Sir Purshotamdas Thakurdas Memorial Lecture, 1999

Resurgence of Innovative India : The Challenge and The Strategy

By

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New Delhi – 110 001

16 July 1999

The Indian Institute of Bankers
Mumbai

I feel greatly honoured and privileged that I have been invited to deliver the 1999 Sir Purshotamdas Thakurdas Memorial Lecture. I wish to thank Dr. Bimal Jalan, Governor, Reserve Bank of India and the President of Indian Institute of Bankers for doing me this honour.

Sir P T, as he was fondly known, had enormous influence on the Indian financial sector. Famous for both the driving force and the restraining influence during the deliberations in the board room of the Reserve Bank of India, Sir P T was known for his exceptional courage and for his great commitment to the cause of India's prosperity and progress and I consider this as an opportunity to pay my own humble tribute to Sir P T, this great son of India. I accept this honour with great humility.

I feel truly overwhelmed when I look at the list of the most eminent economists who have delivered this prestigious lecture in the past. I am a scientist and not an economist. But surely there must be a purpose in Dr. Jalan's invitation. I can only link it to the ever increasing influence of science and technology on economic progress. Everyone today recognizes the great value of the linkage between science & commerce and therefore of the economics of knowledge. The emphasis has shifted from producing and processing merely physical resources to producing and processing information and knowledge for economic growth. Indeed, the traditional factors of production - land, labour and capital - are becoming less important when compared to technology; the economists have termed this as the *'expansion of the production factor'*. The source of technology is in science that is rooted in knowledge.

I spoke about the *'Economics of Knowledge',* when I was invited to deliver the 16th Dr. C.D. Deshmukh Memorial Lecture in Delhi early this year. I thought it would be logical to take further the theme that I had developed during the Deshmukh memorial lecture. It is rather unconventional to begin a memorial lecture by citing the end of another memorial lecture, but I thought I would do

it none the same. I quote from the concluding paragraphs of my Deshmukh Memorial Lecture.

"I believe the next century will belong to Asia. I believe India will have a chance to lead. I also believe India will be an economic power, mainly because of its great intellectual capital and its mastery over the theory and practice of economics of knowledge. I do really believe that the creative potential of millions of individual Indians will be unleashed from the bondages of self-inflicted mental sanctions. For too long we have talked about the potential of India. The latent potential energy of the creative Indians will be converted into creative and productive kinetic energy.

I believe many schools will flourish, where brilliant new theoretical frameworks for economics of knowledge of the 21st century will be developed and India will assume a conceptual leadership in this development. This brings us to an interesting thought. 1998 was a great year for India. Amartya Sen won the Nobel Prize in economics. His development of welfare economics combined economic theories with philosophy and ethics. If knowledge economics has to deal with the issues of growth and equity, then it will have to combine economics, science and technology, philosophy and ethics in the most creative and innovative way. Will an Indian win the Nobel Prize in knowledge economics? Why not? We certainly have the right to dream".

Innovation is the key for the production as well as processing of knowledge. Indeed a nation's ability to convert knowledge into wealth and social good through the process of innovation determines its future. I wish to focus on the challenge of the resurgence of an innovative India, since there has been a fear that for some time now, the 'I' in India has stood for imitation and inhibition and not for innovation.

The purpose of innovation is to create a new value for an individual, team or organisation, or for a society at large. New values could be in the form of breakthrough products or services, new strategies, new processes and new

methods for organisation. In this lecture, I will largely focus on S&T innovations, but by implication, lessons drawn from this could be widely applicable to other systems also.

S&T Innovation : The Changing Paths

In the pre-World War II scenario, the only driving force was the search for knowledge. No substantial government funding was available. Scientific research was done by a handful of small enterprises. There were very few industrial scientific research laboratories, very few industries that supported scientific research. Little interaction existed between academics and the industry. The post World War II scenario saw the parenthood of research change. On one hand the research was entirely driven by the search for new knowledge and on the other hand by economics, defence and health. The government became a major funder for research. The science-based industries, such as biotechnology and information technology grew. There was also a growth of industrial scientific research. You could walk into a Bell lab and see Nobel laureates. There was an intense industry-academia interaction.

