns that because of its revolutionary nature, risk and uncertainty may be created by the process of genetic engineering and by the resulting genetically modified products.

First, there are several concerns about environmental safety. Will modified plants transfer their introduced genes into wild relatives growing nearby? Will modified plants that produce new compounds disrupt the *'balance of nature'* in some way? Will genetically modified plants be able to avoid the factors that regulate natural populations and thereby change the usual *'balance'* between populations? Similarly, there are concerns about the social and economic effects. How will the structure of farming (particularly in a country like India) be affected by biotechnology? Will plant breeding be left increasingly in the hands of a few companies, and if so, what effects might this have?

Then there is a set of ethical and moral issues that needs addressing. The consumer has the right. What will consumer be told about the new food products? Is it acceptable to *'interfere'* with nature through genetic engineering? Further, there are several regulatory issues. Will current regulations give sufficient protection: farmers; consumers; those who have invested in research; those engaged in research? Will current regulations compromise the competitiveness of biotechnology companies by being excessively restrictive?

It is clear that advances in technology alone will not help us reach the goal. If all these questions are not answered by involving the society as a whole in a transparent way, then there will be societal barriers impeding this innovation chain. That is one of the big challenges of the early part of the next millennium.

Taking Step Jumps in Ambition

Even in cases, where we have been successful, we will have to set new benchmarks, new targets and raise our ambitions. Let us take two examples, where Indian success has been acknowledged by the whole world; the first being the *'white revolution'* and the second being India's rapid forays into

global software market. These two are dramatically different, but the issue of raising the ambitions remains the same.

Let us take the 'white revolution' first. We have become the highest producers of milk displacing USA to the second position. This was due to the Operation Milk Flood. How did it take place? It was not simply the innovation in animal and dairy science and technology. Great visionary leadership provided by Dr. Kurien, a bold new model of NDDB, novel role of cooperatives etc. made it all possible. But again in the next challenge let us realize that India can beat anyone, when it comes to cumulative numbers. It is the per capita, it is the productivity, it is what we achieve per animal or per physical input per day, per man-hour, where we take a beating. So the next innovation chain in the white revolution will have to focus on this aspect. Also moving up the value chain will become crucial. For example, our exports of milk based value added products are miniscule (0.05% share of global trade), and the next innovation cycle will have to address this issue through innovative technological interventions..

We have a dream to make India a software superpower of the 21st century. A compounded annual growth of 55% in the last five years gives us a hope that we can reach \$50 billion export within the next ten years. But for all this to happen, we must move up the value chain. IT companies need to develop innovative and world class software products and not just rely on providing software services. Let us not forget that a tiny country like Israel has IT companies, whose market capitalization is around 60 billion dollars as against around 20 billion dollars of all of the Indian software companies put together; and this is inspite of the fact that the number of software professionals in India is several times higher. We will also have to convert handicaps into opportunities through innovative and daring approaches. For example, certain basic infrastructure is necessary for IT industry to boom. According to the experts, there is a golden opportunity to leap frog several generations of technology and go directly to the latest technologies. In 1980's France had

extremely backward telecom infrastructure. But they directly jumped to the latest technology. Doing this will, of course, require daring and vision and the IT task force set up by the Hon'ble Prime Minister, I am happy to say, has given such a mood and tone.

Environment and the Technological Challenge

In the characteristically integrative Indian tradition, equity, environment, ecology and economics will have to be viewed, not in isolation, but in tandem with each other. Environment will have to be viewed as a unique national asset in the next millennium. The study of the relationship between the land use and soil processes, mechanisms of global environment change, industry-environment interaction, prediction of our environment particularly with respect to human impact, will require innovative tools of science and technology.

There is a growing realisation in India that the sociocultural roots of our present environmental crisis lie in our failure to recognize the physical limits imposed by ecological systems on economic activity. The future economies must expand within ecosystems, which have limited regenerative capacities. In the new millennium, the old ideas of quantitative growth must give way to the idea of qualitative growth within the limits of the ecosystems.

The key question is how do we reconcile the developmental goals with ecological capabilities? The carrying capacity based planning processes, innovative technologies for enhanced material and energy effectivity of production and consumption, structural economic change towards less resource intensive sectors, and preventive environmental management through increasingly interventionist policies are some of the strategies for reconciling developmental goals with ecological capabilities.

