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Sir Rajendra Nath Mookerjee Memorial Lecture

A Compilation of Memorial Lectures presented in

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Background of

Sir Rajendra Nath Mookerjee Memorial Lecture

The Council of The Institution of Engineers (India) decided to institution an Annual Lecture in the name of Sir Rajendra Nath Mookerjee who was the first Indian President of the Institution to commemorate his contributions to the nation as an engineer and is delivered at the Annual Convention of the Institution, redesignated as Indian Engineering Congress. The first lecture was delivered at the Diamond Jubilee of the Institution in 1980.

Sir Rajendra Nath Mookerjee had the vision of an engineer and the comprehension of an intellectual. Born on June 23, 1854, he rose on the Indian scene in the 19th century and continued to serve the engineering profession and the country until the thirties of the 20th century. He died on May 15, 1936. The life story of Sir Rajendra Nath Mookerjee is the story of a great businessman, equally great of heart as of head, generous of instinct and charitable of soul, who brought glory to everything he touched.

Born in a typical middle-class family, Sir Rajendra Nath Mookerjee lost his father when he was six. Having matriculated from the London Missionary Society's Institution of Calcutta, he joined the engineering department of Presidency College, Calcutta. The satisfactory execution of the construction of Palta Water Works for the city of Calcutta gave him the confidence and experience that enable this self-made man in later life, to build an industrial colossus and a trading conglomerate. Sir Ranjendra Nath Mookerjee was the President of Science Congress in 1921 and in 1931. The Calcutta University conferred on him the honorary degree of Doctor of Science. He was the first President of The Institution of Engineers (India) during the session 1920-1921. He was knighted after his successful construction of the Victoria Memorial Building at Calcutta.

An abiding and deep interest of Sir Rajendra Nath Mookerjee in all kinds of social welfare work brought into being and sustained many a charitable institutions. Essentially a man of science, Sir Rajendra Nath practiced technology for the development of his country.

Sir Rajendra Nath Mookerjee Memorial Lectures

delivered during Annual Conventions & Indian Engineering Congresses

Science, Technology and Development

Shri S K Datta, *FIE*

INTRODUCTION

Having undertaken, at the behest of the IE(I), the task of delivering the first Sir Rajendranath Mookerjee Nemorial Lecture, I take, this occasion of your presence, to express my deep gratitude for the confidence which has been placed in me and to admit, in all sincerity, that indeed I have my own doubts whether I can be equal to the task. However, as a professional engineer myself, I was at the same time attracted by this opportunity of paying my respectful tributes toa person no less than Sir Rajendranath whose eminence and distinction in the profession of engineering knew no equals.

SIR RAJENDRANATH MOOKERJEE

Life is like a game of chess but infinitely more difficult and complicated than chess A Like chess this game has the board i.e. the world, the pieces, i.e. the phenomena of the world and the rules i.e. the laws of nature. One who plays ill is checkmated and to the man who plays well, the highest stakes are paid-recognition and fortune. Sir Rajendranath was a man who played well. He had the vision of an engineer and the comprehension of an intellectual. He rose on the Indian scene in the 19th Century (Born on 23.6.1854) and continued to serve the engineering profession and the country till the thirties of nur 20th Century (Died on 15.5.1936). His biographer (Mr. K.C. Mahindra) has recorded that Sir Rajendranath's ‘life story is the story of a great businessman, equally great of heart as of head, generous of instinct and charitable of soul, who brought glory to everything he touched’.

Born in a typical middle class Brahmin family, Sir Rajendranath lost his father when he was six. Having matriculated from The London Missionary Society's Institution at Bhowanipur, he joined the engineering Department of Presidency College. The satisfactory execution of the contract for construction work at Palta, gave him the confidence and the experience that enabled this self made man, in later life, to build an industrial colossus and a trading conglomerate. He was the President of Science Congress in 1921 and in 1931 the Calcutta University conferred on him the honorary degrees of Doctor of Science. He was the first President of this Institution of Engineers (India) and the Chairman of the Governing Body of B E College. He was knighted after his successful construction of Victoria Memorial.

Sir Rajendranath’s deep and abiding interest in all kinds of social welfare work brought into being and sustained many a charitable institution.

Essentially a man of science, Sir Rajendranath practised technology for the development of his country. I shall feel amply rewarded if I can place before you and share with you my thoughts on the interactions and the consequences of Science, Technology and Development.

SCIENCE (Universal)

The word Science comes from Latin SCIENTIA meaning 'to know'. The word Technology comes from Greek TECHNE meaning ‘art’. Science is a means of understapding the natural, environment. Technologyis a means of controlling and managing it. Born are essential tools for the efforts of achieving all round objectives. Science is universal. Its significance does not depend on clime or time. Boyle’s Law is true anywhere in the world and all the time. Whether in Greece, China or India, Newton's three laws will always hold good. The principle of transformation of energy from one form to another was upheld for obtaining industrial power in the last century. It is upheld in this century and will remain so in future unless fresh knowledge challenges it as in the case of the principle of conservation of matter which no longer holds good. But the principle of conservation of energy is still not disrupted although it has derived a new significance since convertibility of mattrer to energy was discovered by Einstein and represented by his formula $E = mC^2$.

The history of science is not the history of some sort of automatic development. The actual course which science has pursued, depends largely on the types of mind which, as historical accidents, happen to have arisen to the level of genius at favourable instants. Scientists are bot supermen, they are more intelligent than the average. Their minds work in the same way as other minds. Most scientific theories are based on analogy with know facts and careful experiments must be devised to see if these are correct.

The progress of science has been anything but uniform in time and place. Periods of rapid advance have alternated with periods of stagnation and even of decay. Babylonia, Egypt, India have all been the foci of ancient science.Greece became their common heir and there the rational basis for, modern science was first worked out. There was little place for science in Rome and none in barbarian Kingdoms of Western Europe. The heritage of Greece returned to the East from which it had come. In Syria, Persia and India, even in far away China, new breaths of science stirred and came together in a brilliant synthesis under the banner of Islam. It was from this source that science and techniques entered Medieval Europe. There, these underwent a development, which though slow at first, was to give rise to the great, outburst of creative activity which resulted in modern science (Scientist & Historian J.D. Bernal).

Hindu scientific ideas and methodology, we know, had deeply influenced the course of natural philosonhy in Asia - in the East - in China and Japan, as also in the Arab Empire - in the West, (Sir Brojendranath Seal). Perusal of Sir Brojendranath's "The Positive Sciences of the Ancient Hindus" in which he has made a brilliant exposition of Hindu concepts of atomic theories, differential calculus, theory of gravitation, chemical technology, sound end echo, blood circulatory system, heredity, influence of nutrition on sex etc is a rewarding exercise.

All scientific knowledge, however, being based on evidence which is formally incomplete, is only probable and never absolutely certain. All predictions based on scientific knowledge must, therefore, be fallible and must in fact prove wrong, in the long run, to the, anticipated extent (Prof P C Mahalanobis). In the whole field of science, the deductive - mathematical process of absolutely certain inference, has been gradually replaced by the probabilistic statistical method of uncertain inference. The long history of science and philosophy is in large measure the history of the progressive emancipation of men's minds from the theory of self evident truths and frnm the postulate of complete certainty as the mark of scientific knowledge (Ernest Nagel). Undoubtedly, however, science found its fulfilment in the growth of technology.

TECHNOLOGY (Instrumental)

'A technique' wrote J D Bernal, is an individually acquired and socially secured way of doing something, while a science is a way of understanding how to do it in order to do it better. The gap between understanding how something would work and making it actually work can be quite a substantial one, and some of the major problems of technological advance in developing countries seem to arise from difficulties in the translation of science, into technology. New technologies are invented only when there is an active search for such methods. New technologies may emerge in response to economic needs and active pursuit. In fact any one technology may not be like science, suitable in all places or at all times in a place. Transformation of energy from one form to another is a principle of science but whether for industrial power coal, gas, oil, water or atoms should be used is a matter solely depending on the need and the environment.

India differs from many other countries in that it had a flourishing technical tradition in the ancient and medieval periods. In the application of mathematics the names of Aryabhata and Bhaskara are familiar and pre-historic India's Rig Veda has records of measurements for war chariot. In medicine, Charaka and Susruta are well known. Others instance are Kalidasa's air-borne vehicle, existence of which is comprehened by Daniken in his book 'Chariot of Gods', Meghnad's air battle, war weapons like sataghni agniban; barun-ban, sabdavedi ban besides Brahmastra - perhaps a version of atom bomb. The early developments ranging from the tables of mathematical functions to the more concretely visible observatories built in later eras bear witness to India's ancient technical capabilities in astronomy. In astronomy the names of Baraha, Mihir and Kshana are well-known. In metallurgy, iron and steel have been known and made in India since antiquity. The rustproof iron Pillar near Kutab Minar has been a wonder. The use of metals in building construction, for making cannons and for making and coating household utensils were some of the other early developments in metallurgy. The development and utilisation of modern techniques in our country is, however, not an organic extension of the earlier traditions. There has been a break from the historical antecedents. Modern techniques in India are the growth of an implant by the British.

New technology can certainly be created by looking for it, but there also exists at any point of time a vast collection of already evolved techniques. A word on the problem of choice is relevant to the debate which has been currently going on, in this country, on 'appropriate technology'. The problem warns us, on the one hand, against taking technological possibilities as 'given' and against making development planning a choice out of a given 'menu' of alternative technologies. It also warns us, on the other hand, against the frequently held belief that appropriate technology would emerge if some research instituitions began to work in that direction, even if the institutions are remote from actual production. Technological progress cannot be viewed independently of actual production (Prof Amartya Sen).

The optimal choice of a technology should be related to its comparative efficiency. Prof Amartya Sen's example which you will now note is clear on what it means for a technology to be efficient. Suppose goods 0 are to be produced by using inputs I, through a combination of technologies A. Imagine now that by using another combination of technologies B one gets more of some outputs and no less of any other output and use sup no more of any input. This means that by shifting from A to B one gets something for nothing. If then B is available when one chooses A, one is being technically inefficient. One is technically inefficient also if some available combination C can produce no less of any output while using less of some inputs and no more of any other input. If there is no such superior technology compared to A, then A can be described as technically efflcient. Generally speaking a situation can be described as technically efficient if it is impossible, to move to an alternative such, that, the change yields something for nothing. Things are not of-course that easy — there are many other considerations to be made, when the choice of technology is a necessity for the purpose of resource allocation to increase employment. So far as output per man is concerned technology 'factor' is most important. In fact in American economy between 1909-1949, out put per man had doubled itself with 87.5% attributable to technology factor and the remaining 12.5% to increased use of Capital (Dr A. Bhatrtacharyya). Technology factor has many components of which an important one is technical education. Many in this country are, however, inclined to think in terms of increased capital only for increasing output.

Modern technology has a few characteristics which are not traditional. Mass production techhology meant large scale imports ahd exports. The ways of daily life, the carriages in which the people ride, the foods they eat, the clothes they wear, the nails that hold together their houses, the glass for their windows — all these and thousands of others have become more alike than these had ever been before. Broadcasting and television are perhaps the most potent witness to the converging powers of modern technology. When it comes to public events, now you are often more there when you are here, than when, you are there. Communication i.e. moving the message was once an inferior substitute for 'transportation i.e. moving the person but, today it is a preferred one. The advance of technology brings nations together and narrows the differences. Human experience for millions becomes more instantaneously similar than had ever been even imagined before. The momentum created by technology is irreversible. In recent years many countries (e.g. Germany and Greece) have gone from democracy to dictatorship and back to democracy; but we cannot go back and forth be tween kerosene lamp and the electric light. However, in this, country, destiny and or planners willing, we may have to go back to kerosene lamp for good.

The spin offs of space technology in most modern times are also numerous and important and benefit humanity in its everyday life in the form of instrumentation, computers, data handling systems, medical instruments etc. Perhaps one of the greatest dividends from space has peen the demonstration that equipment can be made absolutely reliable. Another unheralded spin off has been the development of a managerial group of people who are able to analyse and, handle complicated problems involving the bringing together of new technologies, of armies of specialists and of immensely complex test programmes — all for the accomplishment of a single goal.

One will be thus inclined to conclude that the blessings of technology are always positive and beneficial. One would think that increased longevity, decline of epidemics increase of industrial production growth of economy, abundance of household conveniences, reduction of discomforts, increase of leisure hours and so on as the results of technological advances do not offer us any dilemmas. Shall we be exhilarated by the achivements and be complacent that the prospects will carry us even beyend our current imagings on shall we have some sense of control ever our own destiny? This is a big question.

DEVELOPMENT (CONSEQUENTIAL)

Mankind has so far been so-much suceessful in maintaining economic development and social amelioration with the help of technology that one would normally expect that technological breakthroughs will go on and physical ceilings will grow indefinitely. But apprehensions are really otherwise. Population, food production, industrialisation besides pollution, depletion of natural resources etc are all increasing and are increasing in a pattern called exponential. An exponential pattern is to be distinguished from a linear, pattern; Linear pattern consists in an increase by a constant amount in a constant time. If a hoarder keeps in his iron safe Rs 5 lakhs every year his horarding follows a linear pattern. Exponential pattern of growth consists in inereases by a constant percentage of the increased whole at the end of a fixed time period. If one saves Rs 1000/- from one's salary and invests the same in the Bank at 7% interest per annum the invested money will grow comparatively much faster than the linearly increasing money in the hoarder's iron safe. In fact the money in the bank at 7% interest will double itself in 10 years. One may incidentally note that the doubling time is approximately equal to 70 divided by the growth rate and also that such exponential growth is a common process in biological, financial and many other systems of the world.

There is another pattern which may be called super exponential. In 1659 world population was 0.5 billion and the growth rate was 0.3% per annum. The doubling time was therefore 70/0.3 or 237 years (say). In 1970 population became 3.6 billion and growth rate was 2.1% per annum. So, the doubling time became 70/2.1 or 33 years (say). Thus not only has the population been growing exponentially, the growth rate has also been growing. The question is why.

In whichever area we consider – world population or world economy – its exponential growth is controlled by positive feedback and negative feedback effects. One example of exponential growth free from any feed-back is investment in a bank account where the rate of interest remains constant.

Exponential growth of population is affected by a positive feed-back i.e.fertility or fraction of population giving birth each year as also by a negative feed-back i.e., mortality or fraction of population dying each year. Interaction of changing positive and negative feed-backs changes the exponential growth rate of population.

Similarly world economic growth (7%) which has been at present higher than that (2%) of human population is also affected by positive and negative feed-backs. Positive feedback consists in ploughing back some variable fraction of industrial output. On the other hand capital (machines, buildings, tools, etc) wears out and is discarded, and this introduces a negative feed-back to the world economic system.

There are other factors like social stability, political peace, education etc which affect the actual growth of the economy and of the population. These factors are being ignored for the present.

Food or agriculture is also a major factor, which should be considered. The primary resource necessary for food production is arable land. The total available arable land will decrease as each addl-person born will also require a certain amount of land for housing, roads, etc. Even with the best of technological achievement in increasing land-productivity, the need of agricultural land will have an exponential growth along with the exponential growth of population. On the other hand the total availability of food producing land will suffer an exponential reduction owing to the reason already mentioned. The critical points are those where these two curves intersect.

Let us next consider natural resources, e.g., minerals and fuels. An exponential increase in the use of natural resources as a result of exponential growth of population, can very quickly diminish the fixed store of resources just as an ponential increase in land use can very quickly run up against the fixed amount of Land available.

For every item of natural resource, technological advancement may discover substitutes or introduce more efficient use but on the other hand as more and more of it is consumed with growth of population, its reducing stock will raise the cost of extraction and processing thereby growth of resource due to technological advances will run against a negative feed-back besides the negative feed-back also owing to exponential, growth of both population and capital. Computer calculations have determined that the net result is a sloping down curve.

One inevitable feature of m6dern technological advances is pollution. Total pollution control is not possible and the trend is a rising curve. If man's energy needs are someday — supplied by nuclear power (at present only 6% of total generation) instead — of fossil fuels, the increases in atmospheric CO_2 and SO_2 will eventually cease. Nuclear power, however, will produce another kind of pollutant i.e. radioactive wastes. The other point to be noted is that if the energy used, is anything (e.g. fossil fuels or atomic energy) other than solar energy, the heat will result in what is called thermal pollution which may have undesirable effects on the climate. A changeover to nuclear power will have also no effect on other kinds of pollution such as pollution from manufacturing process by-products, thermal pollution and pollution from agricultural practices.

Upto certain point, the drooping curve, of natural resources or the rising curve of pollution may not become problems. One should bear in mind that the level of pollution rises despite its control and at some stage it can stop further industrial growth.

From the brief, and non-numerical considerations that have been made it will be appreciated that population, industrial output/economic growth, agricultural, land/food production and natural resources — each has its own growth behaviour; each is governed by positive and negative feed-backs such as fertility and mortality in the case of population, investment and depreciation. In the case of economic growth, land, productivity and non-agricultural usage of land in the case of food production, discovery of reserves and increasing usage with growing population in the case of natural resources. Population, we have noted can also be controlled but not totally —it will rise and fall depending on the different energy sources under use.

With several numerical assumptions, several world models could be and have been indeed computed. We may just have a look at a particular world model on the basis of certain numerical assumptions. The overall trend of the model remains unaltered under varying numerical conditions and the trend is that while industrial output is rising, agricultura1 yield also would be rising and even newlahd may be developed. Nevertheless, some land is eroded by the modern agricultural practices and some will be taken for urban-industrial need. The limit on the arable land will thus be reached, still population is rising and consequently food shortage raises its head. Investment is diverted to agriculture from industry. Industrial output gets a set back. But food shortage cannot be stopped from sinking to a subsistence level and the negative feed back of mortality becomes more dominant and population growth comes to an end. Further projection leads to, a collapse.

It has been determined that if the present growth rate in world population industrialistion, pollution and resource depletion continue unchanged, the most probable result will be a rather sudden and uncontrollable decline of everything within a hundred years.

The only way to get out of the rut is to balance positive feed-backs with negative feed backs for population and capital. Such a requirement is surely from mathematical point of view but is surely complicated from social consideration. Simultaneously we could balance investment rate with depreciation rate. In this instance, capital should cover industrial service and agricultural combined. In this controlled state, if that is socially, politically and internationally possible, an equilibrium may be reached in the world system.

But these alone are not enough because resources depletion and increasing pollution effects disturb the stability. Therefore, the question becomes as to at what level, the state of equilibrium should be sought and at what levels or rates the positive and negative feed backs be balanced. In a water tank, one can fix the level at which the water, should remain but the same or any level may be maintained by fast inflow and fast outflow or by slow inflow and slove outflow. These questions also plague population and capital — at what levels these should be made stable and at that levels the feed backs should be balanced for maintaining a stable level.

It has been found that these levels are a function of time period during which the scability is sought to be maintained remembering that natural resources are really non-renewable and pollution cannot be completely eliminated. The longer a society would prefer to maintain the state of equilibrium, the lower the rates and the levels must be.

Population and capital are the only quantities which need to be constant to achieve a staple world system. The role of technology will still remain as important as ever. Technological innovations would continue to be both welcome and necessary to maintain a stable world system of population and capital. These innovations should be towards better product design to increase product life time, towards easier, repairs so that depreciation is minimised, harnessing solar energy so that pollution growth is restrained, contraceptive methods that would equalise the birth rate with death rate, etc. Besides, the effect of technological advancement would result in increased leisure for the population thereby helping the turning of an Affluent Society to a Creative Society on which subject I address this IE(I) on a previous occasion.

It would be of interest to have an understanding of the nature of global equilibrium without the threat of a collapse. Such an equilibrium has been claimed to be achievable under specified conditions. In fact more than one stabilised world model has been computed each one under different conditions and differopt numerical assumptions. The simplest one depicting the outcome of stabilisation has been computed on the basis of some numerical assumptions and the following stipulations:

i) Control of fertility so that births are set equal to deaths.

ii) Increased life time of capital and lesser emphasis on industrial production in an attempt to set investment equal to depreciation.

iii) Diversion of canital to feed prodution even if such a diversion is uneconomic and emphasis on agricultural capital being used for also enribhment and preservation of soil by composting organic wastes and returning these to the land.

iv) Reduction of resource depletion by discovering new reserves by resources recycling as well as by shifting human preferences more towards education health esthatic values, etc and less towards industrially produced material goods and

v) Extensive application of pollution elimination devices to keep it under some control.

Numerically some of the results depicted by the stabilised world model under consideration are:

i) Pollution is under control and almost ceases to increase.

ii) The stable world population is slightly more than the current figure, the stabilised life time being about 70 years.

iii) Industrial output per capita is higher than the present level but services per capita are about three times the present availability.

iv) Food per capita is more than twice the present average figure.

v) Resources depletion is so slowed down that there would be enough time fer adjustments! Innovations to prevent this from being a disturbing factor.

Stabilisation, let it be noted, can achieve the above globalistion if the, lots of the underdeveloped and developing countries in the world are substantially improved through a global stratedy. Short of a global strategy, today's gaps and inequalities will only further grow to a disastrous, situation which would not be good for the rich nations. World is to be looked upon as a Big Village - the theme of a recent United Nations film and then only will last the world as such.

Admittedly things are not just as simple as you have now heard and seen. Deliberate limiting growth is not easy but not impossible either. On the other hand, without planned limiting, a collapse will take place sooner or later. With planning, co-operation and sincerity, an orderly transition from growth to global equilibrium is possible and should be planned so that mankind may avod a collapse and continue to exist for generations. Whether politicians and policy makers of the present day world will remain unconcerned with the predicament of growth threatening an inevitable collapse in due course or plan for stability by limiting growth with a view to avoiding mankind from being wiped off in the foreseeable future, is indeed extremely difficult to predict. The purpose of this presentation of the realities of human destiny, as gleaned from the research works of eminent personalities, on this occasion of a celebration in memory of a great man of science and technology, into foster this new understanding and to help create a public opinion, if possible.

One may in fine quote the famous lines:

One ship sails East -
Another sails West
By the self-same wind that blows;
It is the set of sails
And not the gale
That tells the way to go.

And we keep wondering:

Which way will the world go?
Will the world go the way to collapse or stability?
Who will set the sails for the world?

Indian Development — Challenges and Tasks of the Eighties

Shri A L Mudallar

Chairman, ICI Companies in India

INTRODUCTION

At the outset I would like to record my sincere thanks to the Institution of Engineers (India) for doing me the honour of this invitation to deliver the Sir Rajendranath Mookherjee Memorial Lecture for this year. I do indeed feel privileged to be accorded this opportunity of being associated with you in paying tribute to someone who has done so much in the cause of the engineering profession in the country.

I propose to talk to you today on the subject of "Indian Development - Challenges and Tasks of the Eighties". To my mind, this subject would be appropriate for a lecture which has been set up to commemorate the many-splendoured achievements of Sir Rajendranath Mookherjee. A titan of his time, Sir Rajendranath blazed a trail throughout his career so substantial in scope and so chequered in variety asto leave a distinct impression in terms of efflorescence of Indian entrepreneurship in the early part of this century. A professional par excellence, he was not only eminent in his own field – his election as President of the Indian Science Congress in 1921 bears testimony to this aspect of his career – but Sir Rajendranath was also the architect of one of the largest industrial groups in the engineering sector of our country. In this context, I may again recall the tribute that was paid by Shri K C Mahindra who wrote an excellent biography of Sir Rajendranath Mookherjee: "his life story is the story of a great businessman, equally great of heart as of head, generous of instinct and charitable of soul, who brought glory to everything he touched".

The industrial landscape of our country has changed significantly since Sir Rajendranath's time with the momentum of industrial progress radically stepped up in the years following Independence. In this process, the demands on various professional disciplines have accentuated in a steady manner to a considerable extent and I daresaythe response has not been found wanting. Let me start out by noting this overall context in some detail.

INDIA'S DEVELOPMENT EXPERIENCE

It has become rather commonplace these days to say that India's position among the developing Third World countries is of a special kind. Although with about 16% of the world's population, India produces less than 2% of the world's income – and consequently the per capita GNP at around $170 is one of the lowest – yet India's natural resources and development potential far exceed those of most nations. India, more than perhaps all other developing countries, combines modern and traditional institutions and technologies into a diversity that tends to become lost in any generalization and statistical averaging.

The country is marked out by its possession of a large industrial base, an extensive infrastructure of great capability and a creditable record of developing and adapting technology. Indeed our industrial output in absolute terms at $ 40 billion features among the top twenty in the world and in terms of variety it matches up to any other country. A reference to some of the important markers of India's industrial standing in the world will underline this point.

Our output of coal is the sixth largest in the world, in electricity our rank is tenth and the country's railway network is the second most extensive. India's outputs of cotton textiles and sugar are the largest in the world, in fertilizer nitrogen we outrank all but three other countries at present, in cement our place is eleventh and in steel it is sixteenth while we are the tenth largest producer of alkalis and twelfth largest producer of paper in the world. Our manufacturing capability today straddles the whole range of the industrial spectrum – from jet aircraft to acrylic fibre, from radio-isotopes to radial-ply tyres, fromantibioticsto austenitic steels and from diesel locomotives to diamond cutting tools. Most importantly, all this is backed up by a strength in terms of qualified technical manpower which is exceeded only by the United States and the Soviet Union. The fact that such strengths were built up almost from scratch against the background of long years of colonial rule has underlined the resilience of the Indian system, and particularly the element of enterprise in it.

Putting these substantial achievements in conventional statistical terms, the trend rate of growth of the Cross National Product in course of the years since Independence has averaged at between 3 and 3.5 per cent annually while that of industrial output has worked out at around 6 per cent per year. However, the growth curve has been characterized by interruptions and occasional plateaus. The question as to whether these growth rates have been adequate in relation to available potential or not is of course by definition a relative one but there is no getting away from the feeling that in terms of our planning efforts to optimize the utilization of resources and, importantly, to advance the quality of life for the people at large to a desirable level, there have been deficiencies. Indeed, it is now seen in hindsight that the pace could have accelerated to a higher gear providing some of the deficiencies in policy and planning were made up in time.

There is however, an important point besides the question of the rate of growth. Perhaps in the Indian context, progress can hardly be expected to run on a steady, equally distributed and uniform course but our development experience reveals certain disparities which are almost in the nature of enigmas.

Thus our big industrial programmes have coexisted with widespread sickness in industry; ability to launch space vehicles with poorly built motorcars; brilliant achievements of Indian scientists and engineers abroad with a faltering rate of innovativeness within the country; and despite the existence of a large population of professionals, the level of professional acceptance has tended to remain relatively low. These examples of dissonance were quoted in a paper which was submitted at a recent Conference on India organized by the Stanford Research International in Delhi and, to my mind, they give cause for much reflection. These abrasive dual ities evident in our national growth record are the products of a host of sociological, political and economic factors and they pose a major challenge before our political leadership. I do not intend to go into an analysis of these factors today but it will perhaps be useful to put some of the major aberrant trends in our track record in perspective. With this end, let me now turn to briefly consider a few important features of our development experience.

SOME ABERRANT TRENDS

India's decision to stressrapid industrialization and heavy industry was almost as critical to policy as her choice of growth, equity and self-reliance. The attraction of this approach was not merely psychological. For example, to the extent that India could process its large mineral deposits, it would not only spur industrial progress and import substitution but also enhance the value of exports. Additionally, the logic of investing in heavy engineering was economic; this sector was expected to produce machinery which, in turn, would produce more machines and consumer goods thereby serving both the growth and selfreliance objectives. The soundness of this logic has been vindicated by subsequent experience and a fair measure of success has been achieved in approaching these goals.

However, it will be appreciated that the industrial programme based on these assumptions could not but remain vulnerable to any deceleration in the pace of growth from plan because in the event of such shortfalls, occupacity factors in industry would decline thus leading to considerable opportunity costs. Indeed, these aberrations became apparent in the middle nineteen-sixties when economic growth slackened to almost standstill due to a combination of factors like war and drought and the consequent fall in new investment turned the heavy engineering sector into an unexpected albatross on the system. Following the Third Plan, the Indian economy suffered from a structural problem of insufficient supply of consumer goods and a related insufficient demand for capital goods. The lack-lustre performance of public sector industry into which a great deal of resourceshad been steadily pumped in exacerbated the difficulties of the situation although encouragingly in the last two years public sector performance has been toned up.

These structural problems expectedly tended to rub off on the productivity of investments per se. Productivity of investment is best indicated over a given time-period by the incremental capital-output ratio. Of course it is just an indicator of trends, being essentially an aggregation but one that is widely used in analysis. As Dr Freddie Mehta's paper submitted at the Silver Jubilee Symposium of the Industrial Credit and Investment Corporation of India (IClCI) pointed out, the incremental capital-output- ratio for Indian industry which had worked out to 3.2 (at 1960-61 prices) for the decade of the fifties rose sharply to 5.0 during the years between 1961 and 1971. While estimates for the decade of the seventies are not yet available, indications are that for every additional unit of output the incremental capital requirement has possibly gone up further to about 6.0. This is indeed a most disturbing phenomenon considering our overall circumstance of scarce capital.

I think it will be appropriate, in a forum such as today's, to consider the factors which have led to the rise in the overall capital-output ratio in our economy. Firstly, the question as to whether the product-mix of the Indian industrial sector has sufficiently matched up with demands must be faced; I suspect there is scope for doubting the relevance of a significant part of our industrial output besides, of course, the issue of widely spread purchasing power. Secondly; there is the very important fact of scale infirmity in our industrial system. The vivisection of capacities that has accompanied a mechanistic application of industrial licensing policy has given rise to the penalty of high unit costs and lack of competitiveness in world markets.

Thirdly, the age profile of capital assets in our industrial system indicates a daunting task of modernisation since much of the technological obsolescence of these assets derives from long years of neglect of the task of refurbishing them. While admittedly in a capital-scarce economy such as ours there is merit in prolonging the lives of assets, this cannot obviously continue beyond a point. The vintage of technologies, Which is associated with this, has to be evaluated in a continuing manner with an eye to costeffectiveness.

All these factors have exacerbated the flagging trend of capital productivity in India. Now that the economy is being opened up to international competition as India seeksto expand exports on a wide front, it is very much time to organize planned action in this regard.

There is also need for urgent action in respect of the growing energy intensity of economic activity in our country. As Dr Manmohah Singh, Member-Secretary of the Planning Commission, noted in his address to the Bengal Chamber of Commerce and Industry last year, for every percentage point increase in the Gross National Product 1.8% increase in energy consumption takes place. This worsens the overall capital-output ratio in view of the fact that energy is a highly capital intensive sector in itself.

The adversetrend of the overall capital-outputs ratio, reflecting falling capital productivity is obviously of concern to our planning process which depends on productivity advances to provide its onward thrust. It signifies a slow learning effect in our industrial sector which in turn also aggravatesthe vulnerability to inflation. The impetus to market expansion deriving from a falling "Boston Learning Curve" consequently remains missing. There are, however, major exceptions like electronics and parts of chemical and engineering industries where unit costs in real terms have been driven down. However, a general buoyancy has continued to elude us with a large section of industry becoming increasingly prone to sickness.

Much of the difficulties of the industrial sector in the more recent years have emanated from the large-scale failures of the infrastructural support system. The poor rate of electricity generation, the deficient transport system and debilitating interruptions to feedstock supplies have devastated industrial occupacities. The world-wide volte face on the energy front which has had a lot to do with the uptrend in costs has added to the problem. Industrial relations have also tended to be restive giving rise to volume losses in important areas.

All these constitute the staple of the tasks before economic management in our country and, as experience in the last two years has demonstrated, once the Government gets about them in a targeted manner and with determination, the situation can be turned around. The personal initiative demonstrated by the Prime Minister in terms of sharpening up targets and accountabilities has had a great deal to do in bringing this about. The significant improvements that have been achieved in, for example, coal and fertilizer production, petroleum output, railway wagon movements and power generation underscore the point. In our mixed economic system, the Government's role and attitude provide the key to the development process and I shall talk about that aspect a little later.

THE APPROPRIATENESS OF TECHNOLOGY

But while yet on the subject of technology, may I share with you my concern over what I feel is a certain lack of direction in the technological progress of India, spectacular though some of the achievements may have been in the years since Independence. Modern technology aswe see it today was developed by the Western countries in response to market needs and on the basis of readily available raw materials and local skills. With the breakaway industrial progress of the Western world, the development gap between industrialised countries and others like India widened at an exponential rate. Quite understandably, therefore, as we set ourselves to the task of industrialisation there was a large void to fill and there could be no way of filling it other than by importing Western technologies. These, by dint of the attributes of the societies which developed them, are essentially urban-oriented, scale-dependent and capital-intensive. While heavy industries in our own country like fertilisers, mining equipment, shipbuilding etc., must of necessity depend on such technology, the question still remains inadequately answeredasto what constitutes appropriate technology for serving the needsof the three-quarters of our population living in villages — technology that would in practice swiftly accelerate rural development to a point when the constant drift of landless labour to our already suffocating urban centres would stop. Strengthening of the agricultural base is of course the prime requisite in this context which implies continued deepening and spread of the Green Revolution so that the land-man ratio can significantly change for the better. Apart from the aspect of technology there is also the basic imperative of curbing the rate of population growth so that the pressures on farm size could be relieved. These are overall development objectives which have long been recognized and the question is that of accelerating their implementation.