Then came the post cold war era. The defence base for science started declining. Economic growth and health became the primary drivers for generation of new knowledge. Industrial basic research started vanishing. Innovation driven by defence spending and its subsequent diffusion into society through technology 'spin-offs' came in for a major revision in countries like the USA, where defence spending has led to investments in R&D. The same model was incorporated in some form or the other in many countries. But serious thought is beginning to be given to this model now.

Advances in knowledge during the post-cold war era also brought up new issues. Genetic engineering and the associated reproductive technologies on plants, animals and human brought forth ethical issues calling for greater regulation by involving social scientists and environmentalists. The process of globalization, privatization and corporatisation of research brought in a new

dimension. Issues of intellectual property rights (IPRs) and proprietary information began to assume importance. As a result, new models of the innovation chain and new paradigms of the science-society contracts began emerging.

Having set a global perspective, let us turn to the Indian innovation challenge now. India needs to view the innovation process in terms of both forward linkages and backward linkages. The forward linkages involve the technology innovation and production chain, with the consequent process of diffusion representing a further forward linkage. For India, equally important is the backward linkage in the innovation chain, which pertains to literacy, science education, public awareness, the mass media and the use of innovation in science itself to further these. I will deal with some of the challenges that we will face in this Indian innovation movement.

S&T Innovation

We can begin by focusing on the forward linkage first, namely that of the technology innovation. In a classical sense, we have three types of technology innovations. Firstly, there is a large system innovation (such as a man on the moon mission), incremental innovation (such as development of an improved fax machine) and finally radical breakthroughs (such as an accidental breakthrough leading to the antibiotic industry). These invariably take place in formal systems of innovation, namely universities, individual inventors, industrial R&D laboratories, etc. Often not recognised is the technology innovation that takes place in an informal system of innovation, be it by artisans, farmers and so on; the grass root innovators. I will deal with each one of these innovations in the Indian context.

Let us take the first one, large system innovation, like a man on the moon mission. John Kennedy dreamt of the man on the moon. His dream gave a challenge to the nation and the man on the moon mission emerged. It became a big innovation project with the challenge of integrating several technologies, people, systems, organisations etc. Such large system

innovations require large funding and complex management techniques. It requires the total commitment by the government and usually requires visionary leaders, who have a faith in the ability of their people. Innovative blending of different technologies, huge systems engineering problems, etc. are part of such innovations. In the Indian context, our strategic programs in space, defence and atomic energy represent such large system innovations.

India has done well in many large system innovations. Just take our space research program as a classic example. Satellite design, fabrication and launching have been mastered by our space scientists. Our space program has been one of the most cost-effective programs in the world. The entire budget of our space program last year was around a half a billion dollars, small when compared to a couple of billion dollars R&D budget of a leading US pharmaceutical company. The interesting feature of such innovations is that they have survived, succeeded and delivered in spite of the technology denial regimes. In fact in some cases, the innovation movement has been boosted due to a denial regime. Let us take India's forays into supercomputers as a classical example to draw some generic lessons about innovation in the face of denials.

Denial Driven Innovation

With their ever widening use, supercomputers are being increasingly regarded as a strategic resource. Supercomputers were denied to India in early eighties even when it wanted it for weather forecasting. India decided to enter this area by using the alternative route of parallel processing. India's journey from 1986 to 1999, shows the way indigenous innovation changes the control regime and vice versa.

CSIR's National Aerospace Laboratory at Bangalore developed the FLOSOLOVER Mk 1, which was the parallel computing product for computational fluid dynamics. It demonstrated its feasibility in 1986. This led Cray Research Inc. (US) to negotiate with India's Meteorological Department

on its safety requirements. The same Cray was reluctant to have a dialogue with India earlier.

In 1987, the major initiatives of creating the Centre for Development of Advanced Computation (C-DAC) in Pune was launched to develop an Indian supercomputer based on massively parallel processing based architecture. US, which was unwilling to give a supercomputer to India earlier responded by clearing Cray XMP 14, under restrictions in 1988. There were conditionalities on non-nuclear use as well as in-situ surveillance by US government officials of the strict observance of conditionalities.