Promotion of environmentally sound technologies warrants large scale technological substitution towards environmentally-benign technologies. Industry as well as R&D institutions will have to change their focus sharply to greener technologies of industrial production, recycle and reuse technologies for end-of-pipe treatment and integrated technologies that minimize cross-media transfer of pollutants thus minimizing overall pollution-induced risks in all environmental components. Emphasis on biotechnology for substitution of non-renewable with renewable resource base would move the chempresent to biofuture.

In general, there are three broad groups of resources upon which economic activity is based, viz. non-renewable resources, renewable resources and information. The sectors of economy that deal with non-renewable resources are environmentally the most problematic. Restructuring of the economy by substituting environmentally harmful endeavours with equally productive but environmentally compatible ones could form an important strategy in the economic policy. Developmental planning, henceforth, should aim at raising material and energy effectivity in production and consumption in order to minimize the expenses on environmental protection while keeping the cost of natural resource exploitation within acceptable limits.

We also need a change in our systems of valuation as well as value systems. For instance, we are well used to the conventional indicators of economic growth measured in terms of Gross National Product, Gross Domestic Product, etc. Should we not think in terms of new indicators such as Gross Natural Product or even Gross Ecological Product? Such indicators will not only themselves measure growth but be indicative of ecologically-sound structural changes in economy.

The industry will have to be rated on the basis of their performance in preserving and protecting the environment. The green rating project launched by the Centre for Science and Environment is a laudable approach. We need

to multiply such examples. Finally, what is crucial is that new and different decisions will have to be made in corporate boardrooms as also in national capitals. Such decisions will have to put the needs of the planets ahead of the profits of the corporation and its shareholders. The Chief Executive Officer of tomorrow will have to view himself as a Chief Environmental Officer in the new millennium. We need to generate a new breed of entrepreneurs, who will not merely be technopreneurs but also ecopreneurs.

Blending Indigenous Knowledge and Modern Science

Many societies in the developing world like India have nurtured and refined systems of knowledge of their own, relating to such diverse domains as geology, ecology, botany, agriculture, physiology and health. We are now seeing the emergence of terms such as 'parallel', 'indigenous' and 'civilizational' knowledge systems. Such knowledge systems are also expressions of other approaches to the acquisition and production of knowledge. They were, as yet, neglected by modern science, as the pharmaceutical industry has realized.

The growing dominance of a single view of the natural world as expounded by modern science will undermine these knowledge systems. Further, the process of globalization is threatening the appropriation of elements of this collective knowledge of societies into proprietary knowledge for the commercial profit of a few. These fragile knowledge systems need to be protected and enhanced through national policies and international legislation, while providing its development & proper use for the benefit of its holders.

In particular, a greater awareness about the cultural relationships between various knowledge systems needs to be created. A systematic and in-depth analysis of the parallelism of insights between indigenous and civilizational knowledge systems, on the one hand, and certain areas of modern science concerned with fundamental aspects, on the other will have to be launched.

In particular, a strong linkage between the indigenous knowledge holders and scientists will be needed in the new millennium to explore the relationship between different knowledge systems. Some of the greatest opportunities are provided, especially in the Indian context, in the area of traditional medicine.

Examples of this new partnership between these two domains of knowledge are gradually emerging in India. Let me cite a couple of examples. The first is a medicine that is based on the active ingredient in a plant, *Trichopus zeylanicus*, found in the tropical forests of southwestern India and collected by the Kani tribal people. Scientists at the Tropical Botanic Garden and Research Institute (TBGRI) in Kerala learned of the tonic, which is claimed to bolster the immune system and provide additional energy, while on a jungle expedition with the Kani in 1987. A few years later, they returned to collect the samples of the plant, known locally as arogyapacha, and began laboratory studies of its potency. These scientists then isolated and tested the ingredient and incorporated it into a compound, which they christened “Jeevani” – giver of life. The tonic is now being manufactured by a major Ayurvedic drug company in Kerala. In November 1995, an agreement was struck for the institute and the tribal community to share a license fee and 2% of net profits. The process marks perhaps the first time that cash benefits have gone directly to the source of the knowledge of traditional medicines and the original innovators. In the next millennium, we need to multiply such examples by millions.