On the other hand, our industrial assets are already there on the ground and were put up at a great cost to the nation. If then for societal reasonsconnected with product mix and structural imbalances domestic demand is going to lag behind potential supply in certain sectors of industry, it must be but logical to make the best possible use of the exportable surplus towards meeting the country's mounting foreign exchange needs. I say this without in any way suggesting that ours could ever be really an export-led economy but to preface my concern over the costineffectiveness of our production vis-a-vis competition in the world markets. Here we come upon the paradox that the product of Western technology made in India using cheap labour and sometimes even indigenous raw materials turns out, cost if not qualitywise, to be an indifferent performer in western markets compared to similar products from some of the spectacular 'island economies' of the Far East.

Without going into the variety of reasons that have contributed to such a situation, may I just place before this distinguished gathering the question as to whether we should be impairing even whatever appropriateness there is in already installed Western technology, for example, through an endless debate and consequent delay over the subject of computerisation of systems for greater productivity? Is it not time rather to harness the technological momentum towards building up the strengths India possesses in, for example, renewable feedstocks to boost the overall productivity of our national economic activity? This is the other end of the much discussed topic of appropriate technology.

THE TASKS AHEAD

It will be accepted that meaningful solutions to the problems of India's poverty and unemployment can only be found in the framework of a rapidly expanding econotny. Hence, the targeted 5.2% annual growth in course of the Sixth Five Year Plan and the indicative 6% rate during the Seventh have a compulsive overtone. But these will need to be achieved in times rendered uncertain by the question marks on the energy outlook, an almost endemic scarcity of resources and a groundswell of inflation.

The pressures on the foreign trading sector have also introduced a radically different parameter on the economic horizon. The wide-ranging and often acerbic discussions on the recent loan we have taken from the International Monetary Fund have highlight this aspect from many angles. In my way of looking at the situation, the most important implication of this indebtedness consists in our deliberate acceptance of a challenge to carry out major structural changes in our economic systemwithin a specific time-frame. The loan of 5 billion Special Drawing Rights gives us a cushion and a breathing interval for us to set various parts of our economy in order, particularly in terms of improving the efficiencies of our industrial production system, sharpening up the energy programme and preparing for taking up international competition on less subsidized conditions.

1984-85 is the targeted year for achieving a substantial portion of these objectives, and we cannot afford slippages. Hence our policies and programmes will need to be more than VA usually informed and imaginative. The aberrant trends in our development experience that I have talked about signal the areas for corrective action. Thus the faltering capital productivity trend must be flexed upwards so that increasing volumes are obtained from our relatively scanty capital resources. In this task, a major desideratum will be filling up unoccupied plant capacities in an optimum manner. The punishing opportunity cost burden of low occupacity factors in our context can be illustrated by, for example, referring to the nitrogenous fertilizer industry where an improvement from the current 61% to a factor of 80% would save imported nitrogen to the extent of Rs 450 crores; in the case of cement a 95% occupacity level against the current 80% would save Rs 150 crores of imports; in caustic soda if capacity utilization were 90% instead of 70% as at present, Rs.45 crores of imports could be dispensed with.

As another imperative, the draft on commercial energy in our growth process has to be brought down sharply as, for example, has been done in Japan where the additional nergy requirement per percentage point growth of the Cross National Product has been reduced from 1.25% in 1973 to only 0.25% at present. By contrast, in our country very substantial electricity generating capacity coexists with a proliferation of diesel generating sets — the latter seeking to cope up with the shortfalls in generation at prohibitive cost. Another aspect of this syndrome is evident in the large-scale haulage of coal by road as railway wagons cannot be organized in adequate numbers. The energy-efficiency implications of the process are of course quite egregious. In bringing about a step change in the energy-intensity of economic activity, a major role will have to be played by science and technology so that the dynamics of innovation can get speeded up. For this to take place, industry and the professions will have to increasingly look beyond the immediate horizons.

Let me deal with the question of the relative impact of energy, capital costs and technological change a little more closely. In the case of the world chemical industry, the technical horizons are shifting towards more elegant processes. The new Union Carbide process for low density polythene, claiming capital costs 50 percent less than those for the ultra high pressure process and energy consumption 75 per cent lower, is a prime example of driving down the experience curve by an enviable slope. Similarly, technological cost reductions for other commodity thermoplastics are expected to be brought about by, for example, conversion to coal for some fuel, direct combustion cracking of lessexpensive hydrocarbons, gas phase polymer processesand super catalyst activities. Away from the chemical industry the rapidly escalating fuel oil costs are leading, for example, paper manufacturers to substitute one form of energy with another; conversions and new installations in America increasingly permit kraft paper producers to raise steam with bark, sawdust and other wood residues rather than fuel oil and when combined with energy conserving electric power cogeneration equipment, many paper mills are tending to become 90 percent Of more energy self-sufficient. In the case of steel, electric furnace technology promises to be a major engine of technological change. In aluminium industry, Alcoa's new processfor aluminium reduction promises greatly reduced energy consumption. These examples will serve to illustrate the manner in which inflation is being sought to be countered by technological change the world over. It is necessary for us to take a cue from these developments so that the rate of technological progressmay be flexed upwards leading to a containment of the rapacity of inflation.

Apart from technology, it is indeed the major task of management today — and the central task of corporate management — to enhance the productivities of financial and human resources and the 1980's are going to call for a gearing up of our management strategies to this end. In the context of strong inflationary advance, the upgradation of financial management to bolster the springs of enterprise so that the vital process of asset replacement and renewal in industry can proceed normally has become a sine qua non. The tempering of credit expansion, to which our monetary policy will be committed in the wake of the IMF loan, is going to pose another challenge to financial management. A greater measure of resilience and finesse is being demanded of the corporate sector, financial institutions and banks for tapping resources. Thus, for example, the explosive growth in world liquidity which has been detonated by the petrodollar phenomenon has resulted in a proliferation of off-shore investment funds that need to be imaginatively and cost-beneficially attracted into our financial system.

With regard to the question of better management of human resources, the outstanding issues are, first, the mobility of labour into gainful areaswith a possible accent on labourintensive exports and perhaps more so on the integrated wage goods sectors — this, as I mentioned earlier, would call for even greater emphasis on improving agricultural productivity. Another major issue is that of adding to the skills and productivity of labour; there is little point in not facing upto the fact that the allegedly low cost of labour in India is more than neutralized by its depressed productivity. The instruments are not only better personnel management strategies built up by drawing appropriately upon the behavioural sciences but also improved work methods and systems. In the latter respect, the point about automation must be properly evaluated in terms of its multiplier effects in terms augmenting productivity and the attendant accretion to the employment potential. Emotive overtones usually tend to mark the approach to the subjects of automation and productivity but that is neither functional nor positive. It is only by meansof a constructive agreement on these basic issues that a continued improvement in the productivity of labour along with harmonious industrial relations can be effectively ensured.

In this section I have traversed a course from the aggregative to the relatively micro aspects in order to underline the responses which I consider are required in the country's growth process from the various professional disciplines in our country. Let me now turn to another very important aspect, namely, that of the social synergies and harmonies that are at one and the same time both preconditions for and the desired goals of the economic progress of a nation.

TOWARDS SOCIAL HARMONY

The wide-ranging developments in the social, political and economic fields of our country in the years since Independence have been accompanied by an upsurge in general expectations. Indeed this is a world wide phenomenon but in our own specific context of transition it hasacquired an added dimension.

While I do not have any intention of putting on a sociologist's hat — and let me hasten to add that it is not my area of specialization — to my mind the many signs of alienation that we see around us at different levels and segmentsof our society today basically spring from this so-called revolution in expectations. The shift in the income-distribution profile, perhaps signals the problem but it goes deeper than that into questions relating to the quality of life.

How is our national progress matching up in this regard and what is the contribution expected from professional expertise? As far as rural development is concerned, I have already touched upon the continuing problem of migration to the cities from villages. While farm technology has made great strides, the technical edge that is required by our village craftsmen to enable them to fend for themselves in the face of urban-based industrial production is still awaited. How many village blacksmiths have, for instance, naturally graduated to making small scale agricultural machinery? Again, it is only recently that we have made a start on 'gobar' gas units in a country acknowledged traditionally to have the world's largest cattle population. To mankind, the need for shelter is second only to the need for food. However, much remains to be done in India by way of arranging accommodation for the bulk of our population. The answer is low cost housing, but here, with all the excellence that the country has achieved in the engineering profession truly low cost housesbasedon locally available materials and skills of construction still continue to elude us. Improved public health and sanitation facilities are yet to be provided to very large sections of our urban population, not to speak of rural India.

I have talked about these problems in order to highlight the professional responsibility of rising up to them. The engineering community has a big role to play in these tasks once they are addressed to with determination. Success thereafter will depend upon the degree of innovation brought to bear by the various disciplines involved in the solution of problems typical to our society for which there mayor may not be parallels elsewhere.

My submission here is that if we as a people wish to establish the kind of synergies that are conducive to sustained social evolution with economic growth, each one of us has his or her own individual role to play and play it with a sense of total commitment and responsibility. The soundness of the structure that we build will depend upon the quality of our own effort, individually and asa people. The Prime Minister's broadcast message earlier this month on a packaged agenda for the nation revealed just such a concern about the quality of effort. The plans for giving a renewed thrust to the rural economy, to family planning, to improving the environment and to upgrade the quality of life in general are indeed the substance of our national endeavour.

GOVERNMENT ATTITUDES

I would now like to turn to the important issueof Government attitudes. In the industrial economy of our country, this is a factor of paramount importance given the pervasive influence of Government in our industrial activity. While Government attitudes to industrial, and specifically corporate sector growth, have tended to alternate between 'stop' and 'go' in the past, to my mind the evolution of policies in the last two years represents a firm move towards the pragmatic and the realistic. The steps taken to permit automatic growth of industrial capacities, the abridgement of the convertibility option, easing of the restrictions on foreign collaboration, the encouragements for export production and the clear intentions of Government not to let industry be starved of essential imports are all indications of a concern for augmenting production volumes. I have already referred to the positive impact that the Government's determination on the question of infrastructural deficiences has brought to bear but would like to commend constant vigilance against slippages. These are indeed welcome and I may note that they haveevoked response in terms of an uptrend in industrial output which may be expected to hit even a 10% rate this year.

It goes without- saying that in an area such as this, policies must be clearly seen as forming an organic unity and any situation where one part of the policy package comes to neutralize another has to be scrupulously avoided. However, in this regard some aberrations continue to persist. For example, while it is the expressed objective of Government policy to develop the usage of renewable sources of feedstocks, the large segment of chemical industry which uses industrial alcohol as feedstock has recently been laid low by firstly, an unplanned diversion of the material to potable applications and secondly, a step-jump in its costs with surplus producing States imposing hefty levies. The framework of a national policy in this regard, which is recognized as an increasing desideratum, is yet to take shape.

To give another example of an area where policy change is long overdue, the structure of indirect taxation in our country has assumed so complex a form that these imposts often tend to cumulate at many points leading to what the Indirect Taxation Enquiry Committee headed by Shri L K Jha termed as a cascade effect with the total incidence of duties far exceeding the manufacturer's unit realisation. In the process, normal market growth expected of these heavily-taxed items, like polyester staple fibre, has continued to be denied. An area where policy would need to be increasingly marked by skillful discrimination is imports, particularly in the aftermath of the IMF borrowing since it enjoins a liberalized approach to foreign trade. While imports can indeed help greatly in boosting industrial production volumes when they are of a supplementary or complementary nature, the consequences for the local economy can turn out to be quite far-reaching when imports merely replace indigenous output. Much of our industrial sector is quite ill-equipped to face up to the chill winds of international competition and the current downturn in the world economy with large unutilized capacities in the developed countries sets an ominous backdrop to any omnibus liberalization moves. There is room for a great deal of circumspection in this regard.

Continuing on the fiscal policy question, I would also like to refer to the issue of imaginatively tackling the corporate sector's real problems of replacing and renewing Capital assets in these inflationary days. Is the trend of return on investment adequate for companies to reward shareholders and plough back money into the business?

How can depreciation provisions in historic terms enable a company to build up enough funds to renew assets?Can the corporate sector be realistically expected to increasingly finance its growth as well as working capital requirements out of its own funds? As Peter Drucker has put it so aptly "There are the costs of today and the costs of tomorrow. I know of no business today which operates at such a rate of return that it can meet the costs of tomorrow ... with today's rates of inflation businesses are not making profits but only destroying capital". Admittedly these go beyond the pale of fiscal policy and involve aspects like pricing controls; however, it will be accepted that Companies need to be positively supported in respect of their ability to undertake new investments for industrial growth to take place at projected rates. This is particularly important considering the new investments now being envisagedon the basis of for example the substantial off-shore natural gas resources that have been recently struck in this western part of our country.

While my remarks may be construed some topicality in this Pre-Budget season — but of course the Finance Minister will have finalized his budgetary exercise by now — I would like to emphasize that it is also for the various professional disciplines to focus their own thinking on these key issues on a continuing basis so that acceptable guidelines for action may emerge. A positive process of interaction between professional bodies and experts in the Government cannot but have a beneficial fall-out in enriching the form and substance of policy.

Before I leave the subject of attitudes, there is one other point which I would like to make. It goes without saying that the quality of our national endeavour to tackle major problems of the times is largely determined by the manner in which the diverse skills and expertise get matched. There is the key issue of proper motivation of people. In this context, the reality which is mirrored by the continued brain drain from our country to distant developed lands has to be taken cognizance of. Our educationists and other policymakers must ponder on the paradox that while Indian talent abroad invariably carves out very distinguished places under the sun, whether it be in bioengineering or energy research or ammonia technology, the many basic problems at home do not get adequately attended to with the necessary vigour and resolution. Perhaps sensitivity to young non-conformist talent needs to be improved as the Prime Minister asked at the recent sessionof the Indian ScienceCongress.

I have no doubt that given the right milieu, this splenoid corpus of excellence could be directed towards the pressing challenges at our own doorstep. In this regard, there is much that I feel can be done imaginatively by professional bodies such as yours, universities and Government agencies.

CHALLENGES BEFORE THE ENGINEERING PROFESSION

I now come to the concluding part of this address where I would like to reiterate what I consider to be some of the basic challenges before the engineering community in the task of ensuring sustained economic progress of our society. These challenges point to the direction that, in my view, engineering research and development in India should be taking, and its major objectives. If technological change in the widest, social, sense is taken to be the principal factor in the transition of our society from where we are today to what is generally called a developed state I would like to submit before the engineering profession the following priorities in the practical application of their science in India:

The first relates to the all important question of developing and adapting technology to meet the local market needs of the bulk of our population. This also encompasses strengthening of rural industry in terms of upgraded traditional systems through better design, higher efficiency and improved economic viability.

Secondly, a clear impact has to be made in the basic areas like food, housing and transportation by way of, for example, better food storage and handling systems, design of low cost housesusing novel construction materials and helping in the development of efficient transport systems.

Thirdly, the engineering profession has to squarely face up to the challenges posed by the energy situation by way of technological finesse and ingenuity.

Finally, the imperatives of ecological protection and balance have to be accommodated in a proper manner in our engineering development. Today my attempt has been to focus on what I consider as some of the key issues and parameters of Indian industrial growth. In my view, these will need to be continuingly approached in a professional manner and with all the weight of the professional inputs that can be brought to bear. Many of the factors relating to the basic problem of flagging productivity of resourcesare of a management nature and in the search for their long-run resolution professional bodies are expected to play a pro-active role of considerable significance. The overall backdrop of Government attitudes in all this is of course crucial and the positive trends that have emerged in the last two years betoken a welcome measure of pragmatism in policies. In order that these policies can be most efficacious, some of the aberrations of the policy package will need to be speedily removed. Again, it is left to a process of constructive interaction between Government, industry and professional bodies to weed out dysfunctionalities in the system.

To my mind it is in such involved participation with the living problems of development that the deepening of professionalism in the country can proceed apace. There are of course no easy and ready-made solutions to the difficulties that cloud the way ahead. The enigmatic dualities in our national situation to which I have referred in the first part of this address reflect certain basic disequilibria which have to be specifically identified for remedial action. Their roots lie outside the pale of the strictly economic sphere and their implications spread out widely into the matrix of socio-political relationships. In grappling with these problems, successcannot be produced by scientists, technicians and economic planners on the basis of some magical model. It can only come when the processof development purposefully embraces the education, organization and discipline of the entire population. And that provides the most exciting challenge, as the Prime Minister's mid-January message connotes, before Indian development in its march towards the objectives it has set for itself. In approaching these tasks, there is to my mind scope for optimism in view of the excellence of Indian professionals which is recognized the world over. The point is to channelize such excellence adequately and in a targeted manner. May I conclude by commending these objectives to the engineering profession.

Thank you for your kind attention.

Quality and Productivity-Some Concepts

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INTRODUCTION

The post-war period has witnessed a sea change in the world economic order. Firstly, protectionism and protected markets have given way to relatively free international trade governed by keen competition. Secondly, before the Second World War, mineral and agricultural resources of the colonial countries of Asia and Africa were a monopoly of a select few countries and obtained cheaply to boot. In the post-war era these countries, after gaining independence, have become sources of abundant raw materials available to all at competitive prices and without discrimination. Thirdly, armament research spurred by the exigencies of the war and continued under the arms race, space exploration, rocketry, among others, have brought about spectacular technological progress. Transistors, silicon chip, materials science, especially metallurgy, microelectronics, polymer chemistry, antibiotics, fertilizers and pesticides have opened up entirely new vistas of applied technology for agriculture, consumer products and capital equipment. And lastly, reforms in the international monetary system have helped expand world trade. These factors have given a real boost to the economic development of the world at large.

Innovative design, manufacturing economics, higher labour productivity and excellence in quality are the tools with which most nations could enhance their prosperity. And yet not all countries of the free world have prospered.' Amongst the developed countries whereas Japan, the USA, Switzerland and West Germany seem to have prospered continually, countries like the UK, Italy, France, Canada, etc have not benefited as much during the post-war economic boom.

In 1978-79, of the total world production, Japan alone contributed 15% steel, 18% plastics, 14 % synthetic fibres, 18% passenger cars, 30% TV sets and nearly 41% of the world's ships. Japan is not endowed with any significant sources of raw materials! It is entirely dependent on import of oil. It has contributed little to the world's scientific knowledge and fundamental research. In fact, Japan finalized over 32000 foreign collaboration agreements between 1950 and 1978 to bridge its technological gap. As against this, Britain has to its credit (i) the first splitting of the atom, (ii) discovery of penicilin, (iii) development of the radar, (iv) the gas turbine and (v) the first commercial atomic power station. It is endowed with vast resources of coal and, recently, oil in the North Sea. And what is Britain's standing amongst the industrialized nations? France and Italy over the years have developed several innovations in the auto-mobile field, and yet their passenger car production is 11.2% and 4.7% respectively as against Japan's 18%. Italy is the world leader in the design of household appliances and office equipment. France is second only to the USA in aircraft and aerospace research. And yet they lag well behind Japan in the economic boom.

What is the secret behind the economic resurgence of Japan? Is there a basic 'systems' approach for rapid economic development? Technological progress by itself is not the answer. Lack of natural resources is not a constraint. When we search and analyze the growth or lack of it among the nations of the free world two factors emerge strikingly-quality and productivity. Productivity not in the limited sense of increased labour output, but an all pervasive contribution through design, materials, manufacturing process, labour and capital resources, backed by comprehensive quality standard in the performance, product life, function and aesthetics.

It is the irony of our times that Japan which had a reputation for poor quality till the 1940's, is today the leader in quality and the guiding light to the rest of the world in improving quality.

The oil crisis of 1973 was a watershed in international economic development. Saving of fuel and development of alternate sources of energy became the new challenge suddenly and seriously. Considerable research and development work was started immediately in this field with some quick results. The USA reduced its oil consumption by 6% and in Japan oil consumption was reduced by 35% in steel production and 27% in the chemical industry, over the next six years. The response of the industrialized nations in meeting the oil crisis is yet another example of human ingenuity and resourcefulness. After all, human progress is a many splendoured story of challenge and response. This is the second point, I want to make.

Whereas quality and productivity optimize the resources of man-power, money, material and machines, the vital force to achieve it springs from human ingenuity — a strong national attribute of our country.

One often wonders as to what is the ultimate purpose behind this market oriented economic boom in the free world. It is necessary to understand its essence before developing a strategy for India. Stripped of the jargon of economics and catchy marketing verbiage, the essential purpose of econotnic development in the free world, perfected through quality and productivity is to enrich human life through (i) health, (ii) nourishment, (iii) comfort, and (iv) leisure. It should now be obvious that quality and productivity determine the level of physical comfort and leisure that a society can aspire for.

THE INDIAN SCENE

Comparative statistics are the best yardstick to know where we stand in our quest for economic development. In the production of steel, against 218 t per man per year in the USA and 133 t in Germany, in India we obtain 68 t of steel ingots per man per year. For aluminium, the comparable figures are 200 t in the USA, 125 t in Canada, 75 t in Japan and only 30 t in India. Per worker production of cement in Japan and America is between 6 and 7 times that of the Indian worker. Even among the developing countries, our performance is no better. The productivity of a Brazilian worker in food and beverages industries is 12.5 times, in textiles 10.2 times and in metal working 8.6 times that of an Indian worker. What should concern us even more is the fact that the productivity gap between India and other countries is widening. Between 1960 and 1977, the productivity ratio between Japan and India has deteriorated from 3:1 to 7:1. Even in agriculture, where we have progressed well, the production of rice per hectare in the USSR is two times, in the USA two and a half times and in Japan 3 times than that of India.

The per capita GNP is the best available index to judge the overall economic development of a country. For 1980, whereas the GNP for India was $ (US) 240, the average of 'Low Income Countries' was $260! Just to complete these statistics the GNP average for middle income countries is $ 1400 and for the economically advanced countries $ 10320. For the centrally planned economies it is $ 4460. It is painful to accept that only 13 countries like Bhutan, Bangladesh, Nepal, Ethiopia have a lower GNP than India. Furthermore per capita GNP alone does not reflect the true economic state of the Indian society. Of the $240 per capita the top 20% population commands almost 50 % of the total disposal income and the lowest 20 % have to be satisfied with 7% of the GNP.

The statistics in the foregoing is indeed depressing. Yet, it need not dishearten us. From the success of Japan, we can draw inspiration and adopt new techniques. And from the experience of Britain and others we can determine the pitfalls to be avoided. After all, it is through the ingenuity of our business leaders, economists, scientists and technologists that these challenges will be met. But, at first we have to identify the weaknesses. set the priorities and hold on course. In fact, even now, in some pockets of Indian industry and agriculture we are exporting, profitably, amidst international competition.

During the 50 years of my active business life, I have been searching for the key factors that make a business flourish. Enterprise, growth and profit alone did not give the fulfilment. The search went on till we diversified into the engineering industry with some reputed Swiss collaborators. I was struck by their adherence to quality and their productivity. We adopted these measures meticulously in our Indian factories with all round success. This conclusion was reinforced by the analysis of the 'West German wonder' of the 1950-66 and currently that of Japan and others.

Quality and productivity are the key factors of a business enterprise whether engaged in manufacturing a product, or a service industry. or even a one time construction project, like a dam, power station, airport or a township.

Before turning to quality and productivity, I must emphasize some basic differences in the two economic models. Whereas in the west the goal of productivity is increased leisure, in India it is employment for the masses. In the field of health, the western thrust is towards increasing longevity our priority is to find cheap and reliable method for limiting new life. As against increased comfort and leisure, our priority is to provide shelter, food, water, roads and little purchasing power for the vast rural population. Notwithstanding this, we need western technology to update our manufacturing industries, our health care, our communications and our defence. To buy such technology we need to export commodities and manufacture products. This dichotomy in the Indian economic development underlines the importance of quality and productivity.

QUALITY AND PRODUCTIVITY — SOME CONCEPTS

Quality and productivity are the two key factors in all economic activity-whether manufacturing, service oriented or a one time construction project. Whereas quality enhances utility and excellence of the product or service or an edifice, productivity optimizes the use of resources in men, materials, machines and money for the best economical result. Quality has a deeper meaning than mere checking the performance and tolerance or the final inspection of a product. Quality starts at grass-roots in the raw materials that go in a product, in the upkeep of a machine and process equipment that are used in the construction, manufacture or provision of service.

Quality is not the exclusive concern of the inspection department. Inspection cannot add quality. It can at best detect. Quality in an organization is the result of contributions from various functions, such as design, purchase, planning, maintenance and various staff specialists in metallurgy, chemistry and other technical services. Each of these functions has a vital contribution in the improvement of quality.

A third element in organization of quality is the 'total approach'. One cannot achieve quality improvement through sectional efforts. Considering the close interdependence between several functions in a business activity, a multi-discipline team approach is necessary for maximizing the standard of quality. Currently popular, the Japanese quality circle movement is but a culmination of these basic concepts.

Quality thus starts at the grass-root level. It is an all pervasive activity and it requires a total approach. It will be evident as we proceed that these concepts are applicable equally to the field of productivity too.

Like quality, a comprehensive study of productivity covers many areas besides labour contribution. These include materials, manufacturing plant, value engineering, improved planning, inventory control, and others. More about them in the second part of this lecture.

Another misconception voiced at times is that quality and productivity are mutually contradictory objectives in a business. This stems from the vague notion that quality adds to cost, hence it is counter-productive. In reality, however, quality and productivity are complementary. To give but a few examples, Improved quality of castings simultaneously reduce machining time and adds to productivity. An efficient system of inspection reduces in-process rejection due to timely corrective action and reduces cost. Process control ensures longer product life and reduces warranty expenses, an element of productivity. Together, quality and productivity ensure product excellence, market leadership, technological advance and as a result business prosperity.

In my lecture this evening Quality and Productivity are analysed keeping in view the manufacturing industries. However, the basic concepts and suggestions are applicable to a service or construction enterprise as well.

QUALITY

When we say that a product or service is of good quadity, many of us have vague notions like:

(1) It is reliable, performs well and is economical to use;
(2) It has longer life;
(3) It performs more functions than other brands;
(4) It is easy to operate; and
(5) It is aesthetically appealing.

When examined critically, the message conveyeo is that:

(1) The design should enrich functions and operating comfort;
(2) Raw materials, components and manufacruring processes should be selected to prolong the working life;
(3) The process of manufacture should be carefully controlled;
(4) Inspection of components and performance testing should be thorough;
(5) Per unit output should save energy or fuel; and
(6) External appearance, colour balance, finish, etc should be pleasing and non-straining.

Relative emphasis between tnese parameters will vary according to the end use of the product or service, but these criteria are applicable almost universally. In the following paragraphs, we will analyse these criteria and their influence on quality.

1.1 Quality through Design

Design for quality should accentuate the functions and economical performance of the product. Sophisticated controls except for process or performance monitoring should be carefully weighed against maintenance facilities at the customer end. Surface treatment and protective finishes should be used intensively to counter stringent climatic conditions in India. Raw materials and components for electric, electronic, hydraulic and pneumatic control circuits should be selected (and imported, if necessary) to give fail-safe performance and a longer life. Concepts such as design for obsolescence and styling are unsuited to Indian conditions where many raw materials are scarce. Maximum use of standard components, interchangeability, variety reduction, adherence to national or industries standards will enhance the intrinsic value, extend the product life and facilitate maintenance.

Regarding appropriate technology for India, expert opinion is veering towards technology which provides increased employment, with low priority to sophisticated automation. Although in general agreement with this view, I would recommend a dual approach wherein sophisticated machinery designs are made available to selected industries whose finished products compete in international markets. With the high quality of our technical manpower, facilities to maintain sophisticated designs can be created, selectively, as and when necessary.

1.2 Raw Materials and Components for Quality

Use of sub-standard raw materials and components has eroded the quality and reputation of many Indian products. Apart from shorter life and customer dissatisfaction these cause severe drain on scarce materials such as copper, zinc, nickel, chromium, plastics, etc many of which are largely imported. Intensive testing of incoming raw materials and components is a must for all progressive industries.

In the recent past, the maximum progress of benefit to the engineering industries, is in the field of material sciences. New materials, both of metallic and non-metallic origin with improved range of physical and chemical properties offer wide choice to the designer. Indian industries must engage more specialists in metallurgy, polymer chemistry and other technological fields to exploit the use of such materials for quality and performance.

1.3 Quality in the Manufacturing Process

Engineering industries widely use processes such as hardening, nitriding, heat treatment, metallizing, electroplating plasma, coating, etc along with a host of other surface treatment and finishing processes. Utmost care is required in the step by step control over these processes. Pre-treatment for cleaning and preparation of surface before painting or electroplating is a simple but vital operation. And yet paint or plating peels off and rusting underneath is common on many of our products. Negligence in this area results in premature wear of components, shortened life, corrosion and poor eye appeal. The most careful attention should be paid to process control to improve the function and finish of engineering products.

1.4 Inspection

Developments in electronics and microprocessors have remarkably improved the availability of measuring instruments in terms of accuracy, repeatable use and rate of inspection. Modular measurement equipment can be economically built for simultaneous-checking of many dimensions thereby reducing inspection time, increasing quantum of component inspection and eliminating human error. Investment in sophisticated inspection equipment has paid rich dividends to industries. Indian entrepreneurs should use these facilities increasingly. Apart from individual component inspection and performance testing, two other techniques, namely, 'inprocess patrol inspection' and 'quality audit' are successfully used by the automobile industry and other mass production units. These and similar inspection methods can be beneficially used by industries engaged in batch production as well.

Over and above, facilities that industries can establish within highly specialized testing facilities are increasingiy available at the National Laboratories, Educational and research institutions. These facilities are very useful in analysis, testing and development, especially in the field of import substitution. A case in point is the indigenous development of special oils and lubricants achieved by several industries with the help of such institutions thereby increasing the working life of the product.

1.5 Quality Ergonomics and Aesthetics

Consumer products and even industrial products are ultimately used or operated by people. And yet in their design and manufacture, the user receives little attention. Household appliances, domestic electrical goods, operating panels of industrialmachines, even gears on our automotive products and material handling equipment are often awkward to operate and cause fatigue. External form, surface finish, jarring colours, ill-designed and misplaced control knobs all add 'to human fatigue and eye strain. Behavioural and social scientists have confirmed that there is a positive relationship between colour or similar environmental factors and fatigue. Product design should give close attention to this man-machine relationship.

Confusion between form and function in the design of our products, in the architecture of our public buildings like hospitals and airports are all evidences of the aesthetic shoddiness we have created around us. There are exceptions. Design and finish of Indian textiles, leather goods, handicrafts and cottage industry products from rural areas have happily preserved the rich aesthetic traditions we have inherited. There is urgent need for revival of this in our domestic and industrial products as well.

1.6 Watch-dogs of Quality

In the foregoing I have discussed several important elements of quality and suggested practical ways of improving them. However, in the ultimate analysis, quality is a matter of self-discipline. Competition on price alone, tradesman's approach to industry, desire for short-term gain, etc result in many consumer and industrial products of poor quality entering the Indian market. Institutional monitoring of quality is the best way to check this practice. Emergence of the consumer movement in India augurs well for maintaining quality of household products, The Indian Standards Institution is another organization through which standards of quality are set and monitored. Associations of various manufacturing industries like Textile Machinery Manufacturers' Association, National Electrical Manufacturing Association and others provide a forum for discussing problems affecting quality pertaining to that industry. Perhaps the only area uncovered is associations of industrial users for monitoring quality from the users' end, a difficult but not altogether impossible objective to experiment with.

2. PRODUCTIVITY

As stated earlier, productivity is not maximized through the contribution of the labour force alone. In a broad sense, productivity aims at optimization of: (i) human, (ii) material, (iii) manufacturing plant, and (iv) financial resources in the business enterprise, The ultimate aim of productivity is to reduce the total cost of a product, and share the benefits between the consumer and the entrepreneur, the former through lower price and the latter through profit, growth and diversification. It is gratifying to note that in the recent past, there has been an awareness in India about the comprehensive role of productivity. Today the term 'Management Productivity' is better understood and implemented. I propose to discuss the key factors of productivity in the following:

2.1 Labour Productivity

Financial incentives, especially those related to output and hours saved are a popular and effective first step in motivating labour. A point to note is the built-in life of incentive schemes. Experience shows that to sustain the level of motivation incentive schemes need to be revis every three to four years. In addition, with his flair for improvization, the Indian worker also responds well tosuggestion and other schemes rewarding innovation., However, the monthly emolument is not the exclusive motivating factor for Indian labour. His socio-economic, needs are elastic as evident from many long-drawn. strikes that our labour has withstood without union. dole. Housing loans, marriage loans and other quantum benefits are more in tune with the occasional needs', of the Indian wor king class. This helps in creating a senseof belonging to the organization. The practice of employing one member of family of each employee within thee, organization has succeeded in many industries and merits, consideration. We have tried these methods with reasonable success in various industries in our group.

Absenteeism is the bane of Indian industries. Statesponsored welfare measures such as ESI, have unfortunately aggravated this problem and tended to be self-defeating. Many units in India have tried schemes likeattendance bonus or attendance-linked productivitybonus, etc, but only with marginal success. This is an. area where the industrialists, Government and social scientists can evolve some innovative ideas to arrest: the loss of human and manufacturing plant resourcesdue to absenteeism.