In 1989, the efforts of C-DAC, DRDO, BARC, NAL to develop parallel processing supercomputers gained grounds and signs of success were visible. Later on, C-DAC demonstrated successfully PARAM-8000, a supercomputer with a peak computing power of 1000 M-Flops. In response, in 1990, the Los Alamos (Worlton) report concluded that supercomputers were not necessary to design the nuclear weapons.

In 1991-92, C-DAC exported its PARAM supercomputers to Canada, Germany and Russia, whereas others such as NAL's FLOSOLVER MkIII, DRDOs' PACE, etc. matched the capabilities of US made mid-range workstations. In December 1992, the US office of Naval Research sent an official to Bangalore conference to assess the Indian capabilities in super computing. In 1993, the US authorised the licensed conditional export of high performance computers to several Indian institutions.

In November 1994, C-DAC's PARAM 8000 was displayed at the super computing' 94 Exposition in Washington. It was also announced that a more advanced supercomputer machine with 10 G flops will be within our reach by the end of 1995, and that the export of such supercomputers from India to the developing countries was also possible. In the same year, in response, US diluted the export requirement on the high performance computers even further.

In April 1995, India placed parallel processing super computing on its list of items requiring an Indian export licence. In July 1995, US began to review its supercomputers export controls and in October 1995, US further relaxed in a marked way the export of computers to India.

In 1998, C-DAC launched PARAM 10,000 demonstrating India's capacity to build 100 Giga Flops machines, which was scalable further to teraflops, reaching the levels reached by advanced nations. In response, the United States further relaxed the export controls. During the same year, the same CRAY company decided to set up a subsidiary in India; interestingly the same company had denied the CRAY supercomputers in 1980s. Then came 11th May 1998, Pokhran II. In response, the US put a complete ban on several components including chips and a new saga begins!

What we see in this process of innovation chain is simply that an Indian innovation movement in supercomputers was able to force changes in the export control regimes. Our ability to receive the technology embedded in the supercomputers simply depended on our own technological preparedness.

There are some interesting generic lessons in this supercomputer saga. The first is that it requires a driving force for innovation, no matter how able and competent you are. When the idea of building supercomputers through parallel processing was gaining ground in 1985, Germany launched a DM 100 million project called 'Suprenum' and gave its scientists five years to build parallel processing based supercomputers. However, this project was abandoned mid way because of several reasons including team management issues between the university and industry; but clearly this was due to the fact that there was no driving force, since Germany had other options. India went ahead, because India did not have any options.

In fact, I remember reading Washington Post, soon after India had exported its PARAM 8000 to Germany, UK & Russia. It said 'Angry India Does It', that

is, India having been angered at the denial of supercomputers, developed its own. So this anger was the driving force for India and Germany had none, although they had a superior technical manpower to complete successfully the Suprenum project.

The other interesting aside is that in 1988, the Russians had made an offer of a supercomputer to India. However, the Indian team that visited Russia was not too impressed with the level of hardware etc. and finally India did not buy the supercomputers from Russia. So, India did not become dependent on the Russian technology. Russians themselves have now been importing the Indian supercomputers since early nineties. In fact, they are now negotiating a deal on the PARAM 10000 supercomputer, our latest.

The last issue is that we have a tendency to become relaxed, when the ban gets lifted or the export regulations become little lighter. For example, in 1991-93, when there was some relaxation from the United States, questions were being asked as to whether India should invest further in supercomputers at all. I remember a battle that was fought in Delhi, when we had to move from the first mission to the second mission; fortunately good sense prevailed, otherwise we could not have seen the birth of PARAM 10000!

When the sanctions again have come back after Prokhran-II, the importance of a sustained long-range innovation policy and continuous investment is being realized again.

Other Large System Innovations

The context decides the content and new innovation cycles need to be evolved as the context changes. Let us take an example of another large system innovation, where India has done well. Take the *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. The good news is that we have produced 204 million tonnes of food grains last year. The bad news is that we have already reached a plateau as can be seen from the data for the last few years. A new innovation model, therefore, now needs to be evolved. Let me explain the innovation challenge ahead.