It needs to be emphasised that “*Health for all by year 2000*” appears to be a dream that remains unfulfilled. India in the 21st century will be afflicted by not only the diseases of the industrialized nations but also the third world maladies such as tuberculosis and malaria. Health promotion and care will require a creative use of explosive advances in life sciences. A fundamental understanding of the disease at the genetic, molecular and cellular level will open up new vistas for curative, preventive and predictive medicines. Modern information and communication systems in health care will need to be used

for driving our dream of health for all in the 21st century. Thus modern science will have to be extensively used for creating healthy India of the next millennium. But our greatest opportunity lies in blending the new and the old, the traditional and the non-traditional, to create innovative preventive and curative systems. CSIR has launched a major inter-laboratory programme towards this purpose; but CSIR cannot do it alone. It has to become a TEAM INDIA effort.

Linking Innovation-enterprise-investment in communities

We need a particular focus on community knowledge and community innovation. To encourage communities, it is necessary to scout, support, spawn and scale up the green grass root innovation. It will generate employment on one hand and it will use natural resources sustainably through linking of innovation, enterprise and investment. This will again require building up adequate linkages with modern science and technology and market research institutions. One will need new innovative models of development, employment generation and conservation of natural resources.

CSIR is building such new innovation models by forging unusual local partnerships by reaching the unreached in the remote corners of India. A village called Athaoni, on the border of Maharashtra and Karnataka is the place from where Kolhapuri chappals come to us. They were till recently made by age-old traditional technique. Our scientists from CLRI studied this and helped them to reduce the processing time from 30 days to 10 days through application of some good science, the stamping process was standardized, certain innovative changes in design, based on computer aided techniques, were made to give more comfort to the wearer. But this was not a top down process. The oldest man in the village was consulted, he was convinced that the age old traditions must change. Today several hundred artisans have been trained by CLRI. This has not only enhanced the family incomes of the villagers but also changed their perception of science,

development and change – in short a micro social transformation. CSIR has realised that in this innovation chain, it is not techno-economics alone, but also the socio-economical and socio-cultural aspects that it needs to be conscious about.

One needs to build more organisations like Gujarat Grassroots Innovation Augmentation Network (GIAN). GIAN has attempted to set up venture capital fund for small innovation providing for its linkage with R&D and scaling it up into viable enterprise. The recent effort by DSIR and DST to set up a Technopreneurs Promotion Program is also noteworthy, since it provides the much needed financial support for the first time for individual innovators, be it an artisan, a farmer, or a school boy. Setting up of the National Innovation Fund, recently announced by our Hon'ble Finance Minister in his budget speech, is another step in the right direction, since it will help create a national register of innovation of these grass root innovators and will also help the process of taking these innovations further to the market place.

Creating a New Perspective on Intellectual Property Rights

Increasingly knowledge is being recognised as a source for wealth creation. However, in the new world, it is only proprietary knowledge that leads to wealth creation. In the world of knowledge based competition, Intellectual Property Rights will emerge as a key strategic tool. In this, India lags behind others and clearly the continued illiteracy in IPR domain will hurt us. Incorporating strong systems on generation of intellectual property, its capture, documentation, protection, evaluation and exploitation will need massive thrust.

Incorporating strong systems on generation of IPR, its capture, documentation, valuation, protection and its use will need a massive thrust in India now. While we are only discussing and debating, the rest of the world is

marching ahead relentlessly. I, therefore, wish to focus on this issue specifically.

The issue of patents in particular, has created a national interest and debate of great dimensions. I thought it might be useful to focus on this specific area. A weak physical infrastructure, inadequate intellectual infrastructure, poor public awareness and delays in framing and implementing government policies are hurting India today. We are behind the rest of the world in patents, both quantitatively and qualitatively partly because of our emphasis on imitative research and partly because of lack of awareness of the power of IPR in assuming a predominant position among institutions and enterprises.