No discussion on labour productivity can be complete without a reference to the current state of the tradeunion movement. This is a difficult area complicated further by factors such as politicization, vested interests, ideologies, power play and trade unionism as a, lucrative business. I feel there are two areas where quick. progress can be made: setting norms of industriah discipline, and in creating a statutory machinery for speeding up settlement of industrial disputes. In the, larger national interest let us all strive to arrest this vast drain on our human resources. due to absenteeism, wild cat strikes and prolongation of disputes.

2.2 Productivity through Materials

The next major contribution to productivity lies in, the economic use of materials. After all ,materials account for between 50-70% of the cost of the product in most industries. The past three decades, especially under the challenges created by aerospace technology, haveopened up exciting choices of materials and processes. The main thrust has been in two directions. Availability of newer alloy steels with vastly improved physical properties like tensile strength, temperature resistance, hardenability, wear resistance etc. which permit more economical design using higher levels of performance and lower per unit cost of materials. The combining the state of the materials and the manufacturing process to give a finished component in a single operation. Progress in powder metallurgy and sintering technology as also the spectacular progress in polymer chemistry and epoxy materials are examples of the latter. The manufacture of ferrous and non-ferrous castings and their subsequent machining is substituted by sintered iron and similar non-ferrous powder metallurgy products yielding components of intricate shapes, critical dimensions calling for little or no further machining. Polymer chemistry is churning out new raw materials which compete in physical properties with metals and can be moulded into finished parts directly usable in assembly. This eliminates expensive metal forming and fabrication operations and avoid unusable scrape the bargain. Automobiles, dorr ertic appliances an similar industries catering to mass consumption are using these components extensively and economically. Epoxy resins have revolutionized the bonding of dissimilar materials and provided a stable mouldable and econornical electrical insulating material among other end uses. To achieve higher levels of prod uctivity through materials, Indian industries must strengthen their technical manpower employing metallurgists, chemical - engineers, industrial chemists and also improve the laboratory facilities within.

2.3 Contribution of Manufacturing Plant

Recent developments in machine tools and other manufacturing plants the world over aim at higher -output and reduced manpower. These are dictated by the very high levels of wages prevailing in the developed -countries, Choice of the capital plant for India is essentially an economic compromise between the latest technology, environment, employment potential, and back-up services.

For the engineering industries, CNC machines, machining centres and special purpose machines are available in a wide range to choose from. For chemical or petro-chemical industry, it is a combination of the best available process and the corresponding tailormade plant. Indian engineering industries have advanced well enough to fully exploit the inherent productivity of sophisticated machine tools, especially in the parent plants, where back services such as, maintenance, electronic engineers are available. We should increasingly use them for higher productivity, repeatability and lower cost. Incase of chemical and petro-chemical industries, the choice is very often limited by the willingness of the country of origin to part with the technology.

2.4 Production Planning and Control

The aim of a sound production planning and control system is to manufacture components in economic batch -sizes and make them available at the right time for the final assembly. Absence of careful planning results in frequent changes in machines set-ups and deteriorates into a group of progressing staff shortages. Much -greater attention needs to be ziven to this function. In 'fact, systems for production planning vary with the type -of industry whether jobbing, batch production, mass production or a process industry. It is necessary to 'identify the key factors in the operations and evolve a system around them. Efficient production planning reduces the manufacturing cycle time of the products and the WIP. These are two major sources for optimizing the financial resources through reduction of working capital in the business.

2.5 Roll of Maintenance

Maintenance of manufacturing plant and equipment is 'vital for increased productivity. As the industries become complex or export oriented, sophisticated, labour-saving machines become a necessity. The need for expert maintenance becomes even more acute. And yet this unct ion is often neglected by industries. One has only 'fo look around the power stations, construction sites, ports, railway yards and some of our factories to gauge both the loss of production and locked up vital resources through equipment under maintenance. A few enterfprises like chemical, petro-chemical and other process in dustries, no doubt, have highly specialized and well manned maintenance departments. Many more should follow their example. Efficient organization of maintenance function includes (i) provision of spare parts, (ii) trained technicians, millwrights and engineers, and (iii) special recognition and reward to the maintenance function in the organizational hierarchy.

Although a service function, maintenance should enjoy the status close to the manufacturing chief. It should get a share of the best talent in the organization. And it should provide opportunities for career advancement. It is desirable for the chief executive of the plant to visibly support and identify himself with this function in view of its vital role in productivity.

2.6 Ancillary Industries Contribute to Productivity

As the business grows, the parent manufacturing unit tends to acquire sophisticated labour saving machines and plant. Specialist services expand and the technical and managerial manpower multiplies. Consequently the product overheads increase rather rapidly; At this stage, the business enterprise finds it necessary and economical to fan out its simpler components and processes to satellite ancillary units, often spread out in the community. At other times, ancillary development is included in the basic plan of manufacture right from the beginning. Ancillary development is also necessary for specialized components such as springs, high tensile fastners, precision pressed-metal components, plastics etc where the economies of scale does not warrant installation of manufacturing facilities within the industry. Whatever the reason, the singular justification for ancillary development is the lower cost in the small, low overhead units or through scale of operation. That it serves a socio-economic purpose of spreading employment within the community is a vital but indirect social benefit.

Successful ancillary development calls for nurturing the units with support in providing quality raw materials, technical knowhow, help in selection of machine tools or processes, tooling, quality control, metallurgical and other technical services and in a few cases even plant maintenance. It is' not a routine supplier-customer relationship. Automobile and other mass production and medium size industries in India have' contributed to productivity through ancillaries developed as above. At the other end, this has also helped in developing specialized industries such as high tensile fasteners, springs. precision sheet metal components, plastic mouldings, etc.

2.7 Productivity through Standardization

The development of national standards, their use in product design and encouragement to suppliers/ancillaries in developing components conforming to these standards benefits the industry and the consumer through interchangeability, variety reduction, ease of maintenance and the economies of scale. Standardization can be beneficially applied to a wide variety of electrical components such as motors, contactors, relays, limit switches, etc, high tensile fasteners, industrial hardware like springs, circlips, pins, eye-bolts, components for hydraulic and pneumatic circuits, to name but a few.

A word of caution is however in order. As a part of the national policy, many of these standard components are reserved for small and medium sectors, where the resources and self-discipline for standardization is minimal. It is necessary that the larger units should influence and propagate standardization among these units, monitor their performance and discipline the waverers. Subject to this caution, standardization can contribute considerably to productivity.

To sum up, QUALITY and PRODUCTIVITY augment the 'VALUE' of a product, a service or even a construction project. The former through improved function and aesthetics and the latter through improved economy. Quality and productivity are complementary functions, in as much as efforts to improve one have a spin off on the other. However, it is only through active involvement, support and guidance from the top, the corporate level, that full benefits of quality and productivity can be achieved. In my lecture this evening, Quality and Productivity were analysed using the manufacturing industry model. However most of the concepts and methodology developed are applicable. equally, to a business enterprise engaged in a service or a project work.

Ladies and gentlemen. more than five decades of vigorous business life has enriched my experience through inheritance and enterprise, through experiment and stagnation and through collaborations and self-developmeht. I too had my share of success and set backs! But most of all, these endeavours have helped build a practical, personal business philosophy. When I ponder over the current economic scene in India and its future I am appalled by the deterioration in Quality inour business. Shape or form rather than Function, Decorative rather than Durable and Fatiguing rather than Facile is the hallmark of many Indian products. Added to this, there is aesthetic coarseness.

We are endowed with substantial material resources. Our human resources are equal to the best in the world. There is no dearth of capital (if recirculation is improved). And yet our products have a poor image and are priced out in a competitive market. From the foregoing it should be evident that only through improvement in Quality and Productivity can we occupy our rightful place among the industrialised nations.

My lecture this evening is not a cure-all based on these twin key factors of a business. The sole purpose is to provoke serious introspection among the Engineers, Technologists, Academicians and Business Executives who have gathered here this evening. There could be no better forum with whom to share my thoughts than this select group of professionals gathered for the Annual Convention of the Institution of Engineers 1983.

Thank you.

The Professional Engineer in India

Shri V Krishnamurthy

Chairman and Managing Director, Maruti Udyog Limited

MANKIND AND ENGINEERING

For some reason, man has been created special. Out of all the creatures of this world, man has been singularly endowed with intelligence. Many tens of thousands of years ago, man discovered that through the use of his intellect he could exercise control over his environment. He learnt to harness fire and to fashion weapons and clothes. Thesewere probably his first engineering feats.

As his understanding of the things about him grew, the greater he was able to control them. He learnt that all physical phenomena were governed by laws of nature. He learnt about some of the properties of materials; he discovered, he developed theories, tested them to prove or disprove them and developed various disciplines of scientific knowledge. Whether through necessity or for other reasons he discovered the joys of invention. That was the engineer in him.

Through engineering, man discovered that he could improve the quality of his life. Today all that we know as modern is the result of a continuous engineering effort in the past. Our homes and offices, buildings and roads, machinery and their products, automobiles, thermal power stations, dams, cloth, electricity, ships and aeroplanes-all these are the creation of engineering efforts.

EMERGENCE OF ENGINEERING AS A MODERN PROFESSION

Engineering emerged asamodern profession with the beginning of industrialisation in the West Most of the modern industries had their roots in the entrepreneurial efforts of young engineers who set about exploiting the material resources to improve the quality of life around them. They devised ways and v means of tapping natural resources for meeting the various needs of the society. Mining for extraction of metals and minerals, building of dams for harnessing the energy of water, metal working for producing tools and implements for agriculture and a variety of other goods for daily uses,are but a few examples. As man's understanding of the physical world grew, he used this knowledge to improve his capabilities further. The scientific knowledge led to new discoveries and inventions while the engineering expertise helped man in converting these discoveries and inventions into products and services useful to mankind.

As different industries came into existence, man searched for engineering solutions to various problems. He became more organised. More and more people were trained into engineering disciplines through these industrial organisations.Somevisionary engineers set up institutions to further promote the growth of engineering as a profession. Academic research and industrial institutions worked hand in hand towards the rapid growth of the engineering capability.

THE INDIAN SCENE

India followed the West in the process of industrialisation before Independence. Entrepreneur engineers like Jamshedji Tata, set about e.stablishing the early metallurgical industry in the country. The British, realising the need for basic infrastructure for managing a large country like India, established a railway and road network, and large irrigation systems for water management. This helped in building civil engineering capability in the country. Foreign multinationals looking for opportunities in the overseas markets, set up light engineering industries in the country to exploit its natural resources like jute, cotton, tea, coffee, rubber plantations etc. Thus, at the time of Independence, there was some engineering activity which had been started in the country. But, the position was far from satisfactory. About three quarters of our gross domestic product still came from agriculture. The industry was based on very low levels of technology. The country depended on imports for the bulk of its requirement of engineering goods. The annual production of steel was hardly a million tons and that of aluminium barely 4000 tons. Basic and heavy industry required for producing metals like copper and aluminium and such items as power equipment, machine tools, industrial machinery and transport equipment, was either non-existent or functioned only in patches. Infrastructural facilities were highly inadequate. The total power generating capacity installed in the country, for example, was less than 2500 MW. Institutional frame work for technical education, research and development, import of technology etc. was poor. The annual intake of students In engineering degree courses was about 4000.

ENGINEERING INDUSTRY TAKES OFF

After Independence, India's planners and policy makers chose a strategy of planned development through industrialisation and upgradation of technology. A commitment to continuous development was embodied in the Scientific Policy Resolution of 1958. This policy clearly brought out that only through the scientific approach and use of scientific knowledge can the material and cultural amenities be reasonably provided for each member of the community.

The first step towards building a strong engineering base in the country was the creation of the institutional and infrastructural framework. Five premier national institutions of technology were established between 1951 and 1960. Besides these, more than 800 other engineering colleges and 480 polytechnics were set up by 1983 as against only 38 and 53 respectively, which existed in 1947. Over 100 institutions have since been created for providing post-graduate degrees in engineering. The annual but-turn from the IITs alone has reached around 1500 graduates, 2500 post-graduates and 250 doctorates. On a macro-level, the annual admission in engineering colleges in 1983was about 42,000; the corresponding figure for polytechnics was about 77,000. About 25,000 teachers are engaged in technical education today. As a result, India has built up one of the world's largest pools of scientific and technical manpower resources.

The next step was to create a research infrastructure. Various facilities were established with the IITs. Specialised institutions like the National Institute for Training in Industrial Engineering (NITIE), and the National Institute for Foundry and Forge Technology were set up. A net-work of research laboratories were created under the Council for Scientific and Industrial Research (CSIR) and the National Physical Laboratory. The National Mechanical Engineering Laboratory, The National Metullurgical Laboratories, Defence Research Institutions, and the Bhabha Atomic Research Centre etc. were set up.

Industries in the core and infrastructural sectors were established to give the necessary fillip to the country's industrialisation efforts. Large scale technology imports were made, to establish asound technological base in the country.

Thus a stage was set for the rapid industrialisation of the country.

PROGRESS MADE SO FAR

Over the last three decades, India has achieved substantial progress on a variety of fronts. However, the achievements have not measured up to what the planners had envisaged. Considering the technical resources which are available with us, the achievements have not been satisfactory. The technological gap between us and the advanced nations has widened further since the technological growth in the West has been geometrical. During the same period, countries like South Korea and some other South-East Asian countries which started industrialising at the same time asIndia, have surpassed India in many areas of technology. Japan, whose economy was in shambles in 1947 after a disastrous war, hasrecouped, and become one of the foremost industrialised countries of the world. How did they succeed; and where did we go wrong?

ENGINEERING IN INDIA-STATE OF ART

The Indian scene isone of contradictions. On the one hand, we have made remarkable progress in some of the advanced areasof technology like atomic energy, space, satellite communication and oil exploration. Civil engineers as a class have produced notable results in their work. Indian engineers are doing remarkably well in foreign countries. Yet, on the industrial front, our achievements have lagged behind. In the case of most of the industries, we are much below the international standards in terms of the quality and reliability of our products. Productivity of our operations is very low. The comparative advantage expected in our costsof production did not materialise. Despite huge investments and technology imports, many of our industrial units haveturned sick. We still have to depend upon imports to meet a substantial part of the demand for engineering goods in the country.

Engineering as a resource has not received the pride of place in the Indian industry. It is not perceived by the industry as a pre-requisite for the long term growth of business. Barring a few examples, the industry in general has not invested in research and development efforts. As a result engineers in the industry do very little engineering.

The engineering profession, itself, has remained at a low key. Young engineers coming out of the colleges do not perceive engineering as an attractive career. Of the students who come out of the IITs, only about 40% enter directly into the Indian industry. The proportion of entrepreneur-engineers is negligible. A majority find it necessary to better their prospects by going abroad or pursuing management studies. The Indian engineer is not perceived as a figure with sufficient status. This is exemplified by the fact that though there are well-known Indian managers and even scientists, there are no household names among Indian engineers.

Contrast this with the situation in Japan. According to a recent study on Japan, "The engineer, not the financier or the professional manager, has come to represent the spirit of enterprise in Japanese society. The engineering profession has high social status and attracts the - best and most achievement-oriented young people. Doyens of the Japanese industry come mainly from the engineering function".

DIAGNOSIS OF THE SITUATION

The malaise which afflicts the engineering industry and hence, the profession, is systemic; there are a number of causal factors which are interlinked. Consider the government's role. India has a regulated economy. The government through various controls such as licensing, protective duties, controlled prices and tax measures; and by its own large investment in the core sectors of the industry, has taken upon itself a major role in the development of engineering in India.' Hence, it must share part of the responsibility for the state of engineering today. Probably there have been failures in the implementation of the government policy.

Even so, the industry through its own initiative could have developed strengths in engineering. There are some excellent examples of Indian firms which have been progressive in their approach to technological development, but this is not true for the large part of the industry. Perhapsthe slow growth of the economy has not been encouragi ng. Under a sellers' market condition,the industry has chosen to be complacent rather than innovative. It has, therefore, underutilised its engineering resources.

Why have Indian engineers entering the industry not made the difference? From the West, we have many examples of engineers who have pioneered new ventures and built the foundation for strong engineering companies. Most of the American automobile companies, of which there were a large number in the beginning, were either started by engineers, or in partnership with engineers. Thomas Alva Edisoncame up with numerous inventions aimed at the market place. There are also individuals like Steinmetz who is credited with building General Electric into a strong engineering compqny, who became institutions by themselves. In India, by contrast, engineer entrepreneurs have been few. Our industry haslargely been run by the bureaucrats in the public sector and by businessmen in the private sector and not by engineers. Why have our engineers not come to the fore? Is the lacunae with the educational system which has not created change agents?

Let us examine in depth, the roles of three sectors which have a bearing on the growth of Indian engineering, namely, the government, the industry and the technical educational institutions.

ROLE OF THE GOVERNMENT

The initial policy framework was there. Infrastructural facilities were created. The public sector was strengthened considerably. The government was committed to industrial progress. Yet the results are not commensurate. Why?

The government has not been able to follow a cogent strategy for the management of technology. In the 1950's, most sectors of the industry started off with liberal doses of foreign technology. However, unlike Japan,aserious concerted effort hasnot been made to assimilate and improve upon the technology. As a result, even today, Indian industry remains content with sporadic injections of foreign technology. Indigenous engineering development has remained confined to a few progressive companies. There is hardly any coordination or linkage between the engineering and development effort made by the industry, research institutions and academic institutions. In such an environment, no real need has been perceived for engineering skills.

In contrast, Japan which has been a great success in absorbing technology, has followed a well thoughtout strategy for technology development :

- complete absorption of foreign technologies in specific high value-added and export-oriented sectors like automobiles and consumer electronics
- emphasis on borrowing of contemporary design and product technologies and improvement in material use, process technologies and quality control systems to attain lower cost and higher quality.
- after attaining technological superiority in these sectors, striving for innovation in emerging high growth fields like semiconductors and biotechnology.

This type of concerted effort has been lacking in our planning. The formulation of specific guidelines and instructions by the government, has often thrown up inconsistencies in approach and given the impression that decisions have been taken on short term considerations rather than in accordance with a long term strategic plan.

Instead of being a promoter of growth, the government's role as a restraining force has become more pronounced as the licensing process has over the years become increasingly tied up in bureaucratic delays.

The government has a pivotal role to play in fostering R&D in the industry. People in the government who administer policy need to have a clear vision of possible future technological scenarios and have a clear idea of what path we should take. An overall perspective, guidance, encouragement and fiscal incentives are needed if R&D in the industry is to be pursued seriously. This has, unfortunately, been lacking.

CASE OF THE INDUSTRY

While the government companies have been run by the administrators, the private sector has been in the hands of the businessmen. Perhaps the reasons are historical, since the Indian industry has evolved from the trading houses of the yester years. Approach to business in the industry still suffers from the trading culture; the emphasis too often is on quick returns and not on long term growth. This is one reason for the poor investment in engineering and development which is essentially a long-term measure.

While there has been very little R&D in the industry there has not developed any close links between industry and R&D institutions. The record of projects transplanted from R&D laboratories to industry is very poor.

Within the industry, growth opportunities are perceived to be greater for personnel in marketing, finance and other general management areas. This is exemplified by the fact that there are fewer engineers, especially those who have come up through the engineering functions, at Board level of companies, than is warranted by the importance of this discipline and the number of engineers in the industry.

ENGINEERING TO THE FORE-SOME POINTERS FOR FUTURE GROWTH

During my association with BHEL, we have taken some steps to strengthen the engineering capability in the organisation. Some of these efforts did not meet with success and may also be applicable to many other organisations. let me share some of these experiences with you.

In the early 70s,when we conducted a position audit of the engineering function in BHEL, we found that while the company had a very large population of engineers, the technology obtaining in case of most of the products was quite obsolete. Compared to the international standards, various products compared unfavourably in terms of performance, price and reliability. An in-depth analysis of the situation revealed that the role of the engineering function in the company itself was not clearly defined. Most of the engineering professionals were engaged in work which was routine. There was no emphasis on developmental work for ensuring continuous upgradation of technology for various products. Engineers were not exposed to developments abroad. There was no clear interface between engineering and marketing. Engineers were not conscious of the customer needs or the cost which went into the manufacturing of various products. An urgent need was felt to develop a strategy for revitalising the engineering function.

One of the most important features of the strategy which was designed, was the creation of the post of Engineering Development Manager (EDM). These were people from the middle management levels and were envisaged principally as technology managers. Their first task was to conduct a technology audit in their respective product areas. Having assessed the state of the art of technology in their product areas, they were to keep a continuous watch on emerging technology scenarios in the world and help to keep BHEL technology levels up-to-date. New product ideas were brought before the Engineering Committee. The responsibility for locating new technology and arranging for technology transfer was that of the Engineering Development Managers. As a result of the efforts of these engineer managers, BHEL came to offer contemporary technology in many product areas.

Without going into the other elements of engineering reorganisation which we did in BHEL as part of the above strategy, I would like to emphasise that it is this role which is most important and is lacking amongst our engineers. Only when our engineers would grow to become good engineer managers, can this function really attain the status it should in our industrial organisations.

NEED FOR CONTINUING EDUCATION

Another method by which the industry can promote the growth of engineering is by ensuring the continuous education of working engineers. Industry should realise that this is a basic and essential responsibility.

For instance, we could have courses for engineers from the industry in educational institutions, as well as in training centres in industry. In these courses, emphasis could be put on inputs for future professional development, which include not only new technological developments, but management related aspects of productivity, economy, safety and human relations.

There is also a need for government incentives to the industry, to promote the continuing education of engineers. There is the example of the 1971 legislation in France which made the support of continuous education a legal liability of employers.

The importance given to continuing education in Japan is one ofthe major reasons for their engineering strength. Some of the major Japanese companies, for instance, Hitachi and NEC, have set up Institutes of Technology with curricula designed to meet their specific needs, Employees who take these courses, have to do so in addition to their regular work. The faculty is also most often drawn from the ranks of the company's executives. This achieves, besides the systematisation of the technology transfer within the company, the further training of the instructors who must refresh and organise their knowledge for effective teaching. The Japanese engineerthrough his career thus remains abreast of the latest developments in his field.

REFORM OF TECHNICAL EDUCATION

On the technical education front, India has been successful in setting up a large number of institutions. Some of these institutions also have excellent facilities. However, the desired impact in terms of contributions to the industry by the graduating engineers has not been substantial.

There are several factors which could be identified as shortcomings in the current educational system. These include the failure to attune the curriculum in technical institutions to real environmental needs, lacunae in the structure of the educational systemand teaching methodologies; and lack of substantial interaction between the educational institutions and industry.

CURRICULA IN CONSONANCE WITH ENVIRONMENTAL NEEDS

To be effective, technical institutes should be sensitive to the developments taking place in the industry. When technological upgradation is taking place rapidly in the industry, the curricula should also respond. This is rarely happening, so that students emerging from our institutes find their knowledge base inadequate.

Curricula planners should achieve a balance between technological and economic needs. High growth sectors should be identified and catered to. For instance, today the automobile industry is coming up as a major growth sector but there is no course on Automobile Engineering in the IITs.

The curricula should put emphasison national priority areas such as agriculture, energy, natural resources and transport.

In addition to harmonising with the physical and economic environment, engineering education must reflect the cultural values in the social environment. Too much Western bias in Indian technical education hasresulted in the output of 'elitist' graduateswho are dissatisfied with working in the Indian rural and industrial milieu. This situation is perpetuated because students learn from teachers who are committed to research and not social' or industrial progress.

Another problem is the lack of inputs in the areas of management and social sciences. Curricula in engineering colleges contain some courses on these areas. However, they are insufficient in number and inadequate in quality. The result is that graduate engineers find themselves in a real-life environment where they cannot comfortably apply, their theoretical knowledge. This, and the quest for more lucrative jobs, causes the annual exodus of engineers to non engineering professions. .

If industry and the institutions could get together and design a more comprehensive environment-oriented package for engineering curricula, the chances of orientation in real-life environment, and acceptability of graduates as capable engineer-managers might increase. The prime reason for the low involvement of industry in engineering education is perhaps the low relevance which the academic and research work in educational institutions have for the industry. Since the industry tends to keep away from the academic and research work of these institutions, the possibility of their adapting this work to the industry is further reduced. Thus the whole relationship has become a vicious circle.

The only way to break the vicious circle is for the industry and the academic and research institutions to come together. The academic institutions should continuously review their curricula and adapt them to suit the needs of the industry. Similarly, the industry should actively sponsor research work by these institutions to promote their growth in the desired direction. A regular exchange of personnel from one to the other would also go a long way in bringing the industry and the academic and research institutions together.

NEED FOR AN ENGINEERING CULTURE

Traditionally, India is an agrarian society. A large number of people are still illiterate. Even amongst those who are literate, persons who have a technical education as a percentage of the population is quite small. Because of this, as a people, we do not have the type of "engineering culture" which is prevalent in industrialised nations. We need to increase emphasis on exposing our children right from a young age to subjects like mathematics, science and other technical areas. They must be encouraged to work with their own hands and get familiar with scientific and technical tools and implements early in life. I think the primary reason for the success of Japan is the emphasis Japan has placed on attaining almost 100% literacy and on teaching their children from the very young age, technical subjects which may be considered quite advanced even by the developed nations. A Japanese child today, is well-versed in mathematics, science and other technical subjects, and in computers. The spirit to excel, an openness and eagerness for new ideas and a thrust for new knowledge and innovation is instilled right from the beginning. For our children also, applying new techniques and new tools should become a way of life. Only if we could achieve this can we really have hope for this profession, in the future.

CONCLUSION

Our forefathers have left us with lasting evidence of their brilliance. Long before it was thought about in the West, Indian visionaries had conceptualised the aeroplane, The iron pillar of Ashoka still defies our understanding. Architectural creations like the Taj Mahal, and the cave temples of Ajanta and Ellora are testimony to the artistic perfection our forefathers had achieved.

Somewhere along the way India lost the initiative it had held. While scientists and engineers in the West made new discoveries and inventions, enlarging their understanding of the physical world, and spearheading rapid industrialisation and economic progress, India lagged behind and today, is still in the process of catching up. Only a concerted effort on the part of the government, the industry, and the educational and research institutions can change the course of events as they have progressed so far in India, but the critical responsibility in this task of rebuilding our nation still rests with the engineers. It is we engineers who must shoulder the responsibility of building a strong Nation and ensure a high standard of life for our people.

Towards 21st Century Role of Engineers

Col S P Wahi

Chairman
Oil & Natural Gas Commission

NEW ERA OF ECONOMIC DEVELOPMENT

1. The country is marching towards an era of rapid economic growth under the new leadership. A large number of measures have been initiated towards achieving the objective and taking the country with confidence towards 21st Century. The focus is on increasing efficiency, optimisation of existing resources, reducing costs, improving quality and technology upgradation. The entire gamut of new economic policies is oriented towards stimulating growth, promoting savings, investment and reducing the social and economic disparity.

HISTORICAL PERSPECTIVE

2. India, after years of colonial rule of neglect, has come a long way since independence in establishing a strong industrial base, a large reservoir of scientific and technical personnel and an infrastructure capable of taking the country forward at an accelerated pace for the benefit of the SOCIETY, with all its multifarious problems associated with diversity of social, cultural and religious backgrounds. In almost all important sectors of economy; the Engineers have played a major role in achieving a reasonable growth.

3. A few indicators given below project growth in various sectors of economy:

	1960-61	1983-84	1984-85
Total GNP (Current prices) (Rs. Bn.)	140	1727	
Agricultural Production			
Foodgrains (Mn.t.)	82.3	151.5	150.5
Industrial Production			
Coal (including Lignite) (Mn.t)	55.7	144.86	155.24
Petroleum (Crude) (Mn.t.)	0.4	26.23	29.[illegible]
Iron Ore (Mn.t.)	11.0	38.2	42.20
Finished Steel (Mn.t.)	2	6.14	8.77
Machine Tools (Mn.Rs.)	70	2724	3030
Cement machinery (Mn.Rs.)	6	448	540
Power			
Electrically installed (Mn.Kw.)	4.7	43.3	49.25
Electrically generated (Bn.Kwh.)	16.9	150.25	167
Fertilizers			
Phosphatic fertilizers (th.t.)	52	1048	1264
Nitrogenous fertilizers (th.t.)	98	3485.0	3917

4. The increasing investment in the five year plans also indicates the economic progress.

Investment in Five Year Plans

(Figures in bracket indicate percentage)
(Rs. in bn.)

	I Plan	II Plan	III Plan	IV Plan	V Plan	VI Plan	VII Plan
Public Sector	15.6 (46.4)	37.3 (54.6)	63.0 (60.6)	136.5 (60.3)	367.0 (57.6)	840.0 (52.9)	1800 (56.3)
Private Sector	18.0 (53.6)	31.0 (45.4)	41.0 (39.4)	89.8 (39.7)	270.5 (42.4)	747.1 (47.1)	1400 (43.7)
Total :	33.6 (100.0)	68.3 (100.0)	104.0 (100.0)	226.3 (100.0)	637.5 (100.0)	1587.1 (100.0)	3200

5. After Independence, India's planners and policy makers chose a strategy of planned development through industr ialisation and upgradation of technology. A commitment to continuous development was embodied in the Science Policy Resolution of 1958. This policy clearly brought out that only through the scientific approach and use of

scientific knowledge can the material and cultural amenities be reasonably provided to each member of the community.

FUTURE CHALLENGES

6. Inspite of commendable growth in almost all sectors of economy, India continues to be 37% below the poverty line. The first and foremost challenge before us is to increase the industrial and economic growth at a pace faster than ever before for achieving the minimum level of subsistence for our growing population and raising their standard of living.

Growing Population

7. Population in India has grown from 548.1 million in the beginning of 70s to 738 million today,a growth @ 2.25% per annum – posing a threat to the results of the tremendous efforts on economic front reaching everyone. Growing population has emerged over the years as the greatest impediment to the benefit of the population itself. Therefore, controlling the population within the framework of existing cultural, religious, political and socio-economic conditions prevailing in the country is itself a major task.

Human Resource Development

8. India has today World's third largest reservoir of technical manpower after USA and USSR with around 2.5 million people and. about 1,50,000 new personnel in this category joining the ranks every year. Scientific and technical manpower resource base is one of our greatest strengths today but poses the greatest challenge as well in terms of their optimal utilisation towards the growth and economic development of the country, as we continue to depend on external expertise and support in areas that we are capable of handling perhaps even better. There is a need for introspection.

9. There is also a need to have a serious relook at what is being taught in our educational institutions, the methods of training, equipment and scientific apparatus being used. Is there a link with the latest technological and scientific developments? The last 35 years have seen the greatest technological advancement; the introduction of commercial jet travel, widespread use of computers, space travel and many other innovations which have transformed the life styles, living standards and raised new expectations of the society. The developed world is passing rapidly to a new phase of technological revolution.

10. The coordination between the Academic and Research Institutions, industry and the decision and policy makers assumes a great importance. The subject has been debated In several forums in the past and continues to be debated today leading to the evolution of educational policies and appropriate mechanism for an effective coordination but there is considerable scope for improvement.

11. ONGC had organised very recently a brain storming session with the Heads of the Universities, IITs and other scientific bodies to interact and work out a more effective mechanism for University industry collaboration with encouraging results.

Training &: Development

12. With the rapid technological development and new management techniques getting evolved, the knowledge gained in the educational institutions will have to be updated. There is a tendency to be carried away by what was learnt in the school/college/Universities and through one's own experience. This is not a healthy situation. There has to be continuous development of skills and knowledge. We have been witnessing knowledge explosion around us. To remain updated, continuous training and retraining is important on organised basis.

13. The technological developments influence the behavioural pattern of the people. This is an important aspect. It is not easy to bring about change. The normal tendency is to stick to the traditional system. Therefore, to bring about any change to meet the growing needs of the society in line, with the developments in the world, attitudinal change through training and retraining of teachers also assumes importance. Their exposure to latest developments abroad is very important.

TECHNOLOGY MANAGEMENT

Infrastructure

14. Systematic Planning through the vision of our leaders like Pandit Jawahar Lal Nehru has enabled India to build strong engineering and technology base. The setting up of Council of Scientific and Industrial Research (CSIR), a set of Agricultural Research Laboratories under the Indian Council of Agricultural Research and Medical Research

Laboratories under the Indian Council of Medical Research, in addition to specific emphasis in the field of Electronics, Defence Production, Space and Atomic Energy through the creation of separate Departments to deal with these aspects has been a step in the right direction. The technology policy statement of 1984 also highlights the Government's concern and the measures needed at different levels to bring about the required transformation for the benefit of the Society. Inspite of these concerted efforts technology management continues to be the greatest challenge before us for acquiring the required degree of self -reliance.

Research & Development

15. We have continued to import technology for all most every industrial and scientific activity, inspite of the fact that a chain of Research and Development Centres have been established.

16. National expenditure, as evident from figures below has continued to increase without commensurate results.

NATIONAL EXPENDITURE ON RESEARCH & DEVELOPMENT
1980-81 to 1983-84 (Rs. in Crores)

Year	Expenditure	% of GNP
1979-80	674.33	0.71
1980-81	813.64	0.71
1981-82	1003.45	0.76
1982-83	1237.56	0.85
1983-84 (estimated)	1427.87	-

17. India continues to depend on technology support from external sources even in areas which could be indigenously managed. India's investment in R&D is 0.7 to 0.8 percentage of GNP as compared to USA (2.5%), Japan (2.4%), UK (2.2%), USSR (4.9%).