We have the daunting task of feeding almost 1.5 billion with about 350 millions tons of foodgrains by 2040. Thus, an *evergreen* revolution is needed encompassing innovation in the total chain of harvesting, storage and processing. 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 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 cognisance of the best in India's traditional agricultural wisdom and prudence.

If we have to produce more from less, only new knowledge can do that. However, sometimes there can be societal barriers impeding the innovation chain. For example, advances in modern biotechnology are leading to genetically engineered crops. Such technology innovations are taking place all around the world, India being so exception. However, misunderstanding about the dangers of such technologies can stop the process of this new knowledge reaching the farm, the signs of which are already seen in India as judged by debates, which are sometimes not fully informed debates. Empowerment of the society with knowledge is, therefore, crucial for completing the innovation chain.

In some other successful innovations, we will have to set new targets and raise our ambitions. 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 breeding that brought about the white revolution. Great visionary leadership provided by Dr. Kurien, a bold new model of NDDB, novel role of cooperatives made it all possible. But again we have to get into a new innovation cycle as several challenges remain. 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, where we take a beating. So the next innovation chain will have to focus on this aspect, including innovations, which will add further value in the chain. Our exports of milk based value added products are miniscule, and the next innovation cycle will have to address this.

Incremental Innovation

The second kind of innovation is the incremental innovation, the *'nuts and bolts'* innovation, if you like. In the market place, there is a continuous influx of new products. They come in by continuous innovative efforts. Firms try to displace their own products with the fear that if they did not do it, their competitors will do it for them.

As far as India is concerned, in the protected regime of the past, there was no compulsion on producing innovative products nor was there a thrust on cost reduction or quality improvement through process innovation. But now there is a new market dynamics. Only superior products, not only in terms of quality but in terms of features, design, content, and service will sell. Therefore, continuous innovation will have to become a part of all our endeavours.

The short-term challenge for the Indian industry, as I see it, is going to be quality, productivity, cost, response time and innovation. In the long term, the challenges will be scale, technology upgradation, product design and finally strategic partnerships not only within India, but outside. Attitudinal changes and mindset changes will assume the greatest importance.

In the post-liberalisation era, there was an expectation that unlimited flow of technology will start. This has been belied. We must realise that the

technology acquisition game is becoming more and more complex, since India is no longer being considered as a bottomless pit of demand by the developed world any more. Technology buyers from India are being seen as potential competitors in the world market. Therefore, technology sales are being conditioned with marketing territory restrictions. The age of straightforward technology licensing agreement is also over. It is giving way to technology-cum-market, technology-cum-stakeholding, technology-cum-product swap, etc. Technology is available to an India buyer only if it fits in with the supplier's global scheme. If one compares the data in technology related payments during from 1993-94 to 1996-97, one sees a substantial increase in professional services ($95.8 million to $397.8 million), management fees and office expenses ($ 652.5 million to $7147.7 million) but an actual decline in technology fees ($ 603 million to $459 million).

The process of understanding technology involves design, process know-how, and parts fabrication assembly. When we acquired technology in the past few decades, we concentrated on being very skilled assemblers. The real issue is the mastery over process know-how and design. Then only can we master technology. It is an iterative process, full of learning and creative experience.

The entire chain of acquiring the know-how package, evaluating prevailing resources, formulating manufacturing methods, determining import content, accumulating engineering experience, commercializing the product, observing the product behaviour, working out the design modification process and finally using that experience to create new products, forms that real chain of innovation which involves both learning and doing. Had we pursued this innovation path with vigour, Indian industry would have been in a different position today.

The vast chain of national laboratories and institutions in India provide the Indian industry a great opportunity, since they are ideal innovation partners. To forge this partnership, a change of mindset of both the partners is required. Industry should use publicly funded R&D institutions as idea generators and providers of new concepts, and not as super markets where off-the-shelf

technologies are sold. Indian industry should be prepared to assume the role of innovation partners, who have the technical, financial and marketing strengths to take ideas to the market place. The Indian industry should willingly integrate national R&D resources into their business strategy. Improved communication and understanding, faith in mutual growth and development of healthy working relationships is necessary. There has to be a meeting ground between the long-term horizon of R&D institutions and the short-term horizon of business units.