Skills in filing, reading and exploiting patents will be most crucial in the years to come; but our ability to read or write patents is very poor. Neither can we properly protect our inventions nor can we understand the implications of the patents granted to our competitors. Manpower planning for IPR protection needs priority. IPR must be made a compulsory subject matter in the law courses in the universities in India. Our graduates coming out of engineering and technology streams have no idea about IPR, and yet it is these young people, who will have to fight these emerging wars in the knowledge markets. Judicious management of patent information will require well-structured functioning of information creating centres, information documenters and retrievers, information users, IPR specialists and information technology experts.

Before we protect IP, we must generate IP, which is worth protecting. Our institutions, national laboratories and industrial R&D laboratories will have to gear up for this. Nurturing a strong innovation base through a balanced system of recognition and rewards is the need of the hour. We will have to invest liberally to enhance the skills and knowledge base of scientists, through structured in-house and external professional training programmes, some even abroad, on understanding, interpreting and analysing the techno-legal

and business information contained in IP documents, and in drafting of IP documents. For this we need to avail the services of high-class national and foreign consultants and attorneys. We need to encourage the publication of R&D results in scientific papers only after careful consideration of the consequences on IP rights. It is hard to estimate the loss of Indian intellectual property due to the inadvertent publication of usable knowledge in the last few decades. Monitoring national and international patents and other IP through access to on-line databases, to ensure effective protection and to ward off infringements and threats to India's IP portfolio will be crucial. Analysing and assessing techno-legal and business information and market intelligence to identify strategic alliances and to exploit potential uncovered niche areas of opportunities itself will give rise to new knowledge based business.

India, with approximately 8% of world's biodiversity and as one of the greatest storehouses of traditional knowledge, has the potential of becoming a major player in the global trade in herbs-based formulations, medicines and products. An estimate by the EXIM Bank puts the international market of medicinal plants-related trade at US \$ 60 billion per year growing at about 7% annually. India has only 2.5% share of this market.

Many researchers who have obtained knowledge about biodiversity and its uses from local innovators, communities and institutions do not even acknowledge their contributions, let alone sharing of the benefits resulting from such knowledge. The local communities or individuals do not have the knowledge or the means to safeguard their property in a system, which has its origin in very different cultural values and attitudes. A policy that does not obstruct the advancement of knowledge, and provides for valid and sustainable uses and intellectual property protection with just benefit sharing is what we need. When we come up for reviewing TRIPS, we need to push for TRIPS plus, meaning TRIPS plus equity and ethics.

The industrial property systems were set up centuries ago for inanimate objects and that too in formal systems of innovations. As we move into the next millennium, we need to relook at these systems. Because we are now dealing with animate objects (such as plants and animals) and with informal systems of innovation (such as those by grass root innovators like farmers, artisans, tribes, fishermen and so on). The standard intellectual property system will certainly not suit such innovators and their innovations. We need innovation in the *intellectual property system* itself. Shorter duration patents for smaller innovations, including specific improvements in the traditional knowledge need to be conceived. They will involve simple registration-cum-petty patent system where the inventive threshold would be lower but even a small improvement in material, process, product or use could be protected at much lesser costs and for shorter duration. This will give a boost to the creative capabilities of otherwise deprived innovators. We, in India, will have to develop our own models for this.

Paradigm Shift in Industrial R&D

The year 1991 was a watershed in the economic history of India, since it signalled a paradigm shift towards integration of Indian economy with global economy with a sweeping set of reforms. This integration cannot, however, be complete unless we visualise the powerful role of S&T in this process. If this is done, then we will not be a hesitant nation, unsure of our place in the new global order, but a confident one, that is raring to go and find its rightful place in the comity of nations.

India has the image of producing and supporting low-technology products. This image needs a change. Aggressive international bench marking and innovative products and services with variations in features, styles, technology and consumer appeal requires urgent thrust. A strong export led Indian

economy can derive value only from technology led exports and export of technology.

In India, the partnership between the industry and our own R&D institutions has been very weak. Massive efforts need to be made to strengthen it, since, Indian R&D institutions could play an increasingly important role in the process of global competition, restructuring of the economy and in upgrading the local industry to gear it to face the international competition successfully.

A change of mind sets will be required all around. Our Indian industry will have to be champion R&D with a vigour. Apart from willingness to invest in R&D, the industry should be willing to take risks and should have patience to wait for returns.