Our scientists continue to invent wheel and produce excellent reports without any impact on technology upgradation.

19. The industry has also paid little attention to the upgradation of the imported technology, with the result a lot of our industrial products are based on obsolete technologies.

20. A multi pronged approach is needed in managing the Research and Development in the country.

21. The thrust has to be on adaptative R&D to remain in line with the best in the world. There is no point in wasting effort on something which has been developed somewhere else in the world and is available at a price. There has to be the will to continue to upgrade the technology, so that the products are competitive internationally both in quality and price.

22. The R&D units with Industry should be run as profit centres, so that the scientists and engineers have the pressure to maintain time, quality and cost standards. The basic Research to meet the future needs should be farmed out to the educational institutes and pure basic Research Centres.

TECHNOLOGY UPGRADA nON &: TRANSFER OF TECHNOLOGY

Inter-Institutional Level

23. Technology upgradation should be brought about through the exposure of scientific and technical personnel to the latest developments in the world. Inter laboratory links between the Indian institutions and Internationally reputed laboratories in the world in the form of Memorandum of Understanding / collaboration arrangements for two way exchange of experts, scientists, could be an effective medium of technology transfer.

Joint Venture / Technical Collaboration

24. Joint Ventures / Technical collaboration arrangements between Indian and foreign companies in selected areas have become an important source of transfer of technology. There should be a careful selection of both parties and emphasis on continued upgradation of technology as an essential part of the terms and conditions.

Audit

25. Technical Audit, Management Audit and Technological audit should be conducted as a matter of rule with a view to make mid course corrections. A large number of special studies conducted in ONGC and implementation of the recommendations contained in such studies have resulted in savings and generation of newer ideas.

ENERGY MANAGEMENT

26. The rapid economic development would call for matching energy resource development, a major challenge for our survival. We are fortunate to have abundant untapped Natural mineral resources, including hydrocarbons. Oil would continue to play a major role in the energy sector in the foreseeable future.

27. Oil is non renewable resource and therefore calls for efficient use and conservation, so that it lasts longer. There is a need therefore to have a National objective to move away from dependence on oil by switching over to alternative fuels and development of Hydro and Nuclear Energy resources to the maximum.

28. There is an urgent need to have an Integrated National Energy long term plan at least for 25 years to enable switching over to alternative energy systems in a smooth manner.

29. Measures to ensure conservation and efficient use of energy have to be taken up on war footing in case the needs of growing economy and population have to be met adequately. Massive campaigns to make everyone conscious of energy crisis have to be taken up through media and educational system.

30. The management of demand should be effected through a system of administered pricing, the energy audits, effective monitoring mechanism and through the setting up of an integrated energy management Cell at the Apex level to plan, implement and monitor the programmes.

31. Energy inefficient equipment and systems need to be replaced through incentive and regulatory measures. Atleast 10% savings can be ensured resulting in savings of thousands of crores.

32. ONGC has set one of the objectives to assist in conservation and efficient use of energy and development of alternative sources of energy.

INFORMATION TECHNOLOGY AND MANAGEMENT

33. A new emerging technology which is going to fashion the future of the very nature of human society is information technology. This deals with information storage, processing, transfer, communication, retrieval and utilisation. There is a whole information industry which has been created in the recent years. It has its hardware in the form of computers, displays, commercial devices and so on.

COMMUNICATION

34. Most modern communication system for effective flow of information and control of operations and quick decision making is vital. This is one of our weak links and merits a big thrust, to ensure efficient operations in every economic activity.

QUALITY CULTURE

35. The captive domestic market has perhaps led to complacency and lack of quality consciousness in the Indian industry. The variety of engineering goods being manufactured within the country can contribute towards India's much needed foreign exchange reserves through exports if adequate attention is paid to quality aspect.

36. To quote our Prime Minister in his recent address on 22nd March, 1985 to the National Conference on Engineering Exports:

> "Quality of our products really leaves very much to be desired. One of the problems is that we are selling to a captive market. We are selling to a market which is not responsive to quality. We are selling really in an absolutely sellers' market. It will change. In our recent policy statements, in our budget, we have tried to change them to some degree. But our market of 700 million is so vast that is not going to change quickly. The industry will have to change faster and will have to make the market change because ultimately you will be called upon to compete not with each other but with other industries in the world. And we must prepare for that day today."

37. A culture of 'Zero Defect' must prevail if we have to achieve competitiveness in International market, which is so vital for economic development and growth of our economy.

ENVIRONMENTAL MANAGEMENT

38. Over the past decade we have begun to recognise the importance of environment. Earlier, man was but a small entity, consisting of small population with small activities on a globe which by comparison was infinite to absorb all the end products of human activity. Today, the position is quite different with growing population, increasing technological and industrial activities and the limited carrying capacity of the earth to absorb the outputs, the

Management of environment takes on a new important dimension, to protect the society from ill effects of pollution and other hazards created by industrialisation.

INNOVATION AND CREATIVITY

39. In an environment where new technologies, products and methods and systems of operation render the old ones obsolete, at a rapid pace, Innovation and Creativity are vital for the very survival of organisations. All growing economies have witnessed vital role of innovation and creative thinking in their process of development. Appropriate systems and mechanism should be devised to motivate people to come out with ideas through recognition, formation of creative thinking groups etc. A very simple idea could lead to a significant impact on the organisation in terms of bringing about cost savings, improving efficiency and productivity.

LONG TERM PLANNING

40. Long term planning is an essential element for achieving the desired level of growth with efficiency. Ad-hoc decisions could be avoided by this process. Short term goals should be dovetailed into long term plan. This approach avoids compromises and in the long run improves efficiency and ensure growth with stability.

PROJECT MANAGEMENT

41. One of the major challenges for the future is the efficiency with which We manage 'the projects. The past record particularly in the Public Sector has been unsatisfactory. One of the main reasons has been that authority rests with the Bureacracy and responsibility with the Managers resulting in serious delays. Apart from these the Managers themselves have been responsible for delays by not managing the constraint effectively. This aspect calls for serious attention to optimise the slender financial resources at our disposal.

MANMANAGEMENT

42. No doubt management of machines, Technologies and other material resources is important but more important is the managing of the 'Man' behind the machines. His motivation and morale are most important to achieve optimal result from other resources.

43. Engineers all over the world as also in India have made major contributions in bringing about scientific and technological breakthrough for the benefit of the society. Indian engineers have achieved international standards and eminence in various fields - Engineering community should be able to influence government opinion on issues of national importance and manage the challenges ahead of us.

44. The task of gearmg up for moving the country towards 21^{st} Century with confidence is enormous; and engineering community has a positive role to play towards this end. There is a need for "CHANGEAGENT" in every area of activitiy to bring about an industrial and technological revolution to meet the challenges. No one can play this role better than the Engineers.

Approach To Environmental Protection and Role of Engineers

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INDUSTRIALIZATIGN AS AN INDEX FOR CIVILIZATION

'Manufacturing goods in terms of varieties and quantities' is the present day index of advancement of Civilization of a netion. United States of America and Japan today produce more than a million varietics of marketable goods and for some goods the quantity manufactured in a year runs into billions. I am differentiating markcteble good from the componcnts that are put together to make that goods ready to be sold in the market. A pocket calculator requires 50 different components like liquid crystal display (LCD), printed circuit board (PCB) to keyboard, and I am referring the calculetor as the marketable product and not those componcnts.

The size of e country with proportionate resource base is not necessarily an aid in putting the country in the higher renk of civilization in terme of the tndex narreted. If that was so, then Japan could not be bracketed with the USA as Japan is one-tenth of the USA in terms cf size and with very negligible raw material resource base, Similarly, one city nation like Singapore and Hong Kong, or, tiny.country like south Koree and Taiwan are occupying higher rank than the USSR, Canada, China, Brazil, or Australia. If the size of a country and resource base could be the criterioh th putting a country in the higher rank of civilization in terms of the index narrated, then the order would have been the USSR, Canada, China, the USA, Brazil, Australia and then India.

The raw materials that go into manufacturing the components of marketable gocds cannot be totelly transformed into components. A major fraction of the raw meterials is left over as residue. For every 100 t of paper produced 40 t of lime sludge are generated as residue; every 100 t of steel generetes the steel making process 150 t of solid wastes and one can draw a long list. Each city or town is a manufacturing centre not necesserily for industrial goods. Even for the living of the large number of people in the city or town, huge quantities of materials for food, shelter and clothing are required which produce also large quantities of residues. Municipal garbage has become a part and parcel of city living. City dwellers in India produce 2.5 kg of municipal garbage per day per person, while city residents of Japan and the USA produce 4 and 5 kg of muncipal garbage, respectively.

William Rethji, an anthropclogy professor with doctorate in archeology said, 'Archecologists study ancient gerboge te learn about past civilizations. Here we look at our own refuse (municipal garbage) to learn about our own civilizaticn, in terms of behavigur that produces the things we throw away. OUR TRASH IS THE UNVARNISHED IMPRINT OF OUR LIFE STYLES. When I first heard of it, I could hardly believe it that after the garbage is collected twice a week in the city of Tucson, Arizona, USA, some of those big plastic bags ore opened and the contents painstakingly examined, clessified, weighed, and recorded by studunts from the University of Arizona under the guidance of Prof Rathji. What a strange or nauseating material for investigation and research to obtain a doctorate degree. But the study revealed meny truth hidden under the cover of garbage. It was possible to report that some low-income Mexican-Americans in Tucson buy more vitamin pills end educational toys than middle-income Mexican-Americans and Anglos. Or, after interviews with house-holders in a specific area, that while only one family in four admits to drinking beer at home, beer cans turn up in the refuse of three out of four. As Prof Rathji puts it, "People will tell you what they do or think they do, or what they want you to think they do. Garbage is the quantifiable result of what they actually did'.

NEW INDICES TO RANK CIVILIZATION

What I intend to propose is a different yardstick to measure the advancement of civilization of nations of the world. The nation which produces goods with the least production of residues and has achieved proper disposal of that residues having no short-term or long-term side effects of disposal should be ranked highest in the new ethos of grading civilization. Here engineers along with scientists have a dominant role to play. When the miracle drug Dichloro Dibromo Trichloroethane (DDT) was commercial idly produced after achieving its successful killing power for pests on the research table, the world communities welcomed the chemical. The USA, the country which synthesized this chemical first both at research table as well as at commercial plant, never assessed the side effects of this chemical at the consumers' end and also the side effects of the residue at the manufacturers end. The effect of this Chemical as pesticide at the consumer's end has been very ably described in 1962 by Rachel Carson in her shocking book entitled 'Silent Spring'. The application of pesticides effectively killed all insects non-selectively, non-selectively in the sense of whether the insect is pest to agricultural crop or not. As a result, birds predating on insects, either died cf starvation or those who struggled to keep alive by eating DDT-killed insects laid DDT-affected eggs which never hatched. Spring after spring the bird population dwindled and then there were left no bird to usher in the spring with birds' song end steclthily came a Silent spring. The book had its impact. Since the publication of the book, the USA debated for six years before banning application of DDT in the country.

What was not surfaced through the book 'Silent Spring' was the problem of residues at the manufacturers' end. With each tonne of DDT produced, an equivalent amount of lime sludge is produced which is used to neutralize the acidic wastewater. The lime sludge not only traps the main product DDT which comes out along with wastewater as a result of repeated washing but also traps the precursers of DDT (small chemicals which ore put together to synthesize DDT) and the DDT metabolites (breakdown product of DDT). These precursors and metabolites have equal if not greater carcincgenic capabilities than the main product DDT. Proper disposal of this solid waste is still a problem, Because it was not surfaced in the book 'Silent Spring', use of DDT was banned in the USA but not manufacturing. A country cannot continue manufacturing a product unless market is found cut. So smart alecs haunted ill-informed countries and continued production by selling the product to those countries.

ECONGMIC PROVUCTIOGN VERSUS ECOLGGIC PRODUCTION

Through this incident I intend to propose to the chemical engineers, chemical technologists, industriel chemists and people in similar disciplines to question the process of manufacturing you ere planning to adopt and reveal net only the line of production but also the residies — Solid, Liquid or gaseous in nature — and their scope for recycling, recovering and final disposal. If there are more than one processes available, reveal the nature and extent of residues and the arrangements for their dispusal and evaluate the merits of each of the processes in terms of residue recovery/recycle and disposal to help the decision making authorities.

Any process of synthesis or menufacturing any product invented today must be subjected to three basic questions or scrutinity before it is cleared for synthesis or manufacturing.

1. The synthesized or manufactured product must get disintegrated as soon as it comes in contact with nature. The rationale for this question needs elucidation. Age old traditional cleansing soap is the sodium salt of fatty acids like palmitic acid. With the advancement of polymer chemistry sodium palmitate as cleansing soap got replaced by synthetic detexgent end ere sold under the trade name of 'surf', 'det', ''Nirma', etc. The basic chemical which provides the cleensing power is alkyl benzyl sulphonete (A35). The detergent became popular with housewives because of its greater cleaning power and labour saving property. But the flow of detergent in the natural watercourses caused problems. On the one hand, nature did not know how to disintegrete it and, on the other hand, the foam it formed covered the watercourses and caused hindrance to oxygen transfer from atmosphere to the watercourses. Aquatic life including fash requiring oxygen to breath died due to axphyxiastion. Researchers in the labovtetory realized the significance of this question. Concerted end concentrated efforts for developing a detergent that would elean clothes and get casily disintegrated in contact with See neture produced an alternative to ASS. Its chemical name is linear alkyl sulphonete (LAS).

For the same reason, pesticides like DDT know, as Organo-chlorine compouncs got replaced by groups of chemical called organo-phosphorous as the latter groups of the chemical could get casily disintegrated in contact with Nature.

2. The precess of synthesis or manufacturing should be so chosen as to maximize conversion of raw meterils into products and thus minimizing the residdes. This question is relevent not only from the view point of environmental protection but also for the economics cf the process. To make a fertilizer like urea one needs to synthesize ammonia first. Ammonia may be synthesized by taking stochiometric proportion of nitrogen and hydrogen; but in actual production ungeacted nitrogen and hydrogen are left as residues which get vented out. Both nitrogen and hydrogen are obtained at certain cost of energy and effort. Nitrogen is obtained by cryocenic scparation from air and hydrogen may be obtained by electrolysis of water. Every molecule of unreacted nitrogen and hydrogen while synthesizing ammonia costs energy and, of course, money. Here is a caste where venting out of nitrogen and hydrogen to etmosphere would not cause so much environmental problem as both the constituents are part of atmosphere the former belongs to air and the latter to the moisture in air.

3. It is an offshoot of the second question. Recycling of the residues is fully explored at the present state of knowledge. Recycling of residues either in the same process or in some other processes needs exploration. tven then there would be some residues left. Hence it is necessary to ask, as a continuation of this question, if these residues can be disposed off hygienically. While manufacturing phosphatic fertilizer from rock phosphate (the natural raw

materia) phosphogypsum is produced as residue. Gypsum is one of the raw materials for producing cement and phosphogypsumy™ can be used provided the phosphorous and flucrine contents of phosphogypsum can be brought to the level as desired by the cement industry. Gypsum in nature es used by the cement industry contains not more than 40% of calcium suiphate, hence the cement industry needs to throw away the 60% undesired material fer which the industry pays both transporation cost and separation cost. But phosphegypsum from phosphatic industry contains more than 96% as calcium sulphate.

The above example leads to eanuther question relatec to industrial production planning. If tesidues of one industry can become the raw mot rials of another industry why not those two industries be sited together. This concept can be named as Compatible Industrial Cluster. The nature practices it. Take any ecosystem, a village pond say. Here you will find various species of living systems living together on the concept of utilizing wastes of one species by the other species and so on, instead of competing for the same raw materials.

It is interesting to note that everything is cyclic in nature. The well known biogeochemical cycles like CO_2- O_2 cycle, nitrogen cycle, phosphorous cycle, sulphur cycle are too well known. As a result, uninterfered by externalitics all times in the cycle is renewable and hence do not get exheusted. The famous hydrologic cycle tells us of never exhaustible water resources, Whereas all our production systems are linear. Iron ore to steel, steel to pieces of furniture — furniture does go beck to produce iron ore. Of course, production of steel from scraps satisfies the cycle order to some extent.

In the same ecosystem species do not compete for the same raw material. It helps in maximizing production. Following this example as nature practices, composite culture in fish production is introduced by fishery scientists. In a pond six varieties of fishes are cultured: (i) top dwellers feeding on phytoplankton, (ii) top dwellers feeding on zooplankton; (iii) & (iv) mid-level dwellers feeding on phytoplankton and zooplankton, respectively; (v) and (vi) bottom dwellers feeding on phytoplankton and zooplankton, respectively. Further predators-predated systems ketp a balence in population which the human species has lost and now struggling to survive amongst billions.

DEVELOPMENT MODEL OF TODAY

I think most of you would agree with me that the type of development with which we ere familiar teday is the major cause of environmental degradation. Probably vou would be more convinced if some cases are cited. As we increase irrigation we get more end more land waterlogged or turned saline. As we increase roads natural drainage is impaired and many forests get destroyed as these become approachable and hence exploitable. Gur coal mines are death-traps. We uncover iron-ore causing flooding to agricultural land, forests get disappeared to supply paper — a basicingredient for education. With urban sprawl we get urban slums. It is, therefore, imperative for us-to redefine development and also discipline development.

The western model of development set by developed nations would be difficult for the new nations of the third world to imitate. The western industrialization effort of the eighteenth and the ninteenth centuries was conducted at a time when large areas of the third wotld and also the new world were made available to the people of Europe. The ecological. demands of industrializing the West, steadily and rapidly exploding, were satisficd through the creation of a new global niche that would be responsive to the demands of the machine and not to the indigenous communities.

The third world today will heve to develop using the western model under several constraints. Industrielization of the advanced nations is still underway and continuing. The third world or the new world (America and Australia) which served as resource base is still remained intact instead of being rerouted to service the needs of the new nations of the third world who are aspiring development. The cheap human labour available to the developed nations during their initial period of growth was supplied from the thrid world which would never be available to the nations of third world. The present day protagonists of development, oil-rich nations of middle-east, are copiously supplied with cheap human labour from Korea, Thailand, and the Indian subscontinent. Immediately after the Second World War, the Federal Republic of Germany received human labour from Turkey, Iraq and Iran,

Furthermore, the people of Europe could migrate to dominate new lands like North and South Americas, Australia, New Zealand and South Africa. Such opportunity is not aveilable to the exploding population of the third world. Instead, the third world is, faced with brain-drain.

Thus, yyou would notice that the model of development the west has given us requires ample space, geographical space, or should colonies which shoned serve as raw material as well as agricultural and human resource base. How the third world nations would do that without having any scope for building colonies anywhere. Obviously these nations will have to internalise the ccncept of colonies — laying claim to its own hinterlands, mostly settled with subsistence (like West Rajasthan) and ecologically developed communities (like Arunachal Pradesh) and subsume these areas to the requirements of the development programmes. It means development western-style will hove to operste ageinst the millions who would perforce have to remain outside the system, compromiss their life-styles and their rights to survival. Thus the construction labour of Delhi has to come from Western Rajasthan and even "wood - for cremation from Arunachal Pradesh." 'Development then would become officially sponsored triage, as Claouce Alvaorec puts it. 'The evidence can no longer be denied; since the pert four decades, everywhere in the Third World, the condition of the vast majority, after development, has detericreated rapidly'[2].

REDEF INING DEVELOPMENT

Recognizing the constraints narrated and realizing the fact we do not need officially sponsored triage in the name of development, development and clso the process of development need to be redefined. Development must have two merits: (i) equitable distribution of benefit, and (ii) minimal or no degradation of the environment. Even within a country natural resources including agricultural land and water, and skill may not be uniformly distributed, Stimultaneous oecurence of drought in some parts while flood in other parts is seen frequently in India, For equitable distribution of water many excellent ideas including inter-basin water transfer like Gangalauvery link are cunceived and put forward without even assessing the environmental consequences of such intembasin transfer of water. We all know about the Beas-Sutlej link as an engineering marvel wherein the waters of the river Beas, running at an altitude higher than thet of the inner Suilej but parallel to the latter, arc brought to the Sutlej. Taking advantage of the hydraulic drop hydroelectric power is generated through this link. The link is partly canal (open), partly in tunnel through hilly terrain, obviously stands in testimony of the Cavil engineering skill of the engineers of the country. Interestingly not a single word is uttered in the planning of this scheme about environmental consequences. The Delhi School of Planning and Architecture demonstrated some photographic eyidences of the damages the link caused to the pristine environment along the link route. It is but natural that certain trees will be cut, certain rocks will be blasted and certain parts of the otherwise uninterfered jungle will be cleared to lay the link route. One could sit and find out the best link route among several which would cause minimal damage to the environment during construction of the route.

I am talking about still deeper environmental consequences that may be happening as a result of this intra-basin transfer. Remember, Beas and Sutlej bulong to the same river basin, that is the Indus river basin. I am tempted to cite an example wherein a similar hydraulic marvel caused a tremendous environmental damage. The countries are the USA and Canada, the waterbody is Saint Lawrence river. There are five fresh water lakes bordvuring the USA and Canada and these ere Superior, Michigan, Qntaric, Heron and Erie. Saint Lawrence river is the outlet of these five interlinked fresh water lakes and reaches the Atlantic Ocean. The Niagra Fells is located on this river. Below Niagra Falls till to the sea, the river is navigable even for ocean-going vessels. Areas surrounding the lakes, Specially Lake Superior, are rich in iron ore. It was realized that if ocean-going vessels can reach the ports in Lake Superior then a vast hinterland would open up to global trade including iron ore. A well designed canal with lock gates to handle the hydraulic difference caused by the Niagra Falls was conceived to bypass the falls. The Welland Canal, named after the then Governer of New York State; was built. Ten years later it was observed that catch of edible varieties of fish started decreasing. Fishing industry from catch to processing suffered a setback. Researchers started investigating tne cause. It took another five years to realize that the creation of the Welland Canal to bypass the Niagra Falls brought misery to the fishing industry. Niagra Falls, thus far, was acting as a barrier to sea-lamphrey, 40-60 cm long blood-sucking animals which live in sea could migrate to those five lakes through the Welland Canal which was earlier prevented because of the Falls. After passing through the initial period of adjustment from saline marine environment to sweet water lake environment sea-lamphreys started breeding in fresh water lake and thereby could increcse their population at a rapid pace. Edible carps and other table varieties of fish were their prey and they died in millions as their blood was sucked. So the benefit brought through transportation of materials is upset by the less in fishing industry. This type of environmental consequences of deeper concern needs investigation even when considering intra-basin Water transferslet alone inter-basin water transfer.

Again, going back to the question of equitable distribution of the benefits of development we need to give closer look to, our management of water resources. Management of water resources should have received utmost priority as because in the absence of it we would never heave a strong agricultural bese as well as forest and pesture land base. A strong agricultural bese with commensurate forest and pasture land bese minimize erosion of productive soil and maximize economic strength which in turn provides able support to all other facades of development. Five percent of population in the USA produce the agricultural crop of the USA not only to feed the nation with requisite calories of food intake, but also provide enough surplus for buffer stock, export and to negotiate gains from other countries. In India, we still do not have a national policy for water resources management. There are 14 major rivers in the country having catchment areas 20000 km^2 and more; these 14 rivers between them cerry moxe than 860% of water resources, population and land mass of the cauntry. The smallest among them is the River Subarnarekha, originating in Bihar in the Chatanagpur plateau and flowing through the plains of West Bengal and Orissa and discharging in the Bay of Bengal on the Orissa coast. Ranchi, Jamshedpur, and Ghatsila are the three major industrial growth centres on its bank. Year after year there is tremendous erosion in the upper reaches of the river which is in Bihar and there is flooding in the plains of West Bengal and Orissa. This is a basin which is rich in mineral and forest resources, There would be always a conflicting interest between mineral exploitation and forest management. In the absence of a river basin-wise management plan all resource basis are developed but the benefit is not getting equitably distributed. The growth of Ranchi, Jamshedpur and Ghatsila may bring pride to the nation as centres of heevy machine making, steel making, and copper making, respectively, but failed to uplift the quality of living of the people within the Subranarekha river basin area,

TASK AHEAD

I would like to give a call to the irrigation engineers, water resources managers, hydrologists, geologists and geohydrologists thet water resources management plan for each of the river basin needs to be prepared as a sort of master plan with built-in flexibility to adapt to the change in time and mood of the people. In the absence of that political mesters would continue to utilize the weekness in the name of weter sharing for their political gains.

As a matter of fact, each of the river basin must be subjected to a master plan not only for water resources but also for all other resources including human resources, fhe components of the master plan should include inter alia (i) Land use: agricultural, industrial siting, urban centres, forest cover, and pasture lands, (ii) water resoures management and mineral resources management; (iii) storage and distribution of products within the basin boundary; and (iv) river water use base classification and similer classification for coastal water. Within the broad framework of the master plan each of the development project must be subjected to environmental scrutiny besides socio-economic scrutiny. Such a broad based framework for the master plan and undertaking development project subjected to environmental serutiny in addition to socio-economic check may possibly endow the development project with the two desirable merits: (i) equitable distribution of benefit, and (ii) minimal degradation of the environment, It may slow down the process of development at the initial-stage but would surely put it on a broad-based benuficial scale.

Even the USA today, inspite of having the advantage of colonies, is paying dearly in mopping up the mess created in the backyards of industries. There are innumerable industrial waste dumpsites which are now having a concoction of varieties of hazardous and toxic chemicals that need to be cleaned up to protect ground water and surface water as well as land mass, Federal aids in billions of dollars are syphoned to clean that mass. The episode of the Love Canal near Buffalo in New York State is a leeding one. The secant incident of Sandoz at Basel, Switzerland, known for more pharmaceutical chemicals, is a clear case of inappropriate industrial siting. The already polluted River Rhine carries the chemicals, drained out to avoid spread of fire, to spread into the reaches flowing past Federal Republic of Germany. The Netherlands and then into the North Sea. The world today is full of incidences like Basel or Chernobyl or Bhopal; and India is already a partner. It is time for us to think, think deep, to steer in the appropriate path for development. The Western-style development model which is available before us needs to be questioned not once but repeatedly. Engineers and scientists of the country are the right breed of people who can question this model and modify appropriately to suit the need of the country at this hour.

The new ethos proposed for development is itself an approach to environmental protection. Environmental protection is to be recognized as'a part of development, just as economic viability of a development project is always desired. Development without environmental degradation sheuld, therefore, mean internalization of environmental protection in the process of development. Engineers and scientists in each discipline need to recognize this fact and take up the chellenge to work towards thet goal.

REFERENCES

1. T P White and P Louie. 'The Fascinating World of Trash'. National Geographic, Journal of the Netional Geographic apedety, Vol 163, no 4, April 1983,.p 4244

2. C Alvares. 'Development, Plunder and Triage'. The Illustrated Weekly of India, November 16-23, 1986, p 28.

New Horizons of Water Resources Engineering

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THE CHANGING RELATIONSHIP

1. In the recent times the relationship between man and water has been fast changing. It is nor more the same as it used to be in the historical past. Increase in the population has been resulting into less and less share of water per person. Even what is available is not likely to be of acceptable and usable quality. Because of the chemical age, growth of industries and urbanisation, pollution of waterhave been on the increase. There is not only chemical and bacteriological pollution, but also thermal pollution from the waste heat carried by the cooling waters.

2. On the other hand, man’s capacity to manage and handle twater’ has also been changing very fast and favourably. The technology of water storage behind the dams or that of pumping out of water from the ground has made tremendous strides. The gates fitted on the dams have added considerably to the man's manipulative capacity. Wireless communication has made it possible to forecast the floods well in advance and forewarn the people of the incoming danger. The treatment technology has enabled the man to re-use and recycle the waste water and also bring into use the water which in the past was consideredas not usable. Desaliration is no more only an experimental idea.

3. All these factors put together have made the ‘management of water’ quite a thrilling experience and a complex job. Water resources engineering is at present quite different from what it was half a century back or even just a generation before. Futures of the various societies will greatly depend on how efficiently and skillfully they will be able to manage the finite quantity of water available to them.

THE INFLUENCING FACTORS

4. Changes are taking place in the water resources sector on account of various factors. Broadly, these factors belong to three separate categories, viz. (i) the new water technologies arising out of research on the water associated works, (ii) the impact of other technologies on the water resources sector and (iii) the man's changing relationship with water.

5. Many changes have been brought about in the layout of the hydraulic structures and the details of hydraulic systems by the continuous research and experimentation that goes in the Hydraulic Research Institutes, the new innovations tried by the designers and the new construction technologies developed by the builders. All such innovations have greatly added to the efficiency of the water systems and the skills of the water resources engineers. The new methods of water treatment, that are being continuously developed and introduced progressively in the country's water treatment plants, such as the filters from the local coconut husk, or the new designs of spillways and their energy dissipation arrangements, the new layouts and the cross-sectional arrangements for the dams for better structural performance, or the use of rolled concrete rather than the placed concrete for the dam have made significant contributions to the integrity of the engineering structures and the economy of the works. Such varied contributions have considerably upgraded the technological level of the water resource sector.

6. Many changes have been brought about by the impact of other technologies on the water resources sector. Introduction of new materials like plastics has given rise to the use of plastic pipes, plastic tanks and other plastic appliances for the water supply systems where steel or cast iron had been used before. The plastic pipes are smoother, have low rugosity coefficient and are also rust-proof. This by itself provides for a much greater efficiency in water transmission and for a longer life of the system. On similar lines, the use of electronic instruments for the measurement and control of the water structures or the use of computers for compiling and analysing the data lave led to definite improvements in the efficiencies of the different systems. The new tools of analysis like the finite element analysis that have now become available have considerably improved the sophistication in the design of the structures and the water systems. The problems of seepage through the foundations and of analysis of the stresses in the dam can be solved with much greater accuracy and confidence with these tools.

7. To what extent the new technologies and scientific knowledge have been fruitfully utilised in the water resources sector could be itself be a subject for closer enquiry. The frontiers of scientific knowledge and technological innovations are expanding day by day. Hence a constant and systematic dialogue between the scientific community and the water resources engineers will be necessary to ensure the fuller use of the potential developed in the field of science and technology. At the First National Water Convention held this year at Delhi in November 1987 a beginning in this direction has been made. It is hoped that this practice will be continued and the scientific community and water resources engineers will take stock of the situation periodically.

8. But the real major area for our enquiry today is the one of intrinsic changes that are in the offing within the water resources sector as a whole on account of the new problems and challenges faced by this sector. These are the changes which affect the very size, scope and the nature of this sector. They call for a reorientation of the sector's philosophies, organisations, procedures, manpower planning, their education and training. In today's lecture, it is proposed to take a closer lookto this category of changes. In the annual research sessions of the CBI&P or the annual functions of the various professional institutions like the Indian Water Works Association, the impact of the new technologies like the plastics or the research and experimentation work carried out in the country and abroad is generally covered and reviewed. Hence it is not proposed to report such a purely technological review in this lecture.

ATTENTION TO HYDROLOGIC SYSTEM

9. Water Resources Management can be broadly classified in 4 compartments. These are ‘hydraulic structures’, ‘hydraulic equipment’, ‘hydraulic conveyance system’ and ‘hydrologic system’. All these four compartments are showing signs of change and new trends. But the greatest change and the challenge is faced by the fourth compartment, viz. the hydrologic system’. Hence, it would be worth while looking at the fourth compartment more critically.

10. It is proposed to review the new trends in this fourth compartment in greater details compared to those in the first three compartments. Even otherwise, the global technological trends in the first three compartments are being looked into criticallbyy the different national and international organizations, like the International Congress on Large Dams, International Commission on Irrigation and Drainage or the International Water Supply Association, for a long time. But. the nature of changes in the hydrologic systems are area specific. They need quite a detailed and separate consideratioant the hands of the national and regional institutions. Hence it would but be appropriate that at important national gatherings like the Indian Engineering Congress, greater attention is paid to this fourth compartment.

TOWARDS RESOURCE ENGINEERING

11. For a long time, the branch of engineering dealing with water was called hydraulic engineering or water and power engineering or just as ‘water engineering’ — and was treated on the same lines, as the subjects of mechanical engineering, electrical engineering, or the recent subject of electronics. All these subjects are essentially the subjects of technology. They deal with the skills to manipulate and utilise the different forms of materials and energy. They are quite different from the subject of mining or metallurgy, where it is not only the question of technical skill in utilising a certain form of energy or materials, but it is also the capacity to assess, use and re-use the material resource available in nature.

12. Broadly, the engineering subjects can be considered under two groups, the one that deals with the skills for manipulation of different forms of energy and the other that deals with the management of Nature's material resources. This latter group forms the subject of "the resource engineering". It is much more than the technology of conversion or manipulation. Questions of cultures, sociology, economics, limitations to growth — on account of limitations of exploitable resources assume for greater importance under this subject. ‘Resource Engineering' is a much broader field than the traditional technical subjects of engineering. Thus, Water Resources Engineering is much more comprehensive than the traditional subject of water engineering or hydraulic engineering alone.