My own CSIR, as a large publicly funded R&D system, is trying to make a cultural shift in its operations, by looking at research as a business, i.e. defining a new product and doing it in a business like manner, i.e. defining a new process. The transformation process has just begun and the initial indications and the response from industry are encouraging. CSIR hopes that it will become an effective hub in the Indian knowledge network and also an innovation partner with Indian industry in the long journey of mind to market place.

Radical Innovations

The third type of technology innovations arise due to radical breakthroughs. Radical in the sense that when these innovations happen, new industries come up that never existed before. They have the potential to change the society in a fundamental way. The jet engine, the stereo sound, xerox, instant photography, etc. are such breakthroughs. How do they come about? Many a times, they come about by serendipity. People call them lucky accidents. Many big industries, lke the chemical, plastic, and antibiotic industries, came about by accident.

Henry Perkins, for instance, was looking for synthetic quinine from coal tar and he accidentally came across a synthetic purple dye. This was the beginning of the modern chemical industry. Leo Bakeland was looking for synthetic shellac and he accidentally found Bakelite. That was the beginning

of the modern plastic industry. A gust of wind blowing over Alexander Fleming's moulds created the new antibiotic age.

As a proud Indian, it worries me as to why such a wind did not blow over the laboratories of Indian innovators. Why did we not get one breakthrough, which had the potential to lead to a Xerox or a Polaroid? Does this mean that those lucky accidents did not at all take place in India? Or if they did take place, were we equipped enough to spot them? What should not be forgotten is that a trained mind is required to spot these accidents. Eyes do not see what the mind does not know. Perhaps the kind of training and education that we receive puts an assured barrier to making such type of innovations happen in India. The issue is so important that I will come back to it again during the later part of my lecture.

Innovation in other domains of knowledge

We have so far focussed on S&T based knowledge and S&T based innovations. They all pertain to a specific form of knowledge domain, which is established through the rigorous methodology of science. In its rigorous form, such a scientific methodology includes observation, verification, repeatability, hypothesis-making, theorization and a formal and universally valid structure based on a minimum set of universal laws or principles.

But there is another domain of knowledge, which has remained unacknowledged. Many societies in the developing world 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.

It must be recognized that indigenous and civilization knowledge systems, which evolved in different civilizations, led to distinctive systems worldwide and effected the emergence of diverse systems of social structure and governance. 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. Hence, an urgent action is needed to protect these fragile knowledge systems through national policies and international legislation, while providing its development & proper use for the benefit of its holders.

Indigenous knowledge is a living cultural heritage. It transforms and adapts as it is transmitted from generation to generation. There is a need for greater awareness about the cultural relationships between various knowledge systems. Indigenous knowledge systems must be sustained through active support to the societies that are keepers of this knowledge, their ways of life, their languages; their social organization and the environments in which they live.

There is a clear need for 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. In particular, a strong linkage between the indigenous knowledge holders and scientists is needed to explore the relationship between different knowledge systems. For instance, there is a tremendous scope to develop eco-technologies based upon appropriate blends of traditional wisdom and modern science. 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 new innovation movement in India, we need to multiply such examples by thousands.

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 place called Athani, 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 standardised, 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.

IPR in the Innovation Chain

Incorporating strong systems on generation of IPR, its capture, documentation, valuation, protection and exploitation 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.

Our patent offices need modernisation. I recall here the great efforts of Dr. Jalan to move this process, when he was in Planning Commission to help us get the modernisation funds. I am afraid that after eighteen months; we have made little physical progress in the modernisation, thanks to several internal problems! We need to move and move with speed. A number of patent training institutes will have to be set up. China has already set up 5000 patent training institutes!

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.

Innovation in the IPR System

The industrial property systems were set up centuries ago for inanimate objects and that too in formal systems of innovations. A great challenge is now emerging to look at the systems that will deal with animate objects (such as plants and animals) and with informal systems 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.