The concept of partnership between the productive sector and R&D institutions will have to undergo a dramatic change from the current practice. Publicly funded R&D institutions should be used as *idea generators and providers of new concepts*. Indian industry should be prepared to assume the role of partners, who have the technical, financial and marketing strengths to take ideas to the market place. Industry should not simply look at institutions as super markets, where off the shelf technologies are sold. In the true spirit of partnership, the industry should willingly integrate national R&D resources into their business strategy. All this would be possible only when we can change the climate for an interaction between our institutions and the industry with an improved communication and understanding, faith in mutual growth and development of healthy working relationships.

Today there seems to be a difficulty in forging this partnership, because the institutions and the business units in industry have different cultures. The fact that science has to make an economic sense has not been realised by our institutions. On the other hand the fact that competitive advantage in business will be reached by using cutting edge science and engineering has

not been realised by our industry. There are basic incompatibilities, which need to be resolved. The institutions have a long-term horizon on R&D, whereas the business units have a short-term horizon. As regards the financial structure, R&D units are considered as cost centres whereas the business units would want them to be profit-making centres. As regards the products emerging from R&D laboratories, these invariably come out as some sort of packages containing knowledge and information, whereas the business units will have to convert these into goods and services, which are saleable. There is even a difference in the orientation between the institutions and the industry. The institutions work on the basis of scientific novelties and perceived needs, whereas the business units work on the basis of attractiveness in the market and potential for profit. There is a need for both the R&D institutions as well as the business units to change their culture. It is through this cultural change that we will build the new industrial R&D paradigm of the new millennium.

Renaissance of Indian Science

Basic science is an endless frontier, a uniquely human activity without limits. This pursuit is guided by the spirit of discovering truth and it is universal in outlook. The decline of Indian contribution to this endeavour, both qualitatively and quantitatively, is a matter of deep concern. To build a strong edifice of basic research, new mechanisms, including funding, will have to be set up.

The investment in as well as quality of the Indian basic research in the new millennium will have to undergo sea change. We will aim for world leadership at least in some areas. The new Indian science will be one that leads and not one that follows. It will be based on daring and creativity. Promoting curiosity based basic research with a new sense of adventure would be the Indian endeavour in the next millennium.

Realising science as a social movement and development of scientific temper as part of intellectual, emotional, social and cultural life of our masses demand not merely a governmental program but predominantly a program of action undertaken by leaders in different walks of life, peoples groups and non-governmental organisations.

One of the hallmarks of the Indian civilization from the very ancient times was to develop harmony with life and nature and to establish the infinite potential of human development. As a long term vision, India should lead the world in establishing and demonstrating the harmony between science and spirituality, in the development and application of science with ethics as the backbone. Scientific temper and true joy of science will be unfolded when the harmony between the science and the mankind's highest quest is achieved.

About Young Innovators

How do we create young scientists who will be ready to face the challenges of the early part of the new millennium? Do we have educational systems in place at all, which will be cater to the millennium challenge? I do not think so. India will have to remould the school science education radically, if we have to build the innovative India of our dreams. Science education will have to be based on the principles of 'learning' in contrast to the prevailing text-book centred '*learning by rote*' method. A child will have to become an active participant in the process of learning science through field studies, experiments, observation, recording, analysis and discussions. The prevailing discipline-centred approach must give way to a child-centred approach. Science curriculum must relate closely to science and technology experiences of everybody life.

We will have to take into account all the factors that effect the teaching process in the classroom and tackle all of them in an integrated manner. Thus, the total package is concerned not only with curricular innovation but

also with teacher training, kits to do experiments with, examination system, school administration, extra curricular inputs, etc. all of which have been suitably modified to form an innovative package. It is only then that we will be able to create the right environment in which a young scientific mind will be able to flower and express itself.

And Finally

We will need a bold national S&T policy, but more than that we need a national innovation policy. A strategy based on a national system of innovation includes S&T, but goes beyond that by seeking in addition to promote changing the ways in which society and economy do things. A bold and visionary *National Innovation Policy*, which invites a creative participation of every individual in nation building has to be launched. I have every hope that we can create the new India of the new millennium, which will not only reach its potential but surpass it.