13. There is a growing realisation about this and also a clear shift towards this the world over. The excellent book written by Professor Linsley, the Professor Emeritus of Hydraulic Engineering at the Stafford University, was fist published in 1955 under the title of ‘Elements of Hydraulic Engineering’. But later it was revised and published in 1979 under the new name ‘Water Resources Engineering’.

INTER-DISCIPLINARY APPROACH

14. The principal distinction between subjects of engineering “oriented primarily towards technology and those towards resource management, is that the latter is inter-disciplinary in nature, Thus, in the field of water resources engineering, knowledge about the properties of water and the skills in using those properties either for running a

turbine or a pump or for manipulating a river flow will not suffice. In addition to the knowledge of the chemistry and physics of water, hydraulic structures and the subject of hydrology; other subjects like geology, management sciences, economics and agronomy will also have a very great influence in the making of a water resources engineer. A water resources engineer will have to lead a Team of specialists working together, whatever the size of his territorial jurisdiction. He will, therefore, have to be given a good 'grounding in all those s subjects, that are helpful in the proper management of the water resources. wee

THE ECOLOGY

15. Water resources management in its comprehensive sense essentially means the proper manipulation of the hydrological cycle. But the hydrological cycle is greatly influenced by the various factors like the presence or absence of forests, the urbanisation which interferes with the natural soaking of water or which accentuates the accumulation of the rain surplus from the covered areas, the rail/road network which obstructs the sheet flows, diverts water and modifies the time of surface flows and the irrigated farms, that 'consume! large quantities of water. Assessment of the impact of these factors: on the different phases of the hydrological cycle is therefore, going to be very important for the water resources management plan. The Water Resources Engineer will have to be quite conversant with the influence of these factors and will have also to suggest proper manipulative and regulatory actions so as to ensure a proper ecological balance. Afterall water is an essential and dominant element of 'tecology'. Hence a good water resources engineer will have also to bea good 'ecologist'.

16. Thw Water Resources Development programmes need not necessarily be in conflict with the environmental requirements. In fact, in a tropical climate like ours and particularly in the dry parts of the country, the very presence of water is not only pleasing to the eye but also a source of life for the flora and fauna of that area. Hence we will have to see that the water resources development projects are planned in such a manner that they do not cause environmental damage but on the other hand help to strengthen and reinforce the life supporting natural systems of the area. It is inthis contexe that the practice being adopted by some of our dam builders for diverting all the available waters away from the river without releasing anything back into the natural course of the river needs a serious consideration. Total diversion of all the available supply throws the entire life-supporting system along the river bank, out of gear. No project should ever aim at totally drying up of the river but should on the other hand, specifically provide for allowing certain minimum flows if possible perennially down. the river. Our effort should be to correct the imbalance in the nature and not aggravate it.

THE HISTORICAL PERSPECTIVE

17. India has a long historical tradition of developing and using its water resources for the prosperity of the country. In the earlier stages, Indian civilisations were mostly settled 'on the river banks. Diversions of streams and conveyance of water over a distance through aqueducts for agricultural uses, or for the citiy's water supplies, were an engineering accanplishment, recognised and respected by the early societies,also, But we do not find any evidence of the diversions of large river flows through huge canals like the Farakka Canal, the Nagarjunasagar Canal or the Rajasthan Canal in the historical records except possibly in the story of "Bhagirathi".

18. Such gigantic constructions have become possible only when the modern technology for large storages, large hydraulic structures and large control mechanisms was developed. The first recorded effort in India for a large scale diversion of a river flow was the work for the Grand Anicut on the river Cauvery in the second century by Raja Karikala Chola. But, therefore, centuries-passed before the modern technology of construction could give us large barrages across the mighty rivers Mahanadi, Godavari and Krishna.

19. In India tank irrigation had developed extensively in the past particularly in the southern India. The districts of Bhandara and Chandrapur of Maharashtra or the State of Karnataka and Tamil Nadu are strewn with thousands of old historical tanks which are still giving service. The embankments were generally less than 30 m in height. We had to wait for the modern technology of dam building before large dams in thousands could be seen across the country. We have more than 2000 of them now in India. We already have our Bhakra more than 226 m high and we are also planning for many more similar high dams particularly in the Himalayan ranges. The single most important factor that has contributed to the immense increase in the man's capacity to store, control and use the flood wasters that otherwise run to waste is the subject of dam engineering.

SELF-RELIANCE

20. It is a matter of great pride that we are totally selfreliant in matters of all designs-whatever be the complexity of the structure. All dams and barrages, power houses- including under ground power houses, canals and canal

structures are being successfully designed and constructed by Indian Engineers. The Central Water Commission has particularly been the torch-bearer in this field.

21 Bhakra Dam 226 m high is the second highest concrete gravity dam in the world. Nagarjunasagar continues to be the largest masonry-dam in the world. We have by now more than 2120 large dams completed in our country - and are poised to undertake confidently the construction of further higher/taller structures on the strength of our own capabilities - e.g. Tehri Dam on Ganga with its height of 261 m will be 35 m taller than Bhakra - (and will rank as the sixth tallest dam in the world when completed).

22. The entire Farrakka Project with its barrage on sandy foundation been and having as many as 110 gates, has been planned, designed, constructed and operated successfully by Indian engineers. Farrakka Canal which recently established a direct navigational link through Ganga upto Patna - is even larger than the Suez Canal in the cross sectional aréa,

THE GROUND WATER

23. Next to Dams the second powerful factor that greatly influenced the water resources sector is the technology of pumps. The deep well pumping has particularly changed the very significance of the ground water phase of Nature's hydrological cycle. Man's capacity to intervene in this phase and extract large quantities of water has increased tremendously. There is already a risk of overstepping beyond Nature's permisible limits of water drawal. Ground water levels are fast depleting in many areas.

24. Particularly with the advent of machine power and electric power, man's capacity for ground-water extraction has increased manifold. The annual extraction has now exceeded the limits of annual recharge at many places. Deep aquifers in hard-rock areas which are not properly linked with a natural or an artificial recharge system have been found to be not dependable. Ground water is not an independent entity but is only one of the phases in which water exists in its overall hydrologic cycle. There are, therefore, obvious limitations to the extent its use can be stretched. Deep drilling may only help to mine the water accumulated over centuries. Such mining efforts cannot provide a long-term sustainable support for development. The mechanism of recharging of ground water is not yet fully known for many areas. Extensive research in this field is one of the prime needs.

CONSERVATIONAL APPROACH

25. One thing is clear. The philosophy of development has found its expression mainly through the process of acquisition, accumulation, extraction or exploitation. 'The conservation' philosophy has not yet taken roots. Realising that the available waters are finite, and that there are limits to acquisition and exploitation of natural resources lime water, it is time that we switch over from the accumulative or extractive technology to the 'conservation-oriented technology'. With the latter type of orientation, there will be greater and greater stress on utilising the "'available' limited resources in a more efficient manner rather than trying to only acquire or extract more of the water quantities from the nature's cycle.

26. Because of the general developmental phase in India over the past few decades and extensive relief measures undertaken during the drought years, access was established to new — resources of water during the periods of stress and hence the effect of the drought situation stood considerably softened. However, in many sub — basins all the resources now stand harnessed. Hence in the years to come greater reliance will have to be placed on improved operational skills and water saving measures for tackinga drought situation.

PREVENTION OF EVAPORATION

27. Evaporation control in that context will assume the gredest importance on the Indian scene. The process of evaporation and the loss of water by capillary action from the ground surface needs to be fully investigated. We have not yet understood this process fully well to devise correct preventive mechanism against such losses. A totally new and fascinating field of new technologies, chemical as well as physical, or a combination of both, for preventing the evaporation losses from the reservoir surfaces and from the ground awaits us.

28. Faced withte lihmit ed availability of water, all possible efforts are necessary to prevent losses by evaporation from the reservoir surfaces as well as from the irrigation farms, It has been estimated that 6 Mha.m of water evaporates from reservoir surfaces and an equal amount is being lost from high water table areas. Evaporation losses from reservoirs would increase on further development of water resources. Thus, at the ultimate stage of development, evaporation losses from reservoirs and tanks will consume a substantial portion of the total utilizable water resources of the country.

29. Evaporation losses are particularly high in the summer months. Hence irrigation systems particularly those from the water scarcity areas will have to be so planned that the reservoirs are depleted well before the summer season sets in. Irrigation in summer months will have to be essentially from ground water which is not subjected to evaporation. For field applications, the new techniques like. drip will have to be perfected and popularised. Somehow evaporation appears to be a forgotten enemy. In the irrigation sector, there has been much talk about the seepage losses - which replenish the ground water and need not be construed as net loss, but very little attention to the measures for evaporation control, has so far been paid.

30. It would be desirable to hold water for the summer months in small size tanks, because the water held in small tanks and ponds has been found to be somewhat amenable to treatment by spraying chemicals like fatty alcohols in the water surface. Large reservoir spreads cannot retain the monomolecular chemical film on account of the waves generated by the winds on the surface. In Maharashtra, experimental use of such sprays has established a reduction of 30% to 50% in the evaporation losses. The chemicals are, however, costly. Adoption of chemical sprays is a costly one (Rs. 5 to Rs.10 per m of water saved) and will have to be earmarked for high value purpose only. Such measures could still be cheaper than the long distance transport of water by rail or road which is required to be resorted to for the survival of the population under extreme distress. There is also considerable scope for trying other physical measures — like floating plastic/foam/rubber spreads — to arrest evaporation.

31. Irrigated area is 5 to 10 times larger than the surface area of the irrigation reservoir. Moreover, when irrigation water is applied to parched and heated land surface or to open and porous soil crusts, evaporation loss is particularly very high. In the aggregate, evaporation losses from irrigated areas are much greater than even those from the reservoir surfaces. Irrigation systems like drip irrigation will be able to eliminate a substantial part of the evaporation losses from the farms and reduce the water requirement for irrigation by almost 50%. This is a great challenging field for future development. Many enthusiastic researchers and enterpreneurs are already working on this subject. Indigenous techniques of 'suction irrgation' are also being tried out as by the Irrigation Department's officers at Nagpur. Under Indian conditions, costs of drip irrigation systems have been estimated around Rs 20000/ha with additional annual operational costs at Rs 2000/ha. Efforts to develop locally suited cheaper drip techniques should continue.

32. In the meanwhile, greater attention will have to be paid to the measures for reducing the evaporation from the surface of the irrigated farms by developing and popularising appropriate mulching practices and modifying the water application techniques. In this context, use of plastic films to cover the irrigated farms , has a great potential. Mulches of straw, organic compost, coir waste, gravel, plastic sheets or chemicals and 'petroleum products have also been tried on the research farms. It has been seen that introduction of scientific mulching practices on the agricultural farms in the drought areas can improve the retention of moisture in the farm soil by as much as 50% and improve the yields by 75%. Considerable extension work is necessary to popularise the mulching practices.

GROUND WATER RECHARGE

hares For conserving water under the ground a large number of percolation tanks have been constructed in the drought-prone part of the Deccan plateau, But the area of incluence of each tank is limited to about 2 km^2 only. Recharge of ground water can take place to the extent of about 60% of the tank capacity. Improved measures for spreading the recharge effect on an extensive area will have to be evolved through experimentation. This is also a new fascinating field. Rather than storing water above ground, it would be advantageous to store it in the underground aquifers, as it then gets substantially protected from 'evaporation'.

FLOOD FORECASTING

34. Prevention of losses from floods is an important item of the water management programme. It is the most important item particularly in the development of the flood-prone areas in North Bihar, West Bengal and Assam. One of the measures of flood management which has found the greatest acceptance is 'flood fore-casting'. As most off the flood-prone rivers in India are Inter-State, in nature, the Central Water Commission has been entrusted with the task of flood forecasting. There are about 500 rain guage stations, 380 gauge and discharge sites and about 400 wireless stations operated by the CWC's national network. By the monsoon season of 1987, in all 145 flood forecasting sites have been operational. On an average about 5 0000 — forecasts at various places in the country are issued every year during the monsoon period. The largest number of flood forecasts was 6964 in 1978. Such forecasts have been found to be very useful in saving life and property.

35. An unprecedented flood, 0.5 to 1.0 m higher than the previous floods was witnessed in the river Godavari on August 15, 1986. It affected an area of about 1.38 million hectares, 5058 villages and 0.8 Mha croped area in the three deltaic districs of Andhra Pradesh. But there was not much loss of life. Around 1.4 million people,could be

evacuated to safer places, because of the timely flood forecasts issued by the Central Water Commission and broadcast through All India Radio regularly throughout the period of danger commencing from August 14, 1986. Hourly forecasts were issued through Radio informing the people about the expected levels of the river Godavari till the river receded below tne danger level. This flood forecasting work was greatly appreciated in the country by-the newspapers, parliamentatians as well as by the administrators. Because of such achievements, there have been pressing demands for extending the flood forecasting network to other uncovered areas also.

36. The country's flooa forecasting network is now proposed to be progressively utilised for forecasting the low flows and the quality of the river water also. In the meanwhile, the flood forecasting techniques are being progressively refined by use of modern equipment and methodology so as to obtain increased warning time and more reliable forecasts. The Government of India with the assistance of UNDP/WMO took up a pilot project in 1980 in the Upper Yamuna catchment upto Delhi as a focal project.

37. Under the UNDP scheme, a Mini-Computer HP-1000 F Series — 1536 kbyte with a master teleprocessor has been commissioned at the central station in New Delhi. Twenty-one stations have been commissioned in the Yamuna basin at representative locations. Out of these, 9 stations are equipped with automatic data sensors for water level, temperature and precipitation. 7 stations are working as repeater. The master teleprocessor has been programmed to co-ordinate the activities of remote stations. Four computarised hydrological models, viz., SSARR, HEC-IF, NLC AND NAM-SYSTEM II FF Models are being used for the forecast. The system was put to real time use during 1985 and 1986 monsoon seasons with encouraging results. Under the second phase of the pilot project commencing from 1987 a link up of the Delhi station with the Indian satellite facilities is being tried.

REMOTE SENSING TECHNIQUES

38. In addition to the direct aerial photography for topographical mapping which has been widely used, remote sensing technology using both aircrafts and satellite will have also to be brought into use. Several characteristics of water make it particularly amenable to investigation by remote sensing devices, e.g. it holds a promising potential in the collection of flood data. It is proposed to develop capability in remote sensing techniques for mapping of flood plains, rivers and drainage courses, for ascertaining the land use patterns, for assessment of physical damages caused by floods and also for collection of hydrological data for flood forecasting.

DEVELOPMENT OF HYDROPOWER

39. Hydro-electricity continues to be one of the cheapest and cleanest forms of power. At the time of independence, India had just 500 MW of hydro-power installation. This has been stepped up to as much as 15 000 MW by the end of 1985, but the ultimate assessed potential is as high as 84000 MW. Addition to the hydro-power capacity is continuing in the world at a fast rate of as much as 10400 MW per year. A similar phenomenon is expected to continue in India also. For a long time water was used for utilising its potential energy. But with the advent of pumped storage schemes water is also now used as an energy carrier or as an energy-storage. With the growth of thermal stations and atomic stations this role of water will considerably increase.

40. With the development of low head turbines, efficiency of reaching as high as 95% and the electronic load controller replacing the governors, the possibility-of accommodating a large number of small sized generating stations in the extensive electrical systems has greatly improved. We should therefore look forward to a large number of mini plants coming up into the grid in the near furture. The exploitation of the water power in the tidal reaches will also be another promising area for new innovations.

GEOTECHNICAL ASPECTS

41. What is not yet fully realised is the influence of the subject of geology. The study of the ground water phenomenon itself will call for a much deeper understanding of geological set up of the earth's crust. The subject will assume far greater importance in the development of surface water resources also, because the storage sites for the dams will have to be hereafter located in more and more complex geological regions. Moreover, on account of the greater thrust towards pumped storage schemes, and the trend for maximising the energy outputs from the head of water available at hydro-power stations, underground hydro-power stations will be on the increase. Engineering of underground works will naturally attract much greater attention than heretobefore.

42. Hereafter, new large storage will mostly lie in the Himalays. In the north-eastern region itself, the total irrigation potential assessed is about 1.23 Mha of which only 0.184 Mha has so far been achieved. The hydropower potential in this region is assessed as about 34 000 MW at 60% load factor. Most of this remains to be exploited. Similarly, in the Chenab Basin, the total power potential has been estimated to be about 3 256 MW at 60% load factor most of which also remains to be exploited. In addition, Ganga Basin's hydropotential is 10 715 MW of which only 12.4%

has so far been developed. As the simpler and better sites elsewhere have been utilised in the past, the future development will require handling of complex site conditions for.the high dams in the himalayas.This is going to be an extremely challenging job, because Himalayan region is also beset with numerous faults and shear zones, and is subject to earthquakes. Weak, friable rocks and squeezing ground conditions will have to be handled at many of these sites. River valley projects with high dams and underground power houses could not have been conceived under such situations but for the new technological advancements ae the field of rock mechanics and geotechnical engineering.

NAVIGATION

43. Ironically enough, even though the construction of largesized canals was initiated in the modern India by the British engineers who had their roots in the extensive navigational canals developed across Britain during the 17th and 18th centuries, the navigational aspects of water resources development progressively got ignored because of the Indian Railways taking over the transport needs of the country. We do find the impact of the navigational orientation of the earlier British Engineers in the design and layout of the early large-sized canals like the Upper Ganga Canal built in the 40s of the 19th century. It has been provided with navigational locks almost at all the masonry structures along the canal. All of them have gone into disuse by now. But with the increasing volume of traffic and congestion on the railway lines running parallel to the river channels, the interest in the navigational potential of the rivers has been recently revived. An Inland Water Transport Authority has been establiabed by the Government of India. This is a very encouraging sign. The water resources development programmes of the future will have to accommodate the navigational requirements along the river channel by resorting to large scale river training works and adopting the cascade pattern of development on the lines of the Tennesse Valley.

CASCADE DEVELOPMENT

44. The best integrated development of the river's resources is through the construction of reservoirs across the river in a cascade pattern i.e., in close succession one below the other. This is also particularly useful for development of navigation and hydropower generation. It also provide an easy access to water for all the communities along the entire length of the river. Moreover it confines the submergence area as far as possible to the lands close to the river channel only and avoids the problems of displacement of persons from a large contiguous area.

45. The Tennessee Valley Authority has developed the Tennessee river system for navigation, flood control and generation of power on these lines. By constructing a series of multipurpose dams and creating inter connectéd water lakes, a minimum of 3 m of navigable depth has been ensured for over a length of 1000 km in the Tennessee River.

DEVELOPMENT IN PHASES

46. It is not as if our water resources only are limited, our financial resources are also quite limited. Hence conscious efforts will have to be made to maximise the development with minimum financial investments. Whether it is irrigation development, power development, or water supply and sewerage, they are all highly capital-intensive works. Hence, greater attention to the cost aspects of the various elements of these projects is necessary. Rather than planning in a traditional manner, innovation measures, like stage development of the works or postponing the costly elements while simultaneously ensuring early return will have to be encouraged extensively. Even a new technology for developing a dam structure in stages will have to be developed. For conveyance systems also, a system of phased development and with facilities for subsequent expansion, will have to be incorporated. Compared to the development programme woven around a single large storage on the river the cascade pattern of development is more amenable to the concept of development in phases and will have to be encouraged.

RECEATIONAL USE

47. In the hot arid climate like ours the very presence of water is pleasing to the eyes. Hence water fountains or small ponds have been a very popular item of beautification and recreation in the cities and the garden. But somehow the full potential of water as a recreational element has not yet been exploited except at a few places like the Brindavan Gardens at the Krishnaraja Sagar Dam. Water sports like water surfing have also not been sufficiently popularised. Water recreation is not a very costly item. It is bound to catch up in the years to come particularly with greater awareness about the aesthetics of the environment around and a growing demand for facilities for recreational sports.

PISCICULTURE

48. Even the potential for development of fisheries has not yet beet properly utilized at the reservoirs across the rivers except at a few places like Tungabhadra and Bhakra. Even though, the vegetative produce from the submerged land surface is lost, the fishing produce can more than compensate for such a loss. But that will need an organised effort and a social change. The displaced persons will have to be turned into trained fisher men equipped with modern amenities for scientific fishing.

WEED CONTROL

49. Weeds or out of place plants that exercise a negative effect, are posing a great problem in proper maintenance and operation of the ponds, canals, drains and reservoirs. Acute weed problems have been reported in the Rajasthan Canal, Chambal Canal and many other canals and tanks. The weeds have also caused structural damages at many places. Amongst the various methods available for prevention and control such as the manual, mechanical, chemical and biological, the biological methods have been reported to be quite effective and economical. We should therefore look forward to the new thrusts in the 'Biological management of the weed problem'. There is considerable scope for inter-disciplinary work in this area.

GROWTH OF HYDROLOGY

50. Because of the natural variability in the existence and availability of water, and the growing demands for water, the subject of hydrology will assume much greater importance in future ‘Hydrology’ is after all the very foundation of the water resources engineering. Enough attention was not paid to this subject in the past when 'demands' and 'drawals' were small compared to the availability of water in Nattre. But that’ is no more the case in most of India's basins. Hence correct appreciation of the exact hydmlogical cycle of the specific region is very much necessary now for the proper planning and management of the regions water resources.

51. There have been some gaps in our understanding of the hydrology of India's water resources. For example, not much work has been done on the subject of snow hydrology. The Himalayan rivers draw considerable supply during the snow-melt periods. A proper assessment of the availability of water from the snow covered areas will require a much greater insight into the subject of snow hydrology. Recently a small beginning has been made in this direction by establishing a Snow Hydrology Division of the CWC at Shimla. But much still remains to be done. This is going to be an area of challenge for many scientists and explorers alike.

52. Our knowledge about the coastal aquifers is also not yet well developed. With the increasing extraction of ground water even in the coastal areas there had been many cases of ingress of saline water in the ground water acquifers. For the prover management of the coastal areas, a thorough understanding of the ground water - saline water interface will be necessary. Very extensive observational field work and experimental work will be necessary on this problem.

53. Our knowledge about the self-purifying properties of the river system is also limited. Considerable research and field observational work will be necessary before we will be able to confidently manage the quality of the river water by utilising its self-purifying properties in its different reaches. Thus while on the one hand efforts will be required to close the gaps in our knowledge, on the other hand conscious efforts will be required for developing the necessary skilled personnel for utilising the available knowledge.

THE AGING STRUCTURES

54. As the physical infrastructure of the society gets progressively developed, the effects of the process of aging of the earlier engineering structures are also gradually felt. All the structures created by man have a limited life and are bound to show signs of decay through fatigue, wear and tear, weathering or the corrosion process. Particularlthye Water Resources structures which are in close contact with water and are also by and large exposed to the direct action from the sun and the rains, are bound to show larger amount of decay as the time passes. Problems of repairs and replacements of the affected portions of a water conductor system like the irrigation canal system or the the piped urban water supply system, pose numerous technological and socio-economic problems. A proper technology of repairs and replacement causing as little disturbance as possible to the ongoing uses of the system will have to be assiduously developed through considerable innovative efforts in the years to come.

SAFETY OF DAMS

55. Even the large massive structures like dams age and lose their strength. There is a variety of manifestations of aging. At times, it is the incipient and unnoticed alkali-aggregate reaction with in the cement concrete that gives rise to cracks as has happened at Hirakud and Rihand. Sometimes it is the slowly increasing seepage through the body of

the earth mass that can later develop into a major 'pipe' and undermine the safety. Generally the masonry and concrete dams tend to age out faster than the earthen embankments. Occasionally it could be the case of fatigue under constant heavy loads as was probably the case at Bhandardhara. These aged dams are required to be strengthened in the course of time either by cable anchoring as was adopted for the Tansa dam and the Periyar Dam, or by buttressing as was done at Bhandardhara and Radhanagari. Other measures like providing additional upstream impervious membranes to arrest the seepage through the body of the dam may have also to be adopted. In any case, such remedial measures for overcoming the deficiencies arising out of the aging process will need a far greater attention in the years to come. There will have to be a constant surveillance for dam safety also.

56. There has been a race for taller and taller dams during the 20th century. Bhandaradara dam in Maharashtra (58 m high) was the tallest in India upto 1950. But by now we have 15 dams more than 100 m high in India and © more are under construction. The dams are imposing structures and also the most impressive achievements in civil engineering. Progressively dam building has been fairly standardised and dams of normal size have almost become a routine affair. But taller the dam or larger the size of storage, greater is the risk potential.

57. The question of safety of the dams is now uppermost in the minds of dam engineers, because of the increasing population of the dams, the progressive ageing of the old dams and the new structures being taken up at less and less favourable sites. The question of dam safety has been a topic for discussions at International Congress of large dams in 1982 and again at the International Congress in 1985. In India, a standing committee on Dam safety has been working since August 1982.

SILTING OF RESERVOIRS

58. Another factor is the loss of storage capacity on account of silting. Silting is not goint to be totally avoidable phenomena whatever best efforts we make for the catchment protection. The extensive agricultural operations in the catchment are bound to loosen the soil crust and make it vulnerable to survace runoffs. Compensatory action for making good the loss of storage either by progressively increasing the height of the structure or by creating supplementary and subsidiary storages will have to be planned and taken up well in time.

59. There is a case for developing a technology for churning up of the silt accumulating on the bed of the reservoir and holding it in suspension in the reservoir water so as to get it flushed out during the flood period. Agitation of the reservoir beds through air-pressure systems is being tried on some reservoirs abroad. Similar experiments may have to be taken up at some of the critical sites in India also.

DAM OPERATORS

60. For a long. time dams across the rivers were looked upon as passive structures for holding up water and creating storages. But, with the introduction of spillway gates of greater heights, we have almost reached a stage when the entire useful annual storage is against the 'gates' and not against the passive solid barrier. These are regulated storages. Operation of the gates is very critical not only for the successful building of the storage, but also for the safety of the structure. Water is stored behind a dam not in a passive mechanical way. But it has to be allowed to accumulate by manipulating the gates and arranging the releases through them in such a manner that the 'excess' flows pass safely.

61. At Srisaibam, as much as 5.9 km^3 of water out of the total live storage of 8.3 km is stored against the gates, i.e., almost 72% of the live storage is against the gates. Even at Ukai, 5.5 km^3 of storage out of the total live capacity of 7.1 km3 is against the gates. That means almost 78% of the live storage is against the gates and this trend is bound to be on the increase for saving the submergence of the lands and for economising on the cost of the dams.

62. For reducing the uplift on the body of the dam and thereby economising on the size of the dam, seepage through the body of the dam is generally controlled by introduction of impervious membranes and by providing extensive drainage generally on the downstream side of the membrane. The drain water has to be pumped out regularly to keep the major part of the dam body dry and devoid of uplift pressures. For the structural safety of the dam, it becomes increasingly important to have the drainage system working smoothly by continuously attending to the pumps. In addition, there is a large variety of instruments kept in the body of the dam for monitoring the stresses, the temperatures, the inclinations or shifts and such other behavioural signs which indicate the health and the safety of the dam structure. These instruments are also required to be continuously read and monitored. In the Idukki dam, a concrete arch dam of 166 m height, as many as 540 instruments have been embedded. In the Bhakra dam 741 instruments have been embedded.

63. In short, the sophisticated modern dam is no more a silent passive inactive structure but is very much a live structure which needs to be handled, operated and monitored intelligently. There was no concept of dam operation in

the past. But now we have to 'operate' the dam. Hence a trained band of dam operators will bave to be raised and maintained in the water resources sector in a progressively larger number.

INTEGRATED APPROACH

64. In our development of water resources, there came a period of compartmentalisation during which different activities in the water resources sector were assigned to the different organisations which grew in isolation. The result has been a lack of coordinated approach to the development of the most precious resources of the country, viz. the water. But, fortunately, this phase is now getting to a close. In 1985, for integrating the various facets of water resources development, Ministry of Water Resources has been established at the Centre. It is hoped that similar set up may follow in due course in the States also. In any case, there will be greater and greater emphasis on a co-ordinated development and an integrative approach.

65. After working on the different uses of water in an isolated manner over some decades we are now in the phase of synthesis. Integrated comprehensive development and management of the water resources will be the key word hereafter. With the advent of the subject of systems analysis and the increasing use of computer management of the complex water resources system should not pose much of a problem.

BASIN MANAGEMENT

66. With the increasing demands for water from the various growing sectors of economy, in many regions of the country we are quickly moving from the situation of plenty to the one of scarcity of water. From a project-oriented phase, country as a whole, we are now entering into a river management demands on the limited resources of water. We must learn to think about the river and the river valley and not about the 'water' in isolation.

67. Industries, thermal stations, fertiliser and chemical plants and atomic plats need large quantities of water for processing or cooling purposes, They also generate large quantities of effluents. Location of these industries and plants will have, therefore, to be very carefully thought of. The river system can no more accumulate or digest the effluents from the increasing industrial activity. Hence 'treatment of effluents' will have to be a watch-word for management of any basin.

68. Proper handling of water through its different phases, over a period of time and over a large aerial extent also requires continuous collection and analysis of a large volume of data from the basin. Data management by itself is going to be a challenging operation in the water resources sector. Data are required not only for the long range of historical perspectives and projections, but also for the real time operations over a large aerial extent such as for flood forecasting and flood regulation. This complex task is possible only by taking recources to the computer's capabilities, to the telemetry and the wireless communication system. The nature and the magnitude of surpirese events like the floods can be best comprehended and sensed in advance only if it is possible to collect and transmit the real time data. Hydrological observational sensors, the data transmission network and computers will have hereafter to be an integral part of basin management plan.

INSTRUMENTATION

69. Instrumentation alone affords many exciting possibilities for future developments. It has not yet been possible to measure very low velocity or very high velocity of water with any degree of confidence. Similar is the case with the ground water movement or with the testing of chemical impurities in water. There is immense opportunity for development of sensors and sensitive instruments for improving the observational data.

ORGANISATIONAL SKILLS

70. It will be clear from the foregoing discussions that Water Resources Engineering will require organisational skills of a very high order. Because of the fluid nature of water and its natural movement over long distances through the river systems and under the ground, an extensive network of observation and control points is necessary for the proper management of the system. This is fit area for the application of the modern management techniques.

71. It is no more the case of handling and operating one water-use project. It is now the case of managing a large set of projects located in a basin or a sub-basin for optimising the results. It is not the question of operating the gates for flood regulation at one dam, but it is the question of operating the gates over a series of dams. There is, therefore, greater and greater emphasis on the organisational skills of a large team rather than that of the skills of one individual in the command.

72. It is popular among many writers and commentators to degrade the existence of large bureaucracy and describe bureaucracy as a part of the problem and not as a solution. However, rads difficult to imagine the successful

planning, development and management of a large basin without an elaborate extensive and professionally competent large administrative set up. In fact, large size basin management organisations are going to be an important feature of the water resources sector in the years to come. Such organisations will have to be made effective and erfiaecrvent.

TECHNOLOGICAL EXTENSION

73. There has already been a widening gap between the new knowledge generated through research and experimentation and its application in the field. Greater attention will have to be paid to the work of technological extension and also to the development of semi-professionals at the cutting edge level so that this gap is properly bridged.

74. In the hierarchy of the skills, there will have to be a well-defined place for trained and experienced men at the grass root level for ensuring efficient services for the people. Amongst the village craftsmen so far there is hardly any individual as a trained 'water-man'. But with larger dependence of the village activities on the water services and higher level of technical service expected even at the village level, there is a case for developing a village water-man — somewhat of semi-professional category to look to the daily operational needs of the village water systems. In our pursuit for higher skills and intellectual excellence, the operational needs at the lower level are many times ignored or forgotten. Looking to the complexity of the management of a water system, it is high time that the operational structure at the grass root level is properly strengthened by introducing a specialised class of semi-professionals in the Water Resources Engineering.

PEOPLE'S PARTICIPATION

75. Unlike in other branches of engineering, people are an integral part of the water management system. In technology oriented subjects like aeronautical engineering, or even in the resource-oriented subjects like mining, the common man is hardly in the picture. But, every individual in the society is connected with water in one way or the other. He uses water for himself and for his economic activities and affects the trend of consumption as well as the quality of water by his behavioural pattern. Particularly when questions of water quality are involved, or when economy in the use of water is to be aimed at, the habits of the people and their cultural attitudes have a predominant influence.

76. Hence in the management of water, this vital factor cannot be forgotten. At the farm level, at the city level, or even at the village level awareness about the various issues associated with the upkeep and management of water must grow. The community is to be made not only water conscious but should also be made to participate in the water conservation programmes and pollution prevention programmes. Community efforts will have to be made a part of the extensive network of the activities associated with water resources engineering.

77. Times are changing, needs are changing, community·s relationship with water is changing; consequently, water resources engineering is on the threshold of a great change. On the one hand it has to absorb the fascinating new technologies and improve its capabilities and, on the other hand, involve more and more community people in the management process. Only an enlightened approach can bring about the desired transformation and ensure that the new level of technical, intellectual and organisational skills carry the society further successfully even beyond the new horizons of water resources engineering.

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Space Launchers for the Indian Space Programme

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INTRODUCTION

On October 4, 1957, when Sputnik went into orbit, mankind entered a new era; the significance of this breakthrough is often compared with that when 'life' left the oceans to colonize land. Does the dawn of space era signal man's emergence from terrestrial abode to soar up to colonize other planets and other stellar regions? Is man on the threshold of becoming a space colonizer?