Innovation Financing

The government has been the major financer of S&T based innovations in India, with around three fourths of the R&D expenditure coming from government funding. However, as India awakens the scientist in an entrepreneur and entrepreneur in a scientist, we will require significant funding sources for taking Indian innovations to the market place. Take, for instance, the drugs and pharmaceuticals industry. In the old patent regime, where we did not accept product patents, Indian industry could build itself by copying the molecules developed in the west, sometimes with innovative processes and sometimes with not so innovative processes. But with the product patents being accepted from 1.1.2005, Indian industry will lose this luxury of copying and it will have to get into the game of discovery of new molecules. In the current context, taking a single molecule to market place required ten to twelve years and around four to five hundred million dollars; which is approximately the size of our entire space research program, as I said earlier. Therefore, new sources of funding will have to be sought. Let

me focus on one of them in some detail by taking advantage of the fact that I have the privilege of speaking to the distinguished members of the Indian Institute of Bankers.

Let us focus on venture capital. In the west, it is specifically defined as equity linked investments in young privately held companies, where the investor is a financial intermediary, who is typically active in the firm. The venture capitalists provide equity investments in companies that are not mature enough to get access to capital market but have high growth potential to compensate for the concentrations inherent in such ventures. It is the availability of such a venture capital that has led to the spectacular growth of technology driven enterprises around the world. Indeed, Apple in computers or Genentech biomedical products would not have seen the light of the day, but for the availability of such venture capital.

There are both tangibles and intangibles in venture funding. One of the crucial sources of value provided by venture investors is their ability to certify companies to other investors. For instance, venture-backed firms are much more likely to attract the interest of a reputable investment banker and complete an initial public offering. Similarly, corporate business development groups are much more likely to invest in new firms backed by venture investors. Thus, the financing contributed by the venture investor is often relatively modest compared to the total amount that the venture-backed firm finally raises.

US has been a pioneer in venture capital. In the formal venture capital industry in the US dates back to the formation of the first fund, American Research and Development, in 1946. However, the flow of money into new venture funds for the next three decades never exceeded a few hundred million dollars annually. A dramatic change came with the 1979 amendment to the *'prudent man'* rule governing pension fund investments. Prior to 1979, the Employee Retirement Income Security Act (ERISA) limited pension funds from investing substantial amounts of money into venture capital or other

high-risk asset classes. The Department of Labor's clarification of the rule explicitly allowed pension managers to invest in high-risk assets, including venture capital. In 1978, when $424 million was invested in new venture capital funds, individuals accounted for the largest share (32 percent). Pension funds supplied just 15 per cent. Eight years later, when more than $4 billion was invested, pension funds accounted for more than half of all contributions, and this proportion has been growing over the years.

We know the way the venture capital has spurred innovation in the United States, but great results have been shown elsewhere also. For example, the Israel government initiated two programs to encourage the formation of venture capital funds in 1991, these increased from $29 million to over $550 million in 1997 due to a burst of investment by foreign high technology companies in Israeli R&D. We need a serious relook at the Indian situation and provide major incentives for venture financing.

The panel on knowledge based industries set up by the government has made several suggestions on venture capital financing, which require a detailed study and implementation. The suggestions include certain changes in the CBDT guidelines, creation of a proper regulatory framework for structuring the funds, especially a need for a tax efficient vehicle for setting up VC funds, allowing pension funds and insurance companies to invest in VC funds, permitting overseas funds freedom in exit valuation and repatriation without the intervention of RBI, especially replacing the requirement of prior approval from RBI with post-repatriation reporting, removing the concept of *'par value'* of share in knowledge based industries so that technopreneurs can fully avail themselves of the advantages of sweat equity. These and other such measures will require immediate attention of RBI, SEBI, the finance ministry and all of you to spur the growth of innovation in India.

Building Innovative Organisations

How do we build innovative firms, institutions and organisations? For this we will have to set up truly innovative and proactive mechanisms, that will drive innovation. There is so much to learn from the innovative firms around the world. Some firms set up goals that stretch your mind. For example, Du Pont has defined a set of *'unreachable goals'* like immortal polymers, zero waste processes, elastic coatings as hard as diamonds, elastomers as strong as steel, materials that repair themselves, chemical plants that are run by a single chip and coatings that change colour on demand. These may sound unrealistic but they are publicized widely and enthusiastically supported. Intel motivates its innovations by saying *"Double machine performance at every price point every year".* At 3M, which is one of the most innovative organisations, they do something interesting. When people come up with ideas that do not fit in with their divisions' business plan, they can apply for special grants to pursue their objectives. All technical people are allowed to invest 15% of their time pursuing their own ideas – beyond the assigned tasks.