Right now the people who are attempting to answer these questions mostly belong to the genre of science fiction writers. But for us scientists, engineers and technologists assembled here, it is important to know what space technology can do right now and right here on earth, especially right in India. But before I do this, it would be instructive to compare the actual situation prevailing in India in 1957 with the present. I quote S E Doyle from his paper presented at the 39th Congress of the International Astronautical Federation held last year in Bangalore: 'In 1957, there were no launch vehicles, no earth stations, no satellites in India. One had to search long and hard to find Vikram Sarabhai and a small core of scientists doing space research at the Physical. Research Laboratory in Ahmedabad, or to find a training course in aeronautical engineering wherein even the most rudimentary aspects of astronautics might be mentioned. Telecommunication services were scarce; they involved open-wire systems and some modest HF and MF radio. The great bulk of India's population was without communication services of any kind. Television was largely unknown. Electrification had not yet reached thousands of villages and towns. In the 1950s, the success rate of digging and drilling wells for fresh water supplies was below 40%.

Today, India is a world leader in industrial development; it operates centres of advanced research; and launches Indian built spacecraft on Indian built launch vehicles. India is among the top ten nations of the world in space operations and technology development. The country's population is being provided with new jobs, new educational opportunities, new kinds and great volumes of new information. Better public health is practised, modern agricultural practices are spreading. New technical schools and training centres exist, thousands of new space-related jobs exist in almost every state. A dramatic example of use of spacecollected data occurred in Rajasthan, where the Government dug 180 wells using Indian Space Research Organization (ISRO) earth imagery. The success rate was greater than 90% compared to the traditional rate of about 40%.

Well, it will be naive to attribute this transformation in India entirely to the development of space technology. Yet, I would like to emphasize that space technology did playa crucial role.

RELEVANCE OF SPACE TO INDIA

As we all know, India, with its rich diversity of cultures, religions, languages and even climates, is truly a sub-continent. This very diversity of India is at once its strength as well as its weakness. While we all agree that we should preserve and nurture this diversity, we are convinced that it is essential to infuse a sense of coherence, direction, nationhood and unity in that very diversity.

A very first step in this direction is to bring the entire population of over 700 millions into a single, efficient communication network. This is precisely what the Indian National Satellite System, INSAT-I, the multipurpose satellite system, conceived and operationalized by the Indian Space Research Organization (ISRO) and the Department of Space(DOS) is intended to achieve. INSAT-IB, the second in the INSAT-I series, has been providing the nation with operational space services since 1983. These services include: domestic telecommunications, meteorological observations, nationwide TV and radio programme distribution, direct telecast to community receivers in certain chosen rural areas, disaster warning and so on. While recounting the tremendous quantitative changes brought about by INSAT-IB in the above services, it is easy to forget the subtle but more significant role played by the satellite system in the urban-rural dichotomy; in almost all developing nations, the fruits of modern technology first reach the urban sector before percolating slowly down to the rural sector. But because of INSAT, television has reached some rural areas much earlier than it did some district headquarters!

India is also blessed with an abundance of natural resources whose planned and prudent exploitation is vital to the economic well being of its populace. Again, a first step in this direction is to be able to locate, monitor, assess and manage the nation's wealth in agriculture, forestry, water resources, minerals, etc. The Remote Sensing Satellite IRS-IA designed and developed by ISRO and launched into a sun-synchronous orbit in March 1988 represents the first in a series of satellites intended precisely for this purpose. Equipped with the state-of-the art cameras, the indigenous spacecraft IRS-IA is a part of a larger system known as the National Natural Resources Management System (NNRMS) whose responsibility is to monitor assess and efficiently manage the natural wealth of the nation in close association with the Departments of State and Central Government and other user agencies.

INSAT-IB and IRS-IA are only two examples of how space technology could be harnessed for national development. But before I proceed further, I should like to digress a little and answer a question that is frequently asked: Can a poor country like ours afford to undertake development of space technology which is both expensive and risky? More than 40% of our population, the argument goes, does not have enough purchasing power to buy two square meals a day. The other necessities of life like housing, clothing, education, etc are beyond the reach of even larger sections of our population. But the economists say that this situation, namely, the deprivation, is not entirely due to injustice in distribution. Even if all the wealth and income were to be distributed equitably, we would end up distributing poverty: Given such a situation, the argument continues, our primary concern should be to generate more income and more employment from investments made. How can one justify investment in space technology? The answer to this question is rather straight forward: it is by now common knowledge that through judicious and intelligent use of science and technology it is possible to multiply the effectiveness of any investment the country may choose to make. Take, for example, silicon which is abundantly available in nature. By proper processing, silicon can be converted into silicon chips which have revolutionized electronics, and one estimate gives the value added to be almost a million times. Technology has this power of converting simple things to high value products, and space technology has the same power, especially for a vast country like ours. Space technology offers the most cost-effective solutions to our needs in communications and natural resources survey and management. Also, spin-offs from space technology have been very impressive: high performance materials, miniaturization, software engineering, project management techniques and so on. That is why we felt, right from the beginning, that space technology is relevant to our country. In fact, I would go a step further and say that in some areas, space technology is more relevant to developing countries than to developed ones. Let us take the example of telecommunications; the developed countries already had fairly extensive ground-based telecom links, like the microwave networks, much before space-borne systems became feasible; but in developing countries the telecom networks are very sparse and inadequate. Thus, one may question in economic terms the necessity of employing space-based systems in advanced countries but not in a developing country like ours. This is the reason why Sarabhai said the question was not whether India could afford space technology, the question was whether India could afford to do without space technology!

WHY SELF-RELIANCE IN SPACE AND WHAT IS SELF-RELIANCE

The other question of why self-reliance in space, I shall answer with a recent example. Now every one in the country is convinced that we cannot do without INSAT. But when in 1986 the unfortunate Challenger incident occurred, the whole NASA programme got totally derailed and ISRO had to run hither and thither to find a launcher for INSAT-IC. Fortunately, Arianespace could accommodate the Indian satellite at short notice. If this is the situation now, one can only imagine our plight when we enter the fully operational phase needing at least two major launches per year. There is no alternative to self-reliance. Moreover, launch vehicle is one area where no one is willing to share the technology with other. The recent proceedings of the 39th IAF Congress at Bangalore clearly drove home this point. In the space propulsion field there was not a single paper from the advanced spacefaring nations which describe in sufficient detail any real, big working engine or motor that is used for primary propulsion. This only shows that no one voluntarily shares knowledge in crucial fields, whatever the compulsions are.

A similar situation exists in respect of satellite technology as well. The point I want to make is that in space technology, self-reliance is a necessity. This does not mean self-reliance in each and every sub-field like electronic components which are used not only in space hardware but in a host of other systems, and as such are not specific to space technology. At systems level at least there is no escape from self-reliance.

To me, self-reliance means the ability to design, fabricate, produce and test entire systems for their performance and reliability. Thus to be self-reliant we must not only possess the needed human skills but the appropriate physical infrastructure. Secondly, we must be able to sustain a competitive edge at the state-of-the art level. This means that the technology must continue to grow, which is possible only if both the human skills and physical infrastructure also grow correspondingly. To achieve this, we must be able to foresee future trends and plan accordingly. Lastly, we must be in a position to produce the system in required quantities without compromising on quality. It is just not enough to have produced an item once.

WHAT ARE SPACE LAUNCHERS?

A space launcher, in simple terms, is a guided rocket, usually multi-stage, that can lift a given mass (payload) from ground and inject it into a specified orbit around the earth. Also called satellite launch vehicles, they derive their propulsive power from either solid or liquid propellants or a combination of them in different stages. Also used are cryogenic substances like liquid oxygen, liquid hydrogen, etc. Different types of controls like thrust vector control, reaction control systems are used in various stages. The guidance scheme can either be open-loop type or closed-loop type depending on the injection accuracies demanded. Telecommand and telemetry systems provide means of communication between ground and onboard systems. A large variety of mechanisms for stage-separation, heat-shield jettisoning, etc is used for getting rid of 'dead-weight.' These mechanisms are initiated through a host of pyro devices onboard.

It must be noted that each of the major systems in turn consists of many sub-systems and components. For example, in inertial guidance there are components like gyros, accelerometers anCl sub-systems like onboard computers.

This brief listing of hardware does not include the ground systems necessary for launching and tracking a vehicle from a range. Also not included in the above list are various types of software essential for carrying out a mission.

Instead of listing merely the hardware systems, it may be more informative if I dwell on the specializations and the R&D infrastructure in the Vikram Sarabhai Space Centre (VSSC), which is the lead centre in ISRO for rocketry in general.

R&D INFRASTRUCTURE FOR LAUNCHER DEVELOPMENT

For convenience the R&D infrastructure essential for launcher development is divided into about half-a-dozen fields of specialization. These are: avionics and mission dynamics, materials and mechanical systems, solid propulsion, propellants and chemicals, information systems and systems reliability.

Avionics and Mission Dynamics

Under this broad field come specializations like flight dynamics, aerodynamics, wind tunnel testing, applied mathematics, electronics, inertial systems, navigation, and guidance and control.

The very first job in the development of a launch vehicle is to define the mission in terms of the spacecraft weight, the orbital parameters and the allowable deviations in these parameters. Since several launch vehicle configurations could, in principle, achieve a given mission, the next step is to select the most promising configuration that could be realized within the constraints of the available infrastructure and expertise, and that has the growth potential. This is followed by detailed design of the various sub-systems. The aerodynamics characteristics are determined and the trajectory is properly shaped. Also, the impact of any mid-course change on design is computed in terms of deviations from the original mission specification. Both theoretical and experimental methods are used for this purpose. Thus, over the years, VSSC has accumulated a rich collection of sophisticated software incorporating computer simulation techniques and the data from wind tunnel tests carried out on sub-scale models of rockets. Finally, after a rocket flight, the data obtained through telemetry and tracking are checked against predictions made earlier to see how good were the simulations.

Another crucial area is navigation, guidance and control. Considerable progress has been made from the open-loop guidance system employed for·SLV-3 to the closed-loop system developed for the ASLV. Inertial sensors like gyroscopes and accelerometers measure onboard the position, orientation and velocity of the rocket in flight at every instant, while computers onboard compute the trajectory. Deviations form the intended trajectory are automatically corrected in flight in closedloop mode. Two types of inertial navigation systems have been developed: (i) the stabilized platform inertial navigation system (SPINS) has already been flown on the first two flights of the ASLV, and (ii) the redundant strapdown inertial navigation system (RESINS) uses the indigenously developed dynamically tuned gyros (DTG). Optical gyroscopes are also under development. Since the systems which automatically pilot the vehicle in flight have to be reliable, redundancy is provided wherever feasible.

The major electronic packages developed for launch vehicles are telemetry, tracking and command systems which include C-band radar transponders, S-band range and range rate transponders(SRR1) and telecommand receivers(TCR). While the telemetry systems enable one to gather information on how the various sytems onboard a rocket in flight are functioning, the telecommand systems allow commands to be sent from ground to the rocket. The telecommand systems are provided mainly for sending commands for destruction of the rocket, should it deviate from its specified path violating flight safety conditions.

Fabrication of the electronic packages is taken care of by a judicious blend of in-house and external facilities. For example, a separate Space Electronics Division has been created in the Bharat Electronics Ltd, Bangalore, for production of some of the packages. In electronics, efforts at micro-miniaturizing various circuits continue because, in a launch vehicle, both volume and weight are available only at a premium.

Materials and Mechanical Systems

This area covers, mechanical engineering, materials science, metallurgy, composites, structural engineering, aerospace mechanisms, mechanical facilities and integrated structural dynamic test facility.

A piece of hardware as simple as a fastener or as complicated as a liquid engine calls for expertise in materials science, structural and mechanical engineering for its ultimate realization. Design, development and fabrication of hardware are the main ingredients of VSSC's efforts in materials and mechanical systems.

A large variety of materials which possess properties of light weight, high strength and easy processability is routinely used in the fabrication of rocket and satellite hardware. Examples are: stainless steel, magnesium alloys, aluminium alloys, 15 CDV-6, maraging steel, beryllium, titanium, pyrolytic graphite, molybdenum, polyaramide, glass and carbon fibres. One of the important milestones is the successful development of a catalyst for dissociation of monopropellant used in reaction control systems. Indigenization of maraging steel production, titanium alloy forgings are notable achievement of VSSC in the area of materials.

Some examples of hardware developed using these materials are: nozzle throat inserts, high pressure gas storage bottles, large size hemispheres for liquid stage, etc.

The importance of composite materials like fibre reinforced plastics in the fabrication of space hardware was recognized quite early in VSSC. Thus, over the years a large variety of rocket and satellite hardware has been fabricated using different types of composites, motor cases, nozzles, heat shields, pressure bottles, igniter cases, destruct system covers, parabolic antenna for communication satellites, etc. For the INSAT-II TS, which is being developed indigenously, quite a few composite items are being developed by the VSSC: solar panel backup, C-band and CIS band antennas, helium pressure bottles, yoke and SADA (solar array drive assembly) core.

Today, the Reinforced Plastics Centre (REPLACE) at Vattiyoorkavu, Trivandrum, is fully equipped to cater to the needs of ISRO in the field of composites.

Aerospace mechanisms constitute a vital part of rocket hardware. Examples are: separation systems for stages including strap-ons, jettisoning systems, heat shields, satellite separation and so on. These systems are crucial to the success of any mission. Over the years VSSC has accumulated a wealth of experience in this field.

Research in structural engineering complements the efforts described above. The structural analysis software known as FEAST (Finite Element Analysis of Structures) has been of great use not only to VSSC but to other agencies in the country as well. Photoelastic, holographic and acoustic emission methods are routinely used to test various structural elements in addition to vibration testing of flight hardware. VSSC has also played an important role in designing the Acoustic Test Facility at the National Aeronautical Laboratory, Bangalore.

The backbone for all hardware activity is the Mechanical Engineering Facility which takes care of machining and fabrication. In addition, fabrication of large-size hardware like motor cases and inter-stages by external agencies like Walchandnagar Industries Ltd, Larsen & Toubro, Hindustan Aeronautics Ltd, etc is looked after by the engineers of this group.

Solid Propulsion, Propellants and Chemicals

Under this are grouped: Propellant engineering, solid propulsion, polymers and special chemicals, chemical engineering, pyrotechnics, chemical analysis, heat transfer, a multipurpose pilot plant in special chemicals, named the Propellant Fuel Complex, Rocket Propellant Plant, Ammonium Perchlorate and Solid Motor Propulsion.

The energy needed to propel a rocket comes from propellants and certain special chemicals. Evidently, the critical importance of R&D in this field cannot be over emphasized, especially when the aim is self-reliance. VSSC's efforts include development and supply of both solid and liquid propellants.

Over the year VSSC has developed a range of composite solid propellants based on polymers like, ISRO Polyol, PBAN (polybutadiene acrylo nitrile), HEF-20 (high energy fuel), CTPB (carboxyl terminated polybutadiene) and

HTPB (hydroxyl terminated polybutadiene). By combining the high energies of the composite propellants with the natural ruggedness of the double base propellants containing nitroglycerine and nitrocellulose, a new formulation of composite modified double base (CMOB) propellants has also been developed.

Research in this field has resulted in development of many polymeric materials and chemicals like propellant binders, aromatic polyaramides (Kelvar type), aromatic polyamides (Kapton type), adhesives, sealants, potting compounds, etc. These have been used successfully not only in sounding rockets and launch vehicles but in satellite systems like apogee boost motors.

The expertise gained in chemical engineering has resulted in the establishment of production units like the Solid Propellant Rocket Booster Plant(SPRBP) at Sriharikota, the Ammonium Perchlorate Experiment Plant (APEP) at Alwaye and the Propellant Fuel Complex (PFC) at Trivandrum. Originally established to scale-up laboratory level processes to viable production levels, PFC has also helped demonstrate viability of some of the processes for technology transfer to Indian Industries.

The Project Engineering and Productionalization Facility (PEPF) has ensured reliable supply of all the important liquid propellant ingredients like RFNA (red fuming nitric acid), hydrazine, UOMH (unsymmetic dimethyl hydrazine), Green N204 and so on. The liquid propellants thus produced are used both in satellites and rockets.

Another crucial area is pyrotechnics which include igniters, pressure cartridges, cable cutters, pyrojacks, explosive bolts, safe-arms, delay columns, explosive transfer assemblies, etc. A pyrovalve designed for the poison injection system has been successfully adopted by the Tarapur Atomic Power Plant. In pyrotechnics, VSSC is self-sufficient both for rocket and satellite applications.

Finding solutions to problems in ignition, combustion, thermal insulation and heat transfer is another important field of research in VSSC.

Solid rocket propulsion concerns design and fabrication of the propellant charge, ignition and nozzle systems through which hot combustion products in 2 500°- 3 000°C range are accelerated to supersonic speed. The evolution of nozzles has progressed from the simple graphite and metal construction of early days through graphite and asbestos phenolic ablative liners to carbon phenolic and silica phenolic ablative liners. Today, VSSC has competence to solve most of the design and hardware realization problems associated with the design and development of composite nozzles for solid motor propulsion.

A range of facilities supports the development efforts in this field. Sophisticated instruments like gas chromatograph mass spectrometer and facilities like arc jet facility enable complete characterization of all chemicals and ablative materials developed in-house. In addition, facilities exist for vacuum, multiple and pressure casting, curing, propellant trimming, etc.

New R&D efforts include fuel rich propellants, air breathing propulsion systems, etc.

Information Systems

To meet the complex computational needs in fields like aerodynamics, structural enqineerinq, etc VSSC is equipped with powerful digital computer systems which function round-the-clock. Supporting features include interactive computing, graphics, data base, etc. These facilities enable the researchers to model their designs and to simulate the behaviour of their systems even without the actual hardware. Designs are also validated under permissible perturbed conditions. To study the behaviour of the integrated inertial guidance hardware/software under simulated flight conditions, a hybrid computer (analog and digital) is used. In this simulation, the actual hardware units that would fly in a rocket can be connected in the simulation loop.

Systems Reliability

Reliability is a statistical concept which connotes the user's expectation that a system would work acceptably under given environmental conditions. It is to be distinguished from quality which is a measure of how closely a system conforms to stipulations on the design, manufacturing, test and evaluation process. Taken together the efforts in this direction may be termed as reliability and quality assurance (R&QA) management; they pervade all stages of our activities from conceptual design through fabrication, test, operation and post flight analysis. To ensure adequate practice of the quality culture, various check lists and acceptance criteria are prepared depending on the product. A catalogue of various components approved for use consistent with reliability requirements is prepared and any deviation from this list has to go through predefined discussion, test and review protocols before acceptance. Initially qualification tests are done on a prototype which may be viewed as an intensive search for inherent defects in the design, and the realization process with respect to the hostile flight environment. Having passed these, the design and manufacturing processes are frozen realise the flight units of the product, which undergo acceptance level tests to detect workmanship defects. Individual failure unearthed in this process are adequately analysed, corrective actions are identified and documented for future guidance. Even up to the lift-off, the obsession for checks continues and the computerized countdown is automatically stopped if any parameter shows off-limit values. Dedicated facilities have been established to implement the various facets of R&QA.

Liquid Propulsion Systems Centre of ISRO

When we started development of launch vehicles in ISRO, we first concentrated on development of solid propulsion systems only because their development is relatively easier than that of liquid systems. We knew even at that time that sooner that later, we would be needing liquid propulsion systems because they are more efficient. The efforts over the years in this field have been so successful that recently ISRO has created a new centre called the Liquid Propulsion Systems Centre (LPSC) with a mandate to develop thrusters needed for both control purposes as well for primary propulsion in rockets and satellites. Headquartered at Valiamala in Trivandrum, LPSC has laboratories and large test facilities at Bangalore and Mahendragiri in Tamil Nadu.

STRATEGY FOR DEVELOPMENT

Once the decision to go in for the space programme was taken, the question that confronted pioneers like Vikram Sarabhai and his close associates was: what is the strategy to be adopted? Two approaches, which represented extremes, suggested themselves, viz, (i) we should develop everything indigenously, perfect that technology and then apply the same to our needs, and (ii) we should go for wholesale import instead of wasting our resources in 'reinventing the wheel.' It was good that ISRO perceived quite early that the most cost-effective and time-saving solution was to go for a 'golden mean' which represented a mix of the two views. This is still the philosophy of ISRO and, I am convinced that it has paid-off handsomely. Let me elaborate on this. We in ISRO had never said that we would not use satellites until we build our own. Indeed, we borrowed satellites to conduct our SITE and STEP experiments. Similarly, we borrowed launch vehicles to orbit our own satellites — Aryabhata and Bhaskara. We even made an outright purchase of a communication satellite from abroad, namely, the INSAT-IB. But the important thing to be noted is that while we were borrowing satellites or buying launch services, we are concurrently developing our own satellites and launch vehicles. This practice continues now in ISRO. Thus, while INSAT-I series represents a bought-out spacecraft, INSAT-II series, presently being developed by ISRO will be indigenous. Similarly, the first few satellites in IRS series will be launched abroad; but the subsequent ones will be launched by our Polar Satellite Launch Vehicle (PSLV). I find this a praqmatic.and very cost-effective approach. By this means we gain hands-on experience even before we have our own systems; in other words, we cut short the lead time required to establish a system of our own. Also, the people of our country start reaping benefits of space technology even before we are ready with indigenous systems, as they are doing now with INSAT-I Satellites.

By adopting this strategy, what we have achieved can be described as leap-frogging. The concept of concurrency has played a vital role in this strategy. Let me elaborate on this. One can say: 'Let us first develop all the technologies needed and prove them before we undertake a major space launcher project like ASLV or PSLV, say. This is a kind of a serial approach which requires enormous time to build a launcher. We consciously did not adopt this method. On the other hand, we said that development of the needed technologies and the development of a major system like ASLV (Augmented Satellite Launch Vehicle) would go on simultaneously. This is what I mean by concurrency. For example, the development of inertial navigation system was undertaken simultaneously with that of ASLV. Similarly, development of maraging steel and associated fabrication technologies was taken up along with the realization of PSLV, the Polar Satellite Launch Vehicle. Again, the development and productionization of HTPB binder and the propellant based on it for PSLV first and third stages are done as part of the PSLV programme itself. Examples like this can be multiplied not only in the launcher development programmes but also in spacecraft development and even in space applications. This approach has yielded rich dividends even though it has caused some anxiety in regard to schedules. It has enabled the country to reap benefits from space even though in certain areas we have not perfected the indigenous systems to the operational levels.

Organization

Having established the relevance of space technology to the country and having defined the strategy, we need to evolve organizational systems that are compatible with the strategy.

The organization at VSSC has two key elements: (1) Projectization of development of multi-disciplinary system, and (2) Build up of R&D groups. Some of the important features of a project are: it has a well defined goal, the end product is generally a sophisticated piece of hardware like a space launcher, the whole activity is non-repetitive, and it implies completion of jobs within specified cost and time envelopes.

An activity is projectized through a series of steps, some of which are: Pre-project activity (Study Plan); Definition of goals like Mission, Configuration, etc; and Project team formation and definition of responsibilities (this includes breaking down of the main task into individual jobs of relatively smaller magnitude, estimation of time and resources needed for each individual job, constitution of review teams, test schedules, configuration control, system integration, maintaining visibility on all aspects of project management, etc).

The R&D groups have both long-term and short-term goals. They have some degree of academic freedom to pursue R&D goals to keep themselves abreast with the state-of-the art in their specialization. These are their long-term goals. On the other hand, they act as sub-contractors to a project in delivering a particular system or sub-system within the schedules specified by the project. These contractual obligations to the project constitute their short-term goals.

The main managerial challenge at a place like VSSC is thus to be able to dovetail the long-term goals of R&D. groups into the short-term goals of a project.

Our experience over the last two decades has vindicated the strategy and working culture we have fostered in ISAD in general and in VSSC in particular.

WHERE WE STAND

As far as space launchers are concerned, we in ISRO have successfully completed one major project, namely, the SLV-3. Two projects, one for the Augmented Satellite Launch Vehicle (ASLV) and the other for the Polar Satellite Launch Vehicle (PSLV) are concurrently running. The work on the definition of the Geo-Synchronous Satellite Launch Vehicle (GSLV) is nearing completion.

SLV-3 — lndia's First Generation Launch Vehicle

The first success in space launcher development came to India on July 18, 1980, when the 17-1,23-m tall, four-stage, solid propellant rocket, SLV-3, successfully injected a 40 kg 'Rohini' satellite into a low earth orbit. This was followed in succession by two developmental flights in 1981 and 1983 which demonstrated the maturity of design and repeatability in fabrication of space launchers in ISRO.

The success of the SLV-3 project may be measured in terms of the following gains: (i) a base for launch vehicle technology in the country has been established, (ii) a basic work culture of organizing a large, goal-oriented, multi-disciplinary R&D activities has been proved to be beneficial for realizing clearly stated technological goals within stipulated cost and time constraints.

The Augmented Satellite Launch Vehicle (ASLV)

ASLV, the second generation launch vehicle of ISRO, augments the payload capability of the erstwhile SLV-3 by more than three times. It is designed for launching 150 kg class of satellites (eg, the Stretched Rohini Satellite Series-SROSS) in low earth orbits. Once operationalized, the ASLV will serve as a low-cost workhorse for India, and possibly for others, for conducting experiments in space sciences, space technology and applications.

The concept of ASLV is remarkable in that while maximizing utilization of technologies already developed for the SLV-3, it employs a host of new ones which will feed directly into the future launch vehicle programmes of ISRO.

Though the first two developmental flights 1987 and 1988 failed to complete their missions, a number of technologies developed for ASLV has been validated through these flights. Some of these which feed directly into the PSLV and GSLV are: strap-on technology, inertial navigation and closed-loop guidanc, vertical integration, S-band technology and bulbous metallic heat shield. In addition, extremely valuable data have been collected on aero-structural and control interactions during the atmospheric flight of rockets.

The Polar Satellite Launch Vehicle

The Polar Satellite Launch Vehicle (PSLV), presently being developed at VSSC, will provide launch services for remote sensing satellites operating in the polar sun-synchronous orbits.

By any standards familiar to us in the country, PSLV is verily a giant. Standing as tall as a fourteen storeyed building and weighing an awesome 275t at lift-off, it is designed for injecting a 1000 kg. Indian Remote Sensing satellite into a special 900 km altitude orbit known as the sun-synchronous orbit.

Configured as a four-stage vehicle, the PSLV will be employing liquid propellants in its second and fourth stages. The main core booster (ie, the first stage) carries over 125t of solid propellant; it is surrounded by six strap-ons each of which is, in thrust power, equivalent to the first stage of the SLV-3. The second stage, which is powered by a liquid engine, carries over 37t of liquid propellant. The third is a soild motor with 7t of propellant and the final stage, being again a liquid one, has provision for velocity cut-off that increases the effectiveness of the closed-loop guidance in achieving a precise orbit. Each of the stages has its own control systems for steering the vehicle through the desired course.

With the realization of PSLV, India would enter the phase wherein indigenously developed applications satellites will be launched from our own soil using indigenously developed launch vehicles-a phase that will bring us closer to the goal of total self-reliance in space technology. The first launch of PSLV is expected within the next two years.

The Geo-Synchronous Satellite Launch Vehicle (GSLV)

This vehicle is being designed for launching INSAT-II type of communication spacecraft that is being developed indigenously. A project team is right now working on the project report, including definition of the vehicle, its sub-systems, cost and schedule for realizing the GSLV.

Participation of Industry and Academic Institutions in Space Launcher Development

The main goal of VSSC to achieve self-reliance in rocketry is sought to be achieved through progressive indigenization of all related technologies. As a natural consequence of pursuit of this goal, VSSC has over the last two decades, established strong and mutually beneficial links with the Indian industries both in the public and private sectors. The interaction between VSSC and industry has two facets:

(1) Direct involvement of Indian industry in the projects of VSSC, (eg, rocket motor case fabrication is undertaken by the industry). Some of industries participated directly in the execution of the SLV-3 project; same is true of the ASLV Project also. With PSLV the number of industries involved has shot up to over 150. Presently, the industries function mostly as sub-contractors or suppliers of goods and services to high-tech projects of VSSC. But in the near future, when VSSC enters the fully operational phase, the industries will have to undertake bigger tasks involving systems engineering and production.

(2)Technology Transfer-Technology transfer, as practised in ISRO is of three types: items for which ISRO itself is the chief buyer; items for which the main market consists of agencies and organizations utilizing spacerelated systems promoted by ISRO, and items which have non-space application (ie, spin-off).

Technologies transferred by VSSC to industries can be classified as follows: Polymers and special chemicals; Avionics systems; Process equipment; and Computer software.

Till date, 53 technologies for various products and processes have been transferred from VSSC to the industries. In addition to the above, VSSC offers consultancy services to the Indian industries in the following fields: chemical engineering, communication engineering, composite materials, environmental testing, strain gauge transducers, optical sensors, precision fabrication, servo-control, structural engineering, fluid dynamics and quality and reliability.

Technology transferred is basically a continuous process and right now 15 new processes and products are being considered for transfer.

Technologies Already Transferred by VSSC to Indian Industries

Polymers, special chemicals and materials-Isropol, Isrothane, UDMH (Unsymmetrical Dimethyl Hydrazine), ISRO-Dry powder for fire fighting, Adhesives, sealants, Dioctylphthalate (DOP) plasticizer, Liquid phenolic resin, Silver-zinc-vented cells, EPR coat formulation, pottofoam-F, dimer acid/ester and polyamide, ISROSILHigh silica content silica cloth, and polydimethyl siloxane and silset.

Avionics systems-Pressure and thrust transducers, Remote monitoring and encoding unit, Data amplifier, Vibration pick-up with charge amplifer, Strain gauge accelerometer, and Microprocessor based real time sytem.

Process equipment-Vertical mixer, *Pultrusion machine for composite extruded products.

Computer Software-FEAST (Finite Element Analysis of Structures).

INTERACTION WITH ACADEMIC INSTITUTIONS

The real strength of an organization like VSSC lies in the quality of its manpower; in other words, the human resource is its greatest asset. But the main sources of trained manpower are the academic and research institutions in the country. This alone is reason enough for VSSC to maintain close links with the academic world.

This interaction with the academic institutions is encouraged through two formal schemes: (1) the RESPOND programme, and (2) the Space Technology Cells.

The RESPOND Programme

Under this scheme ISRO supports specific research projects proposed by scientists from the academic institutions. During the last decade ISRO has supported 200 research projects at 75 institutions in which nearly 600 scientists participated. Nearly 70% of these projects have been successfully completed.

Space Technology Cells

While RESPOND merely sponsors chosen research projects, the Space Technology Cells encourage joint collaborative research in areas of immediate relevance to the Indian Space Programme. In addition, scientists and engineers from ISRO can, under this scheme, enhance their academic qualifications and take up teaching assignments.

The Space Technology Cells are presently operating at the Indian Institute of Science (IISc), Banqalore, and the Indian Institute of Technology (IIT) in Bombay and Madras. The areas identified for collaborative research are: rocket propellants, satellite technology, orbital mechanics, computational techniques, remote sensing, etc.

The ISRO-Academic world interaction is thus two-way street: while ISRO uses the scheme to improve its human resources, the academic institutions get an opportunity to work on real world problems.

CONCLUSION

Space technology can undoubtedly contribute significantly to national development. It is up to us, the professionals, to exploit this potential of space for the development of our nation. Self-reliance in space technology is essential if we wish to provide operational space services to the nation uninterruptedly. This implies self-reliance in space-launcher technology as well. Over the years ISRO has evolved a strategy by which the nation as a whole benefits from space even before all the systems are indigenized. Theconcept of concurrency is fully exploited in this strategy so that within the next one decade or so, India will be in a position to launch its own applications satellites, both for communication and remote sensing, using its own space launchers from its own soil.

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A Hundred Years of Radio Science — Some Milestones

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At the outset, may I express my sincere gratitude to the Institution of Engineers for inviting me to deliver the Sir R.N. Mukherjee Memorial Lecture. I would like to take this opportunity of describing to you an area of science in which India has achieved a high level of international recognition — an area that has had many important engineering and technological applications. This is the area of Radio Science. I would like to take you through 100 years of Radio Science in India and I will do so by selecting a few major milestones.

Before describing these important milestones, perhaps a few words are necessary to explain what Radio Science means. In the early years after the successful communication experiments of Marconi over the Atlantic and the discovery of the Ionosphere in the early twenties, one understood by the word "Radio Science" only the problems of the Ionosphere and the propagation of radio waves through these ionized media. This situation existed for several decades. The second major field of interest in these early years was 'Asmospherics', but mainly as a source of intereference to radio communication. Later with the dramatic discovery of whistlers in the fifties a spectacular aspect of atmospherics for magnetospheric studies began. The whistlers are a result of dispersion of the VLF radio waves introduced by lightning discharges travelling along magnetic field lines from one hemisphere to another. A new element was added with the recognition of the role of tropospheric propagation of radio waves and tropospheric scattering in radar and troposcatter systems. This resulted in the new field of 'Radio Meteorology'. At the same time came a new discovery out of the measurements of short wave signals, i.e. discovery of radio waves emitted by natural processes from astronomical objects. Thus, a new branch of radio science was born: 'Radio Astronomy'. Subsequently, there were major developments in masers, in solid state semi-conductor devices, in miniaturisation of a scale undreamt of earlier and now in optical devices and optical communication. A virtual communication revolution emerged through a combination of satellite links, television, fibre optics and high speed communication leading to a video communication revolution. With the advent of satellite another branch of radio science was born: Remote Sensing. Techniques opened up for sensing through radio waves sent from the satellites or received at the satellite the condition of the land, the ocean, the ice, the atmosphere, the ionosphere and the magnetosphere.