Risk taking must become a part of the innovation policy of firms. Innovative institutions have no place for those who preserve the systems in a pre-fabricated and unaltered way. A friend of mine, who is a CEO of a company from abroad, once said 'we do not shoot people, who make mistakes. We shoot people who do not take risks. What do you do?' I said, 'In India, we shoot people, who take risks!' My banker friends here will know what I mean here. We need a change of mind set.

Just as scientists and technologists are risk averse so are in the institutional systems. One must seriously look at the scope of innovation in government institutions and laboratories, which are risk averse. In fact, it is more often than not that such institutions are run by rules and regulations than by objectives. The system of S&T audit in our laboratories needs an urgent relook. One must understand that manufacturing and S&T are two different endeavours, culturally and operationally. In manufacturing, we look for zero

defects and no failures, whereas in science, there is a fundamental right to fail. An interesting analysis has been done by Stephen and Burley in 1997 for Industrial Research Institute, which lists out the significant odds facing would be innovators by analyzing consistent data from new product development, potential activity and venture capital experience. It has been shown that there is a universal curve, which illustrates the number of substantial new product ideas surviving between each stage of the new product development process. It has been shown that out of 3000 raw ideas (hand written), 300 are submitted, which lead to around 125 small projects, further leading to 9 significant developments, 4 major developments, 1.7 launches and 1 success. Continuous assessment by shedding projects along the innovation chain is a rule rather than exception. In India, it is the other way around, since if they are abandoned at an intermediate pilot stage, there is a risk of the dreaded audit para!

It is worth recollecting my own personal experience in this connection. I remember that in 1996, we launched CSIR 2001: Vision and Strategy, which was a white paper giving a new dream, vision and an action plan to CSIR to make it a performance driven organisation. We took the bold steps of putting down in black and white, almost in a corporate style, quantitative targets that we wanted to reach in 2001 in terms of the industrial earnings, the number of patents, the earnings from export of knowledge, number of globally competitive technologies etc. that we wanted to develop. We had deliberately set up stretched goals for ourselves. Some good friends advised me that it is more than likely that you will fall short of these very high targets and since these are in concrete numbers, this again will be an excellent fodder for the audit. I went ahead and specified them in numbers none the same. It had the desired effect of the entire CSIR trying to meet these targets with a great deal of zeal and enthusiasm in a true *'Team CSIR'* spirit.

I remember after taking over CSIR, I started what was called as the *'New Idea Fund'*. What was my motivation? In science, only two people are remembered, those who say the first word or those who say the last word. In

Indian science, we have not done it often enough. Why? Because we have not taken risks and learned to dare, to stretch, to exceed the limits of the possible and that of the logical. My motivation was to challenge the CSIR. I invited the entire chain of laboratories to submit ideas, which had explosive creativity, and where the chance of success may be even one in thousand. During the last 4 years we have received over 300 new ideas but we have funded only 6 of them; we are so tough on our criteria on what constitutes explosive creativity. This initiative has spurred high level innovation in CSIR and even individual laboratories are setting up such funds now. However, when I first introduced this fund, I remember a well meaning friend mentioning to me that this is going to be an excellent fodder for audit, because by definition you are supporting failure rather than success! I must say that there is a fundamental cultural change that is required all around, if we are serious about building an innovative India.

Management of Innovation

India has a number of outstanding schools of management. Whereas they do an excellent job of providing graduates in management of business, finance, marketing, etc., there is no thrust on technology management – more importantly on knowledge management, and most importantly, on innovation management. Innovation management has to be brought to the centre stage in our management schools. What is so special about innovation management? Let me explain.

Innovation is the first reduction of an idea to a process that rarely can be planned and controlled with the kind of analytical certainty that the conventional manager associates with other operations. The process of innovation tends to advances in a bubbling way. It is intense and tumultuous. It is only the inspired and motivated people that can be innovative. The challenge before an innovator is converting inspiration into solutions and ideas into products.

True innovators are those who refuse to preserve status quo. They are those, who put in all their energy to make things happen. Their incentives are personal and emotional. They are not institutional and financial. They enjoy the fun of creation, the admiration received from them by their peers, and the excitement and glory of taking part in a total process of creation. Innovators are some times extremely intense. A great innovator like Carother, who developed world's first synthetic fiber nylon committed suicide. Diesel, who invented diesel engine, also committed suicide. Managing innovation means managing such creative and intense people.

One can clearly see the conflict between the standard management practices and good innovation management practices. Standard management practices are based on avoiding conflict, whereas innovators are bound to create conflict. The process of innovation brings in spontaneity and exceptionality. Standard management practice is based on how well a job has been done. Innovation leads to things that have never been done before. What kind of management do we need to have then, if that job has not been done before at all? Innovation management is not based on turn around strategy. It is based on turn around thinking.

With the emergence of innovation intensive knowledge industries, in particular, the management structures will have to change dramatically. Around the world, top management is always the grand strategist and decides on the allocation of resources, and the lower management merely implements and administrates the strategy. For sustaining innovation, the new management will create only an overarching purpose and an environment in which the people have the freedom to deliver. This means the emphasis will shift to defining the purpose of the organisation, setting the right process and getting the right people and empowering them to deliver. The shift is from the rigid strategy-structure-systems model to the purpose-process-people model in the new innovation strategy.

Leadership Issues in Innovation

Innovative leaders are necessarily dreamers. They must have the capacity to think of the impossible and motivate the people to do the impossible. Prediction of the future is, of course, a hazardous job and it is interesting to see as to how many times the leaders have made predictions that have gone completely wrong.

'I think there is no world market for may be more than 5 computers' said Thomas Watson, Chairman of IBM, 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. Even Mr. Bill Gates would certainly be happy to know that he was terribly wrong when he said in 1981 that *'640 K ought to be enough computer memory for anyone'*. We are moving from kilobytes to megabytes to terabytes and so on; and our demands are insatiable.

I believe we need to create a new set of leaders who are visionaries and thinkers, who believe in discontinuities, who are capable of thinking of the impossible and inspiring people to make it happen. After all, there is a definition of an innovator. They say innovator is one who sees what everyone else sees but thinks of what no one else thinks. Innovator is also one, who does not know that it cannot be done. An innovative leader sets stretched targets. The chairman of 3M said in 1993 that 25% of its sales would be based on 3M's innovation carried out during the last 5 years. He increased the challenge by changing this from 25% to 30% and 5 years to 4 years. It is clear that in innovative enterprises, our Indian Chief Executive Officers will have to assume the role of Chief Innovation Officers!

About Young Innovators

I have spoken so far about enhancing the forward linkages but not the backward linkages pertaining to literacy, science education, public awareness etc. I will like to focus only one burning issue that has to do with school science education. 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 must perceive Innovation as an integrated whole. An effective innovation 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.

Finally

I have emphasised so far on S&T based innovations but the concept of innovation is a much wider one. It is particularly important to recognise the need of social innovation. Innovation in India's social and economic institutions, in the system of their governance is as crucial as innovation in the products and production processes of its economy. We must also recognise that innovation cannot arise by itself; it is generated and sustained through the efforts of its people. The Government needs to create an environment, in which innovation flourishes. Otherwise the innovators will either play safe and not innovate, or they will leave to become a part of other innovative societies, which encourage innovation, as India has seen to its dismay; since a lot of its young sons and daughters have left, not due to the lure of the physical income alone, but because of the psychic income that they gain in those innovative societies. We must reverse this process with speed and urgency.

India was a leader in innovation several centuries ago. We have an opportunity to start the resurgence of an innovative India today. This will not only entail building new social, legal and economic structures that support innovation, but also making a national symbol of 'I' in 'India' to stand for 'Innovation'. I am convinced that just as we had launched a freedom movement, which freed us from the stronghold of foreign powers, we must launch an *'Indian Innovation Movement'* now, so that India can assume its rightful place in the comity of nations. And the time to do it is now, as the dawn of the next millennium approaches. Thank you.