Thus over the years, radio science has been widening its scope in many directions. As a result it now means a wide variety of things: radio standards, fields and waves, signals and systems, electronic and optical devices and applications, electromagnetic noise and intereference, remote sensing, wave propagation through the ionosphere and the troposphere, waves and plasma, radio astronomy by electromagnetics, Electronics as we now know arises from and is based on many of these branches of radio science.

In these broad canvas of what we now call radio science, there have been remarkable contributions from Indian scientists and technologists for the last 100 years. As a result India's reputation in this area is very high. A visible evidence of this recognition is the fact that in the International Scientific Radio Union (URSI), the apex body in radio science, Indian scientists have occupied positions of honour. I myself was the President of the URSI during 1984 to 1987 and Professor Radhakrishnan was the Chairman of its Commission on Radio Astronomy and Professor Govind Swamp has for several years been a member of IUCAF.

Milestone 1: The first milestone I would like to talk about concerns a series of classic experiments on generation, reception and optical properties in the microwave region of 5cm to lcm by Sir J.C. Bose during the turn of the last century. Wishing to bridge the gap between the long Hertzian waves (a few metres) and long infrared waves obtained by purely optical methods, he built a Park Oscillator to produce microwaves, wire greetings to measure their wavelengths and galena crystals as detectors and conducted experiments as a reflection, most important event was a demonstration in 1895 of wireless transmission through solid walls and its repeat experiment at the Royal Institute of London in 1986 — a year in advance of Marconi's famous experiment. This was the beginning of radio science in India.

Milestone 2: The second milestone really came after a lull of over 20 years. This was the establishment of the Wireless Laboratory at Calcutta under the leadership of Prof. S.K. Mitra. In 1930 a medium wave transmitter made available by the Calcutta Station of the Indian State Broadcasting Service was used and a receiving system was installed and with these the first experimental evidence of the E region of the ionosphere was established in India by S.K. Mitra and his colleagues. This was achieved only a few years after the discovery of the Ionosphere by Appleton and Barnett in England and Breit and Tuve in USA. This was an exciting period for ionospheric science in India. The second polar year was being organized and the study of the Ionosphere was included for the first time. S.K. Mitra decided to formally participate in this programme: this was India's first entry into organized international science. A well-known experiment that was performed were the measurements during the annualar solar eclipse visible in Calcutta on August 21, 1933.

Milestone 3: The third milestone was an organizational one - the formation of the Radio Research Committee in India. This was a critical point in the history of radio science in India. For the first time, funds and support could be provided to groups in universities. Research bagan to be supported in a wide range of area: atmospherics, ionosphere, design and construction of radio valves, communication systems, measurement of radio noise and indigenous system of radio components. Research programmes were supported in areas like carbon-microphones, loudspeakers, volume controls, carbon resistances, microwave condensors and general utility condensors. An important aspect was the initiation of the developmental work on vacuum tubes upto the pilot plant stage in the laboratory of Prof. S.K. Mitra. This was the beginning of research on electron devices in India. Some of early products were rectifier tubes - the type 80 diode and type GC5 triode - the first to be made in India.

Milestone 4: The IGY: The fourth milestone was the Indian programme for the International Geophysical Year (IGY). This was an international programme of vast magnitude involving several thousand scientists. India was a major participant. India's role in this programme was unusual. Firstly, India's location: the geomagnetic equator passes through the southern tip of India. There are a number of phenomena (electrojet is one of these) which occur specially in this region. Secondly, introduction of two special techniques by Indian scientists: the riometer developed a few years earlier by A.P. Mitra and Shain and the three station ionospheric wind measuring system developed by S.N. Mitra. Both were used effectively. Furthermore, radio techniques of a wide variety were commissioned for the detection of solar flares: these included the use of atmospherics, cosmic radio noise, vertical incidence ionosondes, radio emission from the Sun.

Milestone 5: Beginning of space radio research. This was in 1957. This occured when the first satellite Sputnik 1 was launched. Radio scientists at NPL and elsewhere started recording telemetry transmission from the satellite. Serious radio beacon observations, however, began with the satellite COSMOS 5 at frequencies of 20,40 and 41 MHz later. A major event was the establishment of a rocket launching facility at Thumba in 1963 located close to the geomagnetic equator. Soon Indian payloads were designed, fabricated and installed in rockets. A major payload was the Langmuir probe. This was used extensively.

Milestone 6: Bhabha Committee: Setting up by the Govt. of India under the Chiarmanship of Bhabha an Electronics Committee to prepare a ten-year development plan for electronics in 1963. The Bhabha Committee Report (1966) pointed out the dynamical nature of science and electronics, its all-pervading nature and its revolutionary impact on science, industry and society. It pointed out that "the ratio of annual product to investment is less than half in the steel industry and of the same order in the heavy chemical, petrochemical and fertilizer industries, but is nearly two in the electronics industry". It also noted that since the development cycle in several areas was of the order of three years, intense and continuous research is the key to development and so also is adequate test facility. Production of components is the backbone of the electronic industry and must be of adequate quantity and quality. The deliberations of the Bhabha Committee gave an impetus to the technology development then underway in NPL on electronic components (specially mica and ceramic capacitors and ferrites) and the efforts on instrumentation development in BARC. These two activities were later to become the nucleas of the two public sector undertakings: CEL and ECIL.

Milestone 7: Radio Astronomy: Serious beginning of Radio Astronomy should really be dated from the installation of the radio telescope in Ooty. However, quality radio astronomy work had started earlier. In 1965 TIFR had set up near Bombay an equipment receiving radio noise from the sun at 49cm using two multi-element interferometers. The Ooty radio telescope was, however, the most spectacular and in many ways highly original. Construction of the telescope started in 1966 and was completed in 1970. It operates on 322-328 MHz and has an effective collective area of 8000 m^2 (about three times that of the Jodrell Bank 250 ft.dish). It is 530 m long and 300 m wide consisting of parabolic cylindrical antenna array. The most interesting feature is that the long N-S axis is parallel to the earth's axis of rotation. This has been arranged by placing the telescope on a North-South slope equal to the latitude of the place. This allows tracking of the radio source for about 9.5 hours in hour angle by simply rotating the antenna system along its large axis.

Milestone 8: Tropospheric Research: Early seventies saw the beginning of intense troposcatter research in the country. The impetus came from the desire in India to establish transhorizon troposcatter links and increasing requirements of sophistication in radar operation. The Ministry of Defence set up the ADGES programme for this purpose. Radar and troposcatter system research was initiated at five IITs, the Institute of Science in Bangalore, the Roorkee University and the National Physical Laboratory in New Delhi. A wide variety of activities were initiated: phased array radars, establishment of troposcatter radio parameters through radiosondes, introduction of new techniques of monitoring etc. A major achievement was the preparation of Atlas of tropospheric radio refractivity over the Indian subcontinent jointly by the National Physical Laboratory and the Indian Meteorological Department. Also a new tropospheric transmission loss prediction system was worked out. This replaced NBS 101 till then considered the bible in troposcatter systems.

Milestone 9: SITE Programme: One of the most important national effort in the mid-seventies was the programme connected with ATS-6 satellite. There were two major problems: (1) one relating to direct reception of TV signals from about 2330 villages in six widely separated and direct reception clusters and (2) a planned network of satellite radio beacon receiving equipment operating in different parts of india at one or more designated frequencies: 40, 140, 360 and 860 MHz. The direct broadcast satellite programme (known as SITE) was a unique experiment conducted jointly by ISRO and NASA on family planning, agriculture, health and hygiene. The prime earth station was located at Ahmedabad linked to a TV studio which in turn was connected to a VHF transmitter at Fij, 50 km from Ahmedabad. Programmes were sent to the satellite on 6 GHz band and then retransmitted by the satellite at 860 MHz with a 30 ft. antenna. Each village receiving system consisted of: (a) a chicken mesh dish of 10 ft diameter, (b) a front end convertor which converted the YHF signals to video and audio. Both were designed and developed by ISRO and manufactured by ECIL.

The experiment was successful both scientifically and socially. One of the many examples of its success was the Republic Day telecast on January 26, 1976. On this day, the satellite network included all Doordarshan TV stations. The result was that for the first time people in Delhi, Calcutta, Bombay, Poona, Srinagar, Lucknow, Kcrala and 2330 villages saw the Parade in realy time. While the SITE programme was operationally an exciting adventure, the second aspect was scientific. ATS-6 was the first geostationary satellite available to a wise community of Indian ionospheric scientists. The frequency coverage was also very wide extending from 40 MHz to 860 MHz. This allowed a study of the frequency effects in scintilation in equatorial regions. An extensive network of stations could be organized over the entire Indian subcontinent.

Milestone 10: Advances in Radio Standards: Late seventies also saw a major new dimension in time and frequency dissemination and calibration. This came in two ways: (a) through replacement of old quartz clock by cesium atomic clocks and (b) from the use of satellites. The French-German Satellite Symphonie was used to synchronize: (a) two atomic clocks located at Madras and Ahmedabad and externally between NPL, India and PTB, West Germany, the latter with the precision of IOns. Use was made also of the Indian Experimental Satellite APPLE, INTELSAT-IV and INSAT-lB. The crowning event was the initiation of systematic time transfer through INSAT-lB, on 28 March, 1988.

Milestone 11: New Developments in Radio Standards: The new development was basically an approach towards fundamental constants. In electrical standards, this involved the establishment of Josephson facility as a standard for voltage and use of quantum Hall effect as a standard for resistance using a 14 tesla supercondiucting magnet With this farad and ohm were linked with length standard through a specially designed calculable capacitor so that second-meterohm-ampere-volt become interlinked.

Milestone 12: Radio Remote Sensing: Radio Remote Sensing began in India with the operation of satellite BHASKARA-I AND II. These were two nearly identical low-orbiting satellites carrying microwave radiometers (SAMIR). BHASKARA-I operated from January 19, 1979 to March, 1981. BHASKARA-II was launched in November 1981. There were two radiometers in BHASKARA-I (19.35 and 22.235 MHz) and three in BHASKARA-II (19.35, 22.235 and 31.40 MHz). With these three frequencies, different types of information could be obtaioned: atmospheric water vapour content through 22 GHz radiometer and through all frequencies information on "sea-state" and rainfall rates.

Milestone 13: MST Radar: The MST Radar is a high power, pulse doppler radar operating in the VHF, capable of exploring the atmosphere from surface to about 90 km covering the troposphere, the stratosphere and the mesosphere.

It is a joint effort of scientists from a number of national laboratories amd universities. It is a new generation radar of immense potential for continuous atmospheric probing in a three dimensional form. The Radar will be located at a place called Mittagadanki near Tirupati, not far from the rocket range SHAR — an added advantage providing possibilities of intercomparison. The radar will operate at a frequency of 53MHz with a peak power of 2.5 MW. The antenna system is an array of 1024 Yogi elements spread over an area of 136 m × 136 m. The radar is expected to operate on ST mode by mid-I990 and MST most in 1991. A major point to note is that the scientific design was completed entirely by Indian scientists amd the fabrication and installation has been undertaken by an Indian group, SAMEER. It will operate as a national facility providing major opportunities for atmospheric research to Indian Aeronomers.

Milestone 14: GMRT: The GMRT is a worldclass meterwave radio telescope — the largest in the world for operation over 38 to 1500 MHz — that Professor Goving Swamp and his colleagues are building. The 35 crore facility is expected to be operational by 1992 (the International Space Year). The present design consists of 34 fully steerable parabolic dishes, 45 m in diameter in a very special configuration. There is a central array, 1 km^2 in size, with 16 antennas. The remaining 18 are lined along three arms, 14 km long, with 6 dishes in each arm. The total system looks like a Y-shaped array. The telescope is being set up as a National Facility at Khodad 80 km north of Pune. It will explore a wide variety of celestial objects from our solar system to the very edge of the observable universe. It could also address the most challenging objective of searching for radioline emissions at metre wavelengths; this could emanate from cold hydrogen clouds that are believed to occur in the universe before the formation of galaxies.

Milestone 15: SROSS Aeronomy Satellite: This is a 150 kg satellite earmarked for upper atmospheric and y-ray experiments designed and being fabricated by NPL and ISRO. The orbit is planned to be nearly circular: 475±75 km. The objective of the upper atmosphere experiment is to look at the peak region of the low latitude ionosphere and to measure ionization and temperatures at these levels. The y-ray experiment from ISRO has astrophysical interest.

I have taken you, through hundred years of distinguished record of progress in radio science in a span of one hour or so. Clearly the scope, nature and perspective have changed over the years. But I hope I have been able to convey to you the quality of excellence that have continued over this long period from years much before independence to now. The dominant roles played by a few individuals in clear: J.C. Bose, S.K. Mitra, Saha, Sarabhai, Ramanathan. There is also unmistakable impact of several specific events: formation of the Radio Research Committee, the IGY and the IQSY, the Bhabha Committee Report, the IMAP, availability of new generation of satellites and now the IGBP.

The Engineering Profession in a Changing Context: Challenges and Opportunities

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INTRODUCTION

It is an honour and a privilege for me to deliver the 12th Sir Rajendranath Mookerjee Memorial Lecture. The theme of this Congress 'Challenges of Change' is as much appropriate to his inspiring memory as it is relevant to our times. I wish to make a small contribution to the thinking on this theme by setting the engineering profession in the changing global technoeconomic perspective. To a distinguished audience such as yourselves much of what I am going to say may be known already but I think we need an interrelated and coherent perspective which can lead to action.

Engineering itself is a practical set of disciplines steeped in action. Engineers are, and have been, agents of change. They made and introduced much of the inventions that led to the Industrial Revolution and the rapid growth that has gone on ever since. Craftsmen and artisans too made significant contributions which are often overlooked. But the days of individual inventor and craftsman are gone and have been replaced by organized innovation running on the two engines of 'demand pull' and 'technology push'. The engineering profession too has grown in depth and diversity. Many new engineering disciplines have sprung up. The word 'engineering' itself is used to denote the systematic use of techniques to achieve specific results, such as protein engineering, software engineering, and so on. People with engineering backgrounds have made increasing contributions in other walks of life, such as business management, entrepreneurship, administration and politics and not only as production or design engineers, researchers or teachers. With the increasing complexity of the world, engineers and, for that matter, other professionals have to think in terms larger than those of their every day tasks. This has become particularly necessary for the engineering profession as a means of personal advancement, professional excellence and contributing more meaningfully to society.

I shall begin with a survey, though rather sketchy, of the global economic and technological trends. I shall then invite your attention to some elements of an agenda for action in the Indian context.

SURVIVING IN THE WORLD ECONOMY

Global economic inter-dependence has become irreversible. But for the developing countries the interdependence is largely one way, that of a poor relation and a rich one. There is an increasing danger of their marginalization. The 1980s have been termed to be a 'lost' decade for developing countries. While in the 1970s the annual growth of their Gross Domestic Product averaged 5.5% and per capita growth 3%, during the 1980s their annual growth averaged 3% and per capita growth 1%. The external economic environment for the developing countries in the 1980s was generally characterized by shrinking resource flows, declining commodity prices, rising interest rates and increasing barriers to markets. Those countries have therefore entered the 1990s with a variety of handicaps, some of them passing, yet others fundamental. The progress made in health and education in many developing countries may give some cause for satisfaction but does not alter the basic facts of their plight.

As for industry, the world is tending towards a spread of pre-industrial to post-industrial societies. But almost all societies regard industry as central to their growth and modernization. Even in a service economy, industrial activity is essential to create demand for services or to support their supply; in an agricultural economy to improve agricultural productivity. In the developed countries industrial structure and organization are beginning to change while developing countries are for the most part still passing the early milestones of the previous industrial path. The relatively promising industrial growth of the developing countries in the seventies, in spite of the oil shock, gave way to minimal or even negative rates of qrowth in the early eighties. There were, of course, a few significant exceptions like the Asian 'tigers'. Industrial growth in India too has been substantially higher since the mid-eighties. But by and large industrial growth has been constrained in Latin America and Afric,a on account of the external debt burden, exacerbated in Africa by natural calamities. Some refer to this as deindustrialization of the South, at a time when the North is deindustrializing in a different sense due to the emergence of the service economy.

At the same time the significant efforts in industrialization made by several developing countries, including India, cannot be overlooked. Twenty-three developing countries have now over a 20% share of manufacturing in their gross domestic products. They have achieved rapid growth in some industrial sectors, such as steel and petrochemicals. The entry of developing countries in the mainstream of world industry has, however, coincided with a prolonged slow-down in the world economy and an overwhelming increase in their external debt burden.

There is a close nexus between external debt and industrial growth. On the one hand, the scarcity of foreign exchange severely constrains import of technology and capital goods for new industries. Existing industries suffer for want of components and raw materials and consequently work to less than their capacity. On the other hand, to control, let alone reduce, the debt burden export of manufactures becomes crucial. Primary commodities suffer from inelastic demand and unfavourable terms of trade, while there is not as yet much by way of services that can earn foreign exchange except software exports and tourism. In manufacturing itself, low wages in manufacturing are no longer adecisivefactor in comparative advantage. There are several instances where niche markets have been captured by some developing countries but a niche once captured has to be retained a task which is no longer easy. Competitivity and resilience have become keywords and cost reduction an imperative not only as an oft-neglected obligation to the consumer in the domestic marketbut asa pre-condition for exports. One of the ironies of the situation is that developing countries, having incurred huge external debts to finance their new industrial plants, now have no option but to continue production in order to service their debt obligations, thus joining a stampede for exports at a time when the industrial and consumer requirements in the developed countries are being refashioned. The trends relating to possible adoption and enforcement of trade-related intellectual property rights are liable to create further uncertainties and add to costs.

In the developed countries of the Organization for Economic Co-operation and Development (OECD), the emerging trend is one of what is called 'technoglobalism'. Firms plan and compete for international markets and have international operations. They make strategic alliances across borders. They diversify and become multi-product companies. Competition makes strange bed-fellows, including one's competitor. Innovation has become the watchword and governments which in the past preached laissez faire find that some strategic state intervention and funding become necessary in the field of science, technology and innovation. A number of geographical market alignments have emerged and more are envisaged. 1992 will see the common market in the EuropeanEconomic Community (EEC). Already concentric circles of this market are expected, such as the European FreeTrade Association (EFTA) and the newly opended-up East European market. Changes in East Europe have implications not only for the East and West but for the South as well. There are also trends of market alignments in the Pacific Rim and in North America-between the United States and Canada and the United States and Mexico. South America, South Asia and South East Asia are also regions where some degree of market integration is either planned or talked about. Think globally, act locally' is one of the phrasescoming into vogue.

THE CHANGING TECHNOLOGICAL SCENE

In the present day turbulent world economy, technology is undoubtedly a main driving force for economic growth and a major factor which distinguishes developed from developing countries. There is a school of thought that we are now at the beginning of a new long wave of industrial and economic growth, known as the Kondratiev cycle. Whether or not this is the case,there are at least four categories of technological changes sweeping the globe: (i) there are the technological improvements and changes internal to an industry, which have been accelerated by the internationalization of markets and heavy investments in research and development; (ii) there are the technological changes aimed at energy conservation or reduction in energy requirements, a process which has not been steady over time or uniform over regions, but has proceeded in spurts, depending on the price of oil; (iii) there are new practices and concepts in manufacturing technology which bid fair to create soon a new manufacturing paradigm; (iv) there arethe technological advances in fields, such as micro-electronics and information technology, genetic engineering and biotechnology, and new materials which are generic and enabling and which accelerate change in the other categories mentioned. Microelectronics and information technology could have an impact over the entire range of industries and service sectors, resulting in improvements in productivity and contributing fo accuracy and ease of operation. Their advent has led to radical changes in manufacturing technology. Biotechnology also affects a range of industries, such as food processing, chemicals and pharmaceuticals and energy-related industries. New materials emerge as outputs from several industrial branches, such as the chemical, metallurgical and ceramic industries and figure as inputs for a whole range of industries. With such a multitude of impacts, product and process changes and productivity improvements are occurring and more could be expected in a variety of industries.

Technology generation and application have become increasingly multidisciplinary. More than ever, they require team work. Much of the modern technology is science-based and the lead time between a scientific discovery and its technological application has become significantly short. The boundary between basic research and applied research is becoming thin. There is an increasing knowledge content in products and software, in the sense of human skills, has become more critical than hardware. The ability to build systems and put together skills, technologies and hardware is increasingly a determining factor in competitive edge and value added. So are zero defects, servicing facilities and other factors.

The interaction between different technological advances not only enhances each of them. A given product may involve the application of more than one technological advance, or one technological advance may have application for variety of different products. These trends have created a broad banding of firms and technologies. Product segregation has given place to product continuum. The boundaries of firms working in related technological fields are also substantially blurred. Thus in the field of information technology firms dealing with semiconductors, computers, telecommunications and software jostle together or merge. Petrochemicals and chemical companies acquire biotechnology companies and seed companies. Petroleum firms have heavily invested in solar photovoltaics. Firms moving into new ceramics include materials manufacturers diversifying into new materials, porcelain and glass industries that are upgrading themselves and firms in processing and assembly industries that have identified uses for new materials. In the case of fibre optics, although it is dominated by a few companies, a considerable amount of vertical integration has been noticed between suppliers of fibres, cables and other components.

Manufacturing technology has rightly been recognized as a key factor in competitivity. The fact that in products tending to maturity, it is only the manufacturing technology that provides the competitive edge has been recognized particularly by the firms in Japan and the Republic of Korea.That recognition also extends to process engineering and fermentation technology in chemical and biochemical fields. Distinctive competence is sought to be built up in terms of manufacturing systems capability, rather than solely in terms of product design or market sector dominance. The various elements of the new approach to manufacturing include: a much closer relationship between the design of manufacturing systems, the selection of equipment and process technology, the management of the manufacturing operation, the design of individual products and the choice of the marketing mix. These in turn imply a reorganization of research and engineering activities; redefined linkages between marketing, production and technical activities; new communication patterns; new task allocation and reward systems; and redesigned cost accounting and reporting on marketing and production. In flexible manufacturing systems, economies of scale have given place to economies of scope. A variety of firms is Jnterested in producing such systems, including robot users, machine tool manufacturers, software and engineering and construction firms, electric and electronics manufacturersand computer manufacturers.

What I have said so far is sufficient to underline the fact that the management of technological change .is a key challenge for governments, firms big and small, engineers, scientists and managers. I would like to spend a few minutes on this subject. One of the goals oftechnoloqical management is to identify at an early stage the limits of a given technology. The enterprise can then determine how far it wants to go to approach those limits. It accomplishes this by applying research arid development to narrow the gap between the state of the art and the natural limit. As the limit of a particular technology is reached, the company has to consider alternative approaches and prepare to manage the transition. Engineers with different skills will be needed, new approaches will have to be taken in production and marketing and new financing must be arranged. If technological efforts are not shifted early enough,the economic performance, once it begins to deteriorate, will collapse even for mature products enjoying a good market. Major technological shifts have' been classified as 'competence destroying' or 'competence enhancing'. Theformer requiresnew skills, abilities and knowledge in both the development and manufacture of the product. The latter is the order of magnitude improvements in price and performance that build on existing know-how within a product class. Such innovations substitute for older technologies, yet do not render obsolete the skills required to master the old technologies.

All companies may not hope to be leadersin innovation. Companies with no tradition in innovation might be wise to concentrate their efforts and resources on incremental innovations in various functional areas. 'They may not achieve spectacular breakthroughs, but they may very well achieve worthwhile innovation for a limited amount of investment. Innovative companies in the developed countries have begun to consciously organize, manage and sustain a 'top-down' as well as a 'bottom-up' process. In the top-down process the initiative particularly for heavy innovations with long cycles and a high level of investment and risk, comes fr.om top management. In the bottom-up process, ideas flow freely from employees to managers. That processis crucial to the generation of minor innovations that often have short cycles and can quickly enhance the competitiveness and success of a company. Common to both is a climate of creativity and innovation.

As a report of the International Standards Organization has pointed out, prior to the Second World War, engineering derived more from experience than from theory and the body of engineering knowledge had to be relearned by each generation. Progress tended to be linear. In the last few decades, most fields of engineering have become scientific in the sense that designs, processesand both product and system functions are now modelled, predicted, specified and controlled. The innovation process, once viewed as a linear sequence of events from scientific discovery to applied researchand development and then production and marketing must now be seen as a series of concurrent interactive processes with heavy dependence on basic science and scientific engineering at every step.

Froman engineering point of view, the elements of the current technological change include the following:

- dramatic progress in material and process characterization;
- increasing power of analytical instrumentation, and its transformation into tools for process control in production;
- the shift of key elements of production control from design specifications of mechanical parts and machines to performance requirements for processes and interfaces;
- global computer communication allowing codified engineering practice for design, production and control to be accurately disciplined, and at the sametime geographically disperse;
- intelligent production tools permitting greatly enhanced product diversity without loss of scale economies;
- transnational production systems with global sourcing;
- widespread useof information systems controlling distribution and providing end-user support to integrate products with the services required for their beneficial use.

The global scenario then is one of intensified world competitioncal!ing for greater innovation, improved productivity and utmost efficiency in operation. There will be a marked increase in knowledge-intensive industries, which in turn will play an important part in the growth of traded goods in any country. There will be increased emphasis on customized products and related services. Environment-friendly products and production systems will be increasingly important. Skills at all levels will have to be constantly upgraded.

ISSUES FOR ATTENTION

It may be asked whether all the international trends I have referred to are relevant to India and Indian conditions. The answer is yes, though not necessarily in every detail. India has a fairly developed industrial economy. For her, international trade is a necessity to import a variety of goods not available locally, petroleum and edible oil, for instance. Besides, the increasing debt-servicing obligations have to be met. Exports of manufactures therefore become imperative and this is an area where India has to compete with new technologies and products from the developed countries, as well as with the products of a number of developing countries and in future also of Eastern Europe. Export capability cannot be viewed in isolation from capability for domestic production, since basic to both is cost-effectiveness. But attention to the domestic market alone will be prejudicial in the long run not only to the economy as a whole, but, because of the economy's weakening and the concomitant balance of payments problems, to the growth of individual enterprises as well. We all know that good citizenship is not only an individual virtue but makes for a great nation. Likewise good, healthy enterprises make for a sound economy. But if the economy falters, enterprises too will falter sooner or later.

Engineers of India have acquitted themselves remarkably well, both in India and abroad. Visitors to India cannot help being impressed by its scientific and industrial achievements. Indians abroad have distinguished themselves in leading-edge sciences and technologies. India has a formidable pool of scientific an engineering manpower. Much of the new technologies are knowledge-based. Here is therefore an opportunity, a comparative advantage. The question is how the engineering talent can be galvanized to make an enhanced contribution to India's development ir;ta changing context.

I do not hope to provide a comprehensive answer to this question but wish to highlight some aspects which are important in the context I have been discussing. I have selected for this purpose contain areas where focussed attention could have a pay-off, namely, production technology, energy conservation, materials, and reconditioning and recycling. I shall conclude by touching on engineering education, including continuing education.

PRODUCTION TECHNOLOGY

Coming now to production technology, the current trend is to view the entire manufacturing and distribution process in an integrated fashion. The shopfloor activity is no longer viewed as an isolated or self-contained operation. The imperative of competitivity dictates such an integrated approach which has been facilitated by the advances in information technology. The key factors in competitivity are, however, not low wages or low prices alone. In addition, attention has to be given to other factors, such as consistent quality; dependable and fast deliveries; after sales services; high performance products; and adaptabiiity to rapid design or volume changes. The integration of the factors does not have to mean a system of computer-integrated manufacturing, as conceived, for example, in the United States. The investments for such computer integrated manufacturing are heavy and the skill requirements high. The question is rather one of advancement of manufacturing technology, including improvements on the shop floor. As a matter of fact, the approaches to manufacturing technology and the so-called 'factories of the future' vary in the developed world itself. While in the case of the United States, the emphasis has been more on computer-integrated manufacturing, the emphasis in Japan is more on making gradual improvements in the production process and in quality, often initiated by motivated engineers, technicians and workers on the shop floor. There is close co-ordination between design and process engineering, product quality and production scheduling. In Europe, the phrase often used is 'advances in manufacturing technology' and the approach a cautious and pragmatic one. The centre piece of manufacturing remains by and large the highly skilled worker or technician.

The approach in India should not be the wholesale adoption of automation or computer-integrated manufacturing in the sense in which it may be understood in the West. The emphasis has to be more on incremental improvements and it can be contended that in practically every production technology there is scope for such improvement. There are a number of ways in which incremental improvements in production technology can be carried out in activities like maintenance and energy management. Each increment of change is important not only in providing direct benefits but in establishing the base for the next. The savings generated at each stage can also be used to fund the investments necessary for the next. Traditional concepts like productivity and quality control are still extremely important and their limits have not been reached. Engineers and technicians are the key actors on whom the enterprise has to rely-for such improvements.

Considerations relating to plant engineering, productivity and quality control have to permeate to small and medium enterprises as well. To help such enterprises, institutionalized forms of assistance may be necessary in which professional associations could playa valuable role.

There are, however, areas where improvements in manufacturing capability can be effected by the new information technologies. Computer-aided design is an example. Computer-aided design not only saves the time taken for designing but also enables modelling so that the manufacturer can analyze a new product under development without building a prototype. Mini-computer-based and PC based software packages have made the system more financially feasible for small and medium-scale enterprises. There is also scope for flexible manufacturing in areas, such as textile garments and leather products and for automation in hazardous industries. In general, however, the approach should be to identify discrete stages in the chain of manufacturing and distribution operations and introduce computer applications and other innovations at those stages where they are most feasible and useful in the Indian context. In this sense it is the capability to build systems suitable to a given situation that is to be developed. Thereafter it will be up to each country and enterprise to see how best to derive benefits from information technology and the emerging concepts and practices of manufacturing. But whatever the means of advancement of manufacturing technology, organizational changes become extremely critical and here there is a need for close interaction between the managers and engineers in order to promote such changes.

The improvement of production technology and the incorporation of information technology are important not only for competition and for exports, It has also implications for the capital goods industry built by several developing countries, including India. More and more, the supplies of capital goods by the developed countries are likely to incorporate a substantial amount of information technology. The existing capital goods industries in a country like India will have to upgrade themselves so as to remain competitive both internally and in their exports to other developing countries. But even here, the main capability, in my view, is the capability to build systems of production and distribution which are appropriate to a given situation rather than merely adopt or copy equipment and practices followed elsewhere.

ENERGY CONSERVATION

Several developing countries are both energy hungry and energy wasting. The urgency of energy conservation and efficiency in energy use is by now fully recognized. At the global level. the intensification of the greenhouse effect could be halted costeffectively by investments in energy conservation, thereby reducing more energy generation in its polluting forms. At the level of a country like India, the severe balance of payments constraints dictate the need for energy conservation. At the level of the enterprise, the same need is felt in order to cut down costs. Whereas in most developed countries the energy consumption per unit of production has come down substantially, this is not necessarily the case in most East European as well as developing countries. Even a reduction of 5 per cent in energy consumption in India would ease the burden of additional investment in power generation and also possiblv cut down costs in several industries and in ttansport. At the level of the factory, on a case-bycase basis, energy audits, energy management and microelectronics applications can substantially reduce energy consumption. Energy conservation must therefore be a priority area for the attention of engineers in India.

Even without significant application of new technologies, substantial savings are possible by re-design of systems into a least-cost mix. To minimize new investments, retrofitting of existing equipment is necessary and it carries a good business potential if innovations and adaptations suitable to local conditions are made. Over the 1980s various energy conservation devices and procedures have been developed. Many of them do not necessarily involve heavy investments. Claims are now made in the United States that savings far more than 5%-15%, cited a few years ago, could be achieved. It is reported that new highly efficient technologies include compact fluorescent lamps; appliances that consume only 20% or less of the electricity consumed by conventional ones; optimization of lighting, heating, ventilating and airconditioning systems; adjustable speed drives and high efficiency motors; and advances in integrated process design, control technology and recycling. In the transportation sector, highly fuel efficient vehicles and those that run on alternative energies, such as compressed natural gas, hydrogen and electricity are gaining attention.

It is, however, increasingly recognized that energy conservation requires more than new procedures and devices and retrofitting of equipment. New types of enterprises or agencies may have to be created which provide integrated services including consultancy, supply of equipment, credit facilities, etc. Moreover, there are questions relating to the awareness, attitudes and practices of users, the incentives that they have and the investments they may have to make. to save energy. For example, it may be that the inclination to save energy is not there in a system where future allocations of electricity are based on past consumption; there may therefore be a tendency to use more energy and overstate the energy requirements. Practical problems like this, no doubt, exist and it is necessaryfor the government, the financial institutions, the energy generation agencies as well as the industries and, not least the engineers, to find ways to overcome the problems. Because of its urgency and its multifaceted nature, I believe that the whole subject of energy conservation is fit to be taken up as a 'technology mission'.

MATERIALS ENGINEERING

Energy intensity is but one reason why materials production and use demand attention. Materials are for the engineer what clay is to the potter. It is generally known that a revolution in materials science and in the development of new materials is taking place. Without going into details, I would like to highlight some of the features of that revolution. Firstly, materials are no longer treated in a monomaterial framework. The focus has shifted to the properties desired for an application and different materials could be substituted by one another if they have similar properties. An important steel corporation in Japan, for example, declared that a major element of its corporate strategy was for it to change from a steel manufacturer to a manufacturer of raw materials. Secondly, the knowledge content in the production of materials is increasing. Materials can now be engineered, that is to say, specific properties and characteristics can be accurately achieved with the help of the advancement of materials science and the application of information technology. It is vital for the scientific and engineering community to acquire this basic capacity for engineering materials. In a country like India this will enable not only the development of new materials and composites but also the upgradation of existing materials including traditional materials and the conservation of scarce ones.

Apart from the capacity to engineer materials, the processing of materials has gained particular importance. Materials properties, structure, synthesis and processing are now seen as inter-related aspects critical for applications. Moreover, there is an integration taking place between the producer and user of materials in the sense that the properties desired by the user have to be ascertained, materials engineered to those specifications and feedbacks from the user obtained. In the coming decade the capability to engineer materials and incorporate them in products is expected to be a key factor in cornpetitivity. People differ whether the twentyfirst century will be a century of modern biology or of new materials. It is likely to be both.

The development of a capability for engineering materials has to go hand in hand with their diffusion. Materials are put to diverse use. User awareness and acceptance are important. The use of a new material in industry may involve redesigning production systems and additional investment. Testing and setting of standards will be necessary.The processof diffusion of newly engineered materials has therefore to be studied carefully and understood. I believe, the engineers have perhaps the most important role to play not only in engineering materials but also in introducing such materials in machines and products in a way which is cost-efficient and competitive and also conserves scarce resources.

RECONDITIONING AND RECYCLING

I would like to touch upon the value of repair, reconditioning and recycling. The subject is not glamorous but is quite relevant to India. It is in a sense nothing more than an extension of the need for utilizing fully any investment made, whether in industry or science and technology. It is related to the three areas of action to which I have drawn attention so far. It is also related to the preservation of the environment as well as to the satisfaction of a range of consumers with varying degrees of purchasing power. Product life extension is a concept which has received attention of late. It has been found that product life extension activities are generally labour-intensive and highly mobile but they require a new approach on the part of manufacturers as well as consumers. Developing countries, such as India, cannot afford to become wasteful societies. They have to take a hard look at products which are deliberately designed for early decay and obsolesience. There are certain products the reconditioning of which is already well known, such as automobiles and the retreading of tyres. But there is a need for identifying more opportunities for reconditioning and extending product life and here appropriate technologies and inputs will be necessary. What is now improvisation and at best a craft could be turned into a regular industrial activity. I wish to leave this thought with. Those professionals in the engineering community of India who are interested in developing. productive and useful activities in this field.

A common thread that runs through the subjects I have discussed is that a continuous upgradation of engineering skills is essential. The intellectual and skill base of engineers is an important prerequisite for competitivity. As has been said, the future belongs to the 'learning' and not to the 'learned'. I shall deal briefly with issues relating, firstly, to engineering education at the university level and, secondly, to continuing education.

ENGINEERING EDUCATION

All over the world university curricula lag behind the needs of industry. Engineers recruited have to be trained for varying lengths of time in the firms before they can become useful members of the staff. This lag can be explained to some extent, but it cannot be denied that engineering institutions and universities have also been traditionally slow to modify their curricula. Now with the galloping pace of change, there is a need to review the situation. Ways and meanshaveto be found to move educational institutions out of possible inertia. Science-based technologies are the primary candidates for attention. Manufacturing technologies are another. Multi-disciplinary courses are a third. Generally, there is a reluctance on the part of educational institutions to introduce multi-disciplinary courses. Students too are reluctant since it is specialization which is respected. Material science courses are an example. The curricula will also have to incorporate elements which will enable the students to prepare for lifelong learning and professional development.

I would like to mention in this connection that it is not only the educational arrangements at the level of the universities and engineering colleges but also at the level of industrial training institutes, that should be reviewed. Courses for apprentices, particularly in the areas of mechanical and electrical engineering, may have to be substantially revised because of the new technologies. The entire question of reorienting curricula needs the collective thinking of all concerned, not only of the universities or educational institutions but of the industry and the engineering profession itself. There is also, obviously, a need for more new courses. I would mention, for example, the area of marine engineering and technology.

I wish to emphasize two aspects of engineering education and training: firstly, the need for universityindustry interaction; and secondly the requirements of small and medium industry.

In the developed countries, the interaction between university and industry in relation to education is being intensified. In France, for example, firms receive grants to take on young engineers to conduct research work for them for a two or three year period. This work is carried out in a government laboratory or at a university and leads to a doctorate. The arrangements are managed not by the government but by an industrial association. In the United States, industry-university co-operative research centres and Engineering Research Centres are examples by which academic researchers are acquainted with practical problems on a continuing basis and also convey new knowledge and techniques to researchers elsewhere in the public and private sectors. Other examples are the teaching company scheme in Australia and the 'Open Tech'Programme in the United Kingdom. 'Open Tech' is a decentralized programme which has no campus or teachers of its own. Instead, the collaborative projects are placed with a wide range of educational and industrial organizations, including universities, polytechnics, colleges of further education, and consortia of colleges and industry. The target groups are broad and the learning packages flexible and modular. Dual training schemes in which a student spends part of the time in the educational institution and part of the time is attached to an industrial company is another practice adopted in some developed countries.

In Europe, the strategy for making educational institutions respond better and faster to training needs and innovating firms is threefold. Firstly, countries are trying to improve and speed the flow of information about job content, work organization and training needs from firms to the vocational training system. Many countries have consultative, tripartite commissions, consisting of employers and workers organizations, and representatives of education and training authorities. Secondly, decisions regarding curriculum content are decentralized to individual institutions. Thirdly, educational institutions are encouraged to co-operate closely with innovative firms in designing appropriate new courses, training methods and materials. etc. Training schools and institutions are also urged to solicit the support of industry in supply of up-to-date training equipment and software and in releasing industrially experienced personnel for teaching in schools.

I would like to stress the need for infusing more technical skills into small and medium industry which does not have the resources and facilities to keep its staff up-to-date with technological advances. India has to adopt its own measures but the steps taken by several developed countries may be worth noting. The Netherlands has designed special courses for engineers in small and medium enterprises. A Canadian scheme partially funds students working in small and medium enterprises. The National Employment Office of Belgium runs a programme that assists well qualified job seekersto find demanding positions in small and medium-sized firms and simultaneously helps the latter to expand their activities by providing them with well qualified personnel.

CONTINUING EDUCATION

Apart from university education, continuing education is of paramount importance. I do not need to stress this to the distinguished audience here. Education is now seen as a career long process and the responsibility for such continuing education rests not only with the individual professional but also with the industry, the government and the engineering associations. In the past, continuing education seemed to be largely a matter of personal aptitude of the individual professional but it has now become a matter of urgent necessity for all professionals wishing to be at the cutting edge of technology.

One may distinguish between continuing education provided by the industrial enterprises themselves and that provided through professional associations as well as educational institutions. In India there are several notable examples where industrial enterprises are providing in-house training. European examples indicate both demand-oriented and supplyoriented approaches. In the demand-oriented approach the skills required for the company are clearly forecast and then training to improve the efficiency of the company operations is undertaken. In the supplyoriented approach the company presents to the staff a complete training programme for each financial year, geare9 in content to the future. It also provides the infrastructure' for learning, such as an up-to-date library and other facilities for learning. It is important to note that much of the effort, particularly in a demand-oriented approach, is related to problem solving and practical work. Thus leading-edge companies consider their in-house training vital for maintaining and further developing innovativeness. They also emphasize the development of the desire to learn, problem awareness.capacity for co-operation, coherent thinking and creativeness.

For small and medium enterprises it is obviously difficult to have in-house training programmes and that is where both professional continuing education programmes become even more important.

As one example, I would like to cite the case of the Association for Media-based Continuing Engineering Education in the United States, which provides video taped continuing education courses from its member universities. Course delivery may be via video cassette or by satellite. In Europe, several examples could be cited, such as the Euro Pace, which is a programme sponsored by companies or industrial consortia as well as by higher educational institutions. Euro Pace is a non-profit association, which provides programmes through satellite and video tape on several fields, such as microelectronics, software engineering, telecomunications, expert systems and artificial intelligence, advanced manufacturing technology and technology management. New areas are under consideration, which include materials sciences and technology, information systems management and general management systems. Satellite transmission constitutes the principal means of delivery. Courses are generally pre-recorded, transmitted and viewed afterwards at different received sites. All courses are accompanied by support materials distributed to registered students in advance. Interaction and feedback are arranged through electronic mail, telefax, telex and telephone. Computer conferencing services are also available.

I have mentioned several examples from developed countrie. These are intended to stimulate thinking and spur action and not to suggest imitation. Solutions have to be found which suit the local context. Innovation is essential for survival and growth but innovation should not be confused with sophistication nor professional pride with elitism. Men and women in all professions need to develop a keen eye for the challenges and opportunities of the society in which they live. In India there are a variety of urban and rural problems and consumer needs. There are several commendable groups of professionals working on rural development problems but the results of their work need to be integrated into the mainstream of economic and societal activity. Most of such work seemsto be designed for community action. I wonder whether elements of entrepreneurship and market orientation could not be introduced wherever possible.

In conclusion, the new engineering ethos will be forward looking, systemic, multidisciplinary, teamwork oriented, venturesome, resilient, constantly updating knowledge and ready to manage change. Such an ethos will require changes in attitudes and approaches. Institutional changes alone are not sufficient though they will help. Inspiring individual examples must continue to be set and they will be followed. I am confident that the Indian engineering profession will march on, on the two legs of continuing education and continuing dedication.

Total Quality Management — the Indian Experience

Dr Jamshed Jiji Irani, *Fellow*

Managing Director, TISCO, Jamshedpur

I am happy to be before this august gathering and would like to thank The Institution of Engineers (India) for having invited meto deliver the prestigious Sir Rajendra Nath Mookerjee Memorial Lecture. I propose to dwell on the subject Total Quality Management and would like to share with you some of the experiences with which I am personally familiar.

TOTAL QUALITY MANAGEMENT: NASCENT IN INDIA

Total quality is akin to a total war. As in a war, where every person within the nation, and from each sphere of activity, is involved, directly or indirectly, so also in an organization wedded to total quality. Every division and every employee is involved in quality improvement efforts.

In traditional organizations, quality control is inspection based, and generally refers to product quality. It is essentially seen as a function of the Quality Control Department. On the other hand, in a total quality organization, the word quality has a wider meaning. It means quality of output of every division, and by every employee. All divisions pursue the object of meeting the requirements of the next process,which is treated as. a customer. Cleanliness, orderliness, punctuality, customer orientation, standardization of works-routines and their continuous improvement with involvement of employee up to the lowest level, large inputs of continuing education and training covering every employee, are all hallmarks of a Total Quality Oranization.

In a total quality organization, customers' needs are constantly monitored to improve products and processes to meet their requirements. New products are developed anticipating future requirements of the customers.To do so, there is a close involvement of marketing. Design/development, production, installation and servicing, personnel and other wings of the organization.

All employees receive intensive training in all aspects of their work (standard work routines). They also receive training in basic statistical tools and other techniques for carrying out improvements. They are taught the skills of working together to bring about improvements by team effort.

Total quality management (TQM) has still not become a very wide spread term in Indian industry, and I think this is largely because of the comparatively low levels of competition that are experienced by industries in India. Not that competition is totally absent, but it has been confined to a few industries only, such as those manufacturing Consumer goods, or other durables. Rarely has effective competition existed in core industries such as power, petroleum, or steel. One of the negative fall-outs of limited competition, is the existence of a perception that firms can get away with the production of goods and services that they like to ptoduce and deliver, rather than what the customers are actually looking for.

The stimulus for Indian industry to look toward total quality management as a means to become more competitive has come from the need to step up the export efforts. The realization has at last dawned that we must 'Globalise' or perish in the economic arena We are entering into an arena of global competition, and we have to compare ourselves with the best in the world market. In this endeavour we may note the experience of such economies as those of Japan and the US, where over the past decade revolutionary changes have taken place in how business is conducted. The world has seen Japan rise to economic heights solely as a result of developing a high degree of overall excellence in manufacturing, that has few parallels anywhere in the world. The Americans, realizing that the economic success of Japan is largely attributable to the tremendous commitment to the needs of the customer, consequently have geared themselves up to achieve this objective, and maximize their potential through Total Quality Management.

WHY INDIA NEEDS TQM

One look at the events that are likely to have a bearing on the future will highlight the need for Indian industry to become more competitive. Pressures from outside such as those imposed by the slapping of 'super 301' status on India, as well as the general disagreement on world and tariffs, trade in addition to the growing depreciation of the value of the Rupee, point to the need to systematically prepare ourselves for dealing with markets that are not only teeming with competitors, but where the bargaining power of customers is also high. Obviously, TQM holds the key to success in such a scenario.

In the course of my association with industry leaders in India, I have come to the conclusion that while there are many firms even in the core sector that are committed to total quality, it is largely because of the contributions of one or two committed individuals that total quality is being pursued in such organizations at all. This points to a lack of a systems integration, with more and more of the organizations viewing total quality management as being a 'drive', a programme,or a 'campaign' being led by the concerned person, rather than as a way of life which has to continue irrespective of who leads the firm. In my opinion is imperative that Indian industry views a systematic movement towards performance leadership, which is the essence of total quality, as something which has to be built into the overall business strategy and structure of our organizations. Only, then can such phrases as 'customer orientation', 'organization effectiveness' or,' continuous improvement' begin to be meaningful.

At Tata Steel, we have made a beginning in moving systematically towards better levels of performance through the total quality approach. While the emphasis in the past had always been on technology and on acquisition and deployment of more and more sophisticated equipment. This is gradually changing. The focus now is not only on acquiring better technology, but making sure that fullest potential of even the existing technology is productively exploited and harnessed to meet the value expectations of the end-users of products and services. In the process the organization can look forward to increase. in productivity and quality. The output will also be produced 'right the first time',and would show a general increase in compliance with respect to the requirements of both internal and external customers.

TOM: HURDLES IN THE WAY

One of the overwhelming difficulties faced by Indian organizations in the achievement of total quality concerns the quality of leadership and the basic values that are prevalent in this nation. Leadership is generally of a kind that does not inspire the rank and file in a large number of industries in India. Fortunately there are exceptions.

The average Indian blue collar worker is still not easily taken to a point where he can be brought into a condition of self control where he is responsible totally for the actions that he is supposed to take. The basic deficiency in leadership coupled with a lack of suitable education and the preponderance of certain negative values such as malingering at work and the concomitant high rates of absenteeism, make basic shop floor management a difficult task. However, I reallzethat if we haveto move forward as a nation, we will have to enhance the quality of our human resources nationwide, through a very effective and well organized intervention in the area of training and development. I am aware that such inputs are still viewed by many as being an unnecessary requirement, often motivated more by statutory requirements than by the need to upgrade the quality of operating and other personnel. But this view, if held at all, must change, because it is through people that world class technology can be made to bear the desired results. When it comes to being responsive to the requirements of the customer, there can be no greater asset than trained and committed people who can respond enthusiastically and with competence to sudden demands, because they not only know their job well but take pride and pleasure in what they do well.

There is a great deal being mentioned these days about the beneficial impact of incorporating quality management systems in organizations,especially those that conform to the ISO 9000 standard or its equivalent. Many executives actually believe that the mere accreditation of a firm to ISO 9000 standards, quality will bring about an overall improvement in its quality levels. This is a somewhat myopic view of reality. While it is imperative to have an outstanding system that guarantees consistency in output, the mere placement of such systems, does not upgrade the basic value of what is delivered to the customer or the next process. The pursuit of accreditation to a standard, even for quality management, does not by itself augment performance levels. This is especially true when the process is viewed simply as an exercise in documentation. Hand in hand, with the laying down of operating procedures and work instructions, is the task of training operatives in their roles, and developing a culture supportive of a much needed operating discipline, where standards once set are not violated until improvement is brought about.

CONTINUOUS IMPROVEMENT AND A TOTAL OUALITY CULTURE

In an age of continuously changing value expectations in an organization, we need to have a culture and a system totally supportive of continuous improvement in all spheres of activity. This sounds very basic, and many of my colleagues from industry might wonder why I am emphasizing such a basic point. However, it needs to be mentioned that India the tradition of empowering people to take decisions and to act upon them regarding small or big improvements does not prevail. To that extent Indian organizations will have to go out of their way to stimulate the creation of such systems that encourage people to work together in teams, across functions, to resolve chronic problems through the use of simple statistical and other tools. This calls for delegating authority and responsibility for decision making as far down as possible. This approach, commonly called 'employee empowerment' is one of the most urgently needed requirements to bring about a total quality culture in Indian industry.

TQM AT TATA STEEL AND IN INDIAN HISTORY

At TATA STEEL we were fortunate to have had men of vision with clear and far reaching ideas, on the quality of products and the quality of life,amongst our founding fathers and their successors.

Even at the time of the First World War, Tata Steel developed special steels for shells, helmets and jerry cans. In the early 30's it developed a special corrosion resistant high tensile steel-TISCROM-for the building of Howrah Bridge.

During the Jast 30 years new steels were developed for customers so that they do not have to import them. Some examples are: micro-alloyed high tensile plates and structural, abrasion resistant steels, special forging quality steels such as crankshaft steels, steel sheets of LPG gas cylinders, low residual rimming quality steels for electrodes, and many more.

In recent times, quality expectation of steel consumers has risen. Steel structures and components are lighter and are made from high strength steels, using lower factors of safety. Steel is subjected to higher deformation, higher speeds of machining and extensive welding. The entire Indian steel industry is gearing itself to meet the resultant stringent quality requirements on steel. Strenuous efforts ara on to bring in a total quality culture for making continuous Improvement a way of life. The movement is on from Companies as large as SAIL, the largest steel producer of steel in the country, to Mukand Steel one of the smaller producers.

Concomitant with plant modernization to produce quality products, training inputs on total quality to officers and supervisors has increased several fold. Increasing number of quality improvement projects are being taken up by teams with members drawn from different functions.

Several companies in the engineering industry have adopted TOM, and as a result moved to the forefront in a highly competitive industry. This also helped them to compete more forcefully in the world market.

I can quote several examples: Sundaram Fasteners and Sundaram Clayton of the TVS Group companies of the Kirloskar group; Widia India of Bangalore, Godrej & Boyce and Crompton Greaves, Bharat Heavy Electricals, Bharat Electronics and Maruti Udyog in the public sector.

Some of us in industry have just made a beginning to imbibe this new culture. We have a long way to go. The movement has to spread across the industry and gather momentum.

Thank you.

The 14th Sir Rajendra Hath Mookerjee Memorial Lecture

Building an Effective Organization

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An effective organization is a desired end state in a given context that is determined predominantly by a nexus of interacting forces. Any stabilized, purposive human aggregate working together to create the desired effects is conditioned essentially by the forces of time, people and place (Mukherjee, 1922) and of the purpose for its existence, that is, the mission. These forces are always in a state of flux. Building an effective organization requires emphasis on the process which directs that state of flux towards maintaining or acquiring the effectiveness ofthe organization over changing time, people and place. This lecture intends to highlight, not the description of an effective organization but the process that has been experienced as instrumental in achieving that effectiveness. It has been structured in four parts: (i) Environmental forces, (ii) The conceptual construct of organizational change, (iii) Interventions aimed at generating organizational change, and (iv) Concluding observations.

To achieve any objective where efforts of more than one person are involved, certain level of organization is called for. The size and the complexity would depend on the purpose of which the organization is to be created, the external environment to which it has to adapt itself and the internal strength it has to acquire with its measures. Fulfilment of the objective would depend upon the level of effectiveness of the organization. The level varies from organization to organization. For the purpose of today's discussion, I shall confine myself to industrial organizations.

We have a large number of very successful industrial organizations in our country. These encompass single industry industries or a cluster of industries under a banner of an industrial house. The growth of industrial production in terms of money generation is the principal criteria of success of these organizations. It is largely because of such effective organizations that we today have a large industrial base, covering basic industries such as mining, metallugrical, manufacturing and other treasury industries.

Yet, under a similar environment, and with similar objectives (and sometimes very clearly focused objectives), we have a large number of cases before us where such a success cannot be claimed. Resources have not been effectively utilized. The result as been massive accumulation of losses in the case of public sector companies and closures with sickness in the case of private sector companies. There are thousands of sick industries in the country languishing, yet many of these are retrievable. They require a focused effective organization.

To me, an effective organization is one which can optimally and continually, over a time, through people, utilize its resources to fulfil its mission and objective. Resources are (a) the inanimate ones, like plant, equipment, process and money, etc, on one hand, and (b) the humans in their prime, on the other, who demand to be treated not as mere resources but as what befits the temperament of the ensuing 21st century, and (c) the ability to manage.

If such a situation had been experienced in the past, which was relatively stable and predictable, a lessez faire approach may still have worked. The need for making our organizations effective in the current scenario has become imperative. Even the so far successful organizations have to start looking inwards to feel the chunks in the armour and smoothen them. This necessitates us to examine some of the major environmental forces that I consider are, crucial for an Indian organization today.

ENVIRONMENTAL FORCES

Some of the forces that have the potential for changes with far-reaching consequences are delineated below.

Economic and Business Environment

We highlight here three basic issues.

Government Protection

The business environment has changed from that of a protected one to an open one. For over the last four decades, in search of self- sufficiency and in building up an industrial base, the Governments provided protective environment by building tariff barriers between international competition and our in-country situation, by limiting the grant of licences to set up industries to ensure that at no time the capacity was in excess of anticipated demand. The situations therefore had largely been of demand in excess of production.

Pricing Mechanism

The Government conceded. to many industries, returns on normative costs plus basis. With the changes now ushered, the protection is on a withdrawal track. It will be market driven. It is within market prices, the manufacturing will have to be planned so as to create desired levels of margins.

Customer's Preferences

With short supplies over the decades, the customer had little choice. Mass produced goods had ready acceptance. The situation is changing in our country. It has changed already elsewhere. Customer is finding his true position. It is the customer's satisfaction which directs the company's actions. There is continuous interaction with the customer, not only to meet his current demands, also the future anticipated preferences. The customers also have become choosy. They will no longer accept mass produced goods. They decide on the design, shape, colour, functions they expect from different products and they expect to be catered to.

Technology

There is a rapid growth of information technology. Besides keeping the organizations informed of the changes in demand, changes in production systems and processes, it is also possible now to have a tab on all information as and when generated in geographically spread out units. This is influencing organizations approach to management. Whereas data and information are centralized, decisions are rapid, and also centralized, the action stays decentralized at different points. The pace of work and actions is rapid. The organizations therefore have to reorient themselves to adjust to the new demands.

Manufacturing

Likewise in manufacturing there have been many changes. In countries which have been developed industrially there are glaring labour shortages. The labour is expensive. Automation has been resorted to. For products that call for a high labour content, these are being sourced from low costs economies. Such sourcing is welcome. It gives an opportunity not only for employment which is scarce in the over-populated developing nations. It also brings in discipline of producing quality products. The growth in the developed countries has been largely in service industries whereas in the developing countries, manufacturing seems to be the major focus. With environment concerns, smoke-stack industries would be moved to the developing countries, where the population pressures are already high, environmentally not a happy solution but the economic necessities would .still consider it a deal.

Process

As new technologies are developed, these are being adopted to the current processes. In most of these the attempt has been to amalgamate the different steps and provide for self-regulation by built-in logic reducing dependency of human factor.

We are aware that the processes have been developed after considerable amount of research and expenditure and most countries are keen to protect these. That perhaps is one of the basic reasons for debate on protection of intellectual property which is likely to be more stringent and costly as time passes.

Employee

In the yesteryears work was clearly segmented between unskiilled, semi-skilled and skilled employees and expert master craftsmen. With the changing technology and application, the quality of employee has changed. The new employee is an educated young man with good knowledge. He acquires experience fast and becomes highly productive. The organizations, therefore, are knowledge-employee dependent and that holds the key to success (Handy, 1991). Unfortunately, we in India, have a large number of employees who still are in the low skill category. A massive input in training and providing new skills is called for. It is best done within the organizations.

We have to recognize that 'knowledge' will hold key to effective participation by the employee, in organizatidns growth. Support to employees for continuous updating '9f .knowledge must then be a key thrust area.

Social Environment

One of the impacts that information technology has is on attitudes and expectations of society. Through continuous exposure to the picture of quality of life as available to the affluent nations and the stark differences between the standards of living of the rich and the poor nation to emulate better qualitative aspects of life has become a built-in desire. Neither the country at the national level nor the organizations can ignore these aspirations in setting organizations' goals. This aspect needs to be continuously kept in view.

Even countries with regimented and command forms of government such as the former USSR and the East European countries under communism could not hold back people who strove to fulfil their rising aspirations and resented governmental controls.

On a micro-scale within our limited spheres, the defiance, disobedience and quite often demonstrated opposition to establishment arise from the similar feelings.

Cultural Changes

We have all witnessed the influence of accepted cultural norms. Quite often the rapid progress, in economic areas, of Japan is quoted largely due to their culture. The Asian Tigers who have responded to the use of cultural strength have also moved ahead.

In our case, inherent cultural strengths of commitment to'work, sense of loyalty, acceptance of dignity of man must stay in focus. We also should keep in mind the changes that have taken place in the society from traditional to open, erosion of authority, diminishing blind disobedience and demands for more materialistic needs.

These are some of the environmental considerations which prompt that organizations must acknowledge these changes, and develop suitable strategies for adaptation.

CONCEPTUAL CONSTRUCTION OF ORGANIZATION CHANGE

In the context of the environmental changes what precisely requires to be changed in the organization? lnvariablylinked with this issue is the next question. What is the process by which the change can be ushered in, managed and stabilized?

Often the change target in the organization is focused segmentally and that too on the hard, concrete, tangible options. Preference veers aroundtechno-economic changes. As a consequence, the process of changing gets confined to modification, improvement or innovation in technology, input mobilization, marketing strategy, organizational structure and so on or rotating people with newer responsibilities. These efforts are valuable on 'their own right. But if the organization needs to develop sustained internal strength that will enable it (a) to adapt itself to external environmental demands and cope with it, (b) to make an impact upon it, and (c) to create a setting for employees to derive a sense of significance and worthwhileness in their working life, change has to be organic and the change target has to be searched, in my belief, elsewhere.

It has been a time-tested principle that it is not the mightiest, the biggest or the largest that survives. Survival is achieved by the fittest. From the point of view of systems theory also, a system thrives best not through the process of maximization but through optimization because a system is a multivariate phenomenon.

Looking closely, one can observe that an organization is always subjected to two kinds of forces - the life force and the death force. Those elements and influences that sustain and enhance life can be termed as life force and those that trigger morbidity, decay and death as death force. As an analogy, any living organism faces the set of these two forces in the external environment flowing from the nature on one hand; simultaneously being subjected to anabolic and katabolic processess inside along with the presence of helpful and destructive micro-organisms, secretions, deposits within. Similar support, demand, technology, etc that the external environment provides or restricts can be conceived as life or death forces. The organization creates also intra-organizational life and death processes within it. Wasting input, faulty throughputs and unmet high stakes and irreconcilable losses, obsolescence, hopelessness, stagnation, alienation, etc are some indicators of the intra-organizational death forces. Its life forces can be understood in factors like courage, vi gaur, determination, involvement and motivation of its people and their highly productive pursuits, their efficiency and proficiency, etc. These forces have been graphically indicated in Fig 1.

The interplay of these forces gives rise to four quadrants symbolized as (--), (-+), (+-) and (++) as depicted in the diagram. An organization may find itself in any of these four quadrants. In building effective organization the movement is to be directed towards Q1 (++) quadrant. If an organization finds itself (--) quadrant (Q3), the path seems to be through Q2 to Q1 or from Q3 to Q2 to Q3 to Q1 that is developing internal life force first and with the instrumentality of internal life force gaining access to environmental life force thereby lifting it to (++) quadrant.

An organization by itself cannot change the external environment. It has to start changing within moving from death forces to life forces. It may stimulate process, put more vitality and improve its capability of utilizing life forces that are embedded in the internal environment. Later the organization can find a niche in its own relevant external environment and gradually convert the hostile environment to its own advantage. So the primary target of change is the internal environment in an organization the way the organization is managed within that creates the culture of an – organizatlon if culture is defined as Marvin Bower, the then Managing Director of McKinsey & Co did in 1966 as 'the way we do things around here.' Webster's New Collegiate Dictionary defines it as the integrated patterns of human behaviour that includes thought, speech, action and artifacts and depends on man's capacity for learning and transmitting knowledge to succeeding generations. More formally, according to Pettigrew (1979), 'Culture is a system of publicly and collectively accepted meanings operating for a given group at a given time. Culture can also be regarded as asource of a family of concepts, such as symbol, language ideology, belief, ritual and myth.'

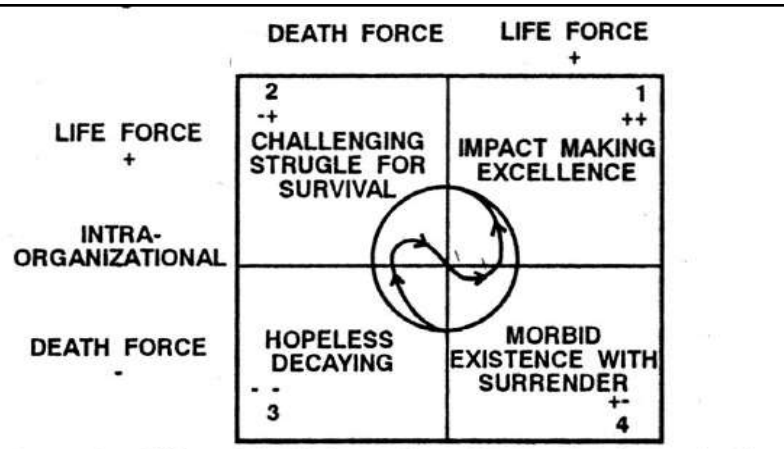

Fig 1 Dynamics of life and death forces in environment and organization

Building an effective organization depends directly on rejuvenating a dying culture to a culture characterized by vitality, vigour and life force. Rejuvenating an organizational culture requires closer exploration of two concepts: (1) Organizational culture, and (2) Organizational development.

Organizational Culture

Byer and Trice (1987) observe that 'Organizational culture is usually defined in management literature as a network of shared understanding of norms and values that are taken for granted and applied within the surface of organizational life.'

Earlier, Deal and Kennedy (1982), exploring on what makes for consistently outstanding company performance opine that it is the strong culture as against the weak culture, which is characterized by strong beliefs. According to them, 'Values are the bedrock of any corporate culture', 'Heroes personify those values ....', '..the rites and rituals of corporate life ... provides the fabric in which heroes can be showcased,' and through the workings of cultural network, communications, the elements of culture get transmitted, reinforced and blended into an overall culture. The four ele ments that they emphasize are values, heroes, rites and rituals and communications.

In their treatment, authors highlighted differently; for example, the philosophy that guides an organization's policy toward employees and/or customers (Ouchi, 1981: Pascale and Athas, 1981), the rules of the game (Ritti and Funkhouser 1982), the observed behavioural regularities with which people interact, use language observe the rituals (Van Maanen, 1979).

A comprehensive and widely accepted view has been forwarded by Schein (1985). In his view, culture is 'a pattern of basic assumptions — invented, discovered, or developed by a given group as it learns to cope with its problems of external adaptation and internal integration — that has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems'. He argues that the artifacts and values by themselves are not the deeper level of basic assumptions and beliefs, and they can at best be treated as surface levels of the culture but not the essence of it. Similarly, behavioural regularities are not the culture but they emerge out of pragmatic interaction, between cultural predispositions (like pattered assumptions, perceptions, thoughts and feelings indicated in his definition) with the contingent situational factors.

What Schein states as problems of external adaptation and internal integration, we have referred to them as death forces that impinge from the external and internal environment upon the organizational functioning and the process of overcoming them can be termed as adaption and integration, respectively. The mode of adaption and integration gives rise in our view that Mintzberg (1991) proposed as configuration of an organization. The discussion presented above may provide some fair idea of the direction to look up for searching what is to be Changed but the guidelines for bringing about change in the culture can be better obtained in the construct of organization devefopment (OD).

Organization Development

Major thrusts of OD can be outlined by some of the definitions cited below:

'Organizational renewal is the process of initiating, creating, and confronting needed changes so as to make possible for organizations to become or remain viable, to adapt to new conditions, to solve problems, to learn from experience and to move towards greater organizational maturity' (Lippiitt, 1982).

'OD is the process of planned change — change of an organization's culture from one which avoids examination of social processes (specially decision making, planning and communication) to one which institutionalizes and ligitimizes this examination' (Burke and Hornstein, 1972).

'OD is a long range effort to improve an organization's problem solving and renewal processes, particularly through a more effective and collaborative rnanaqement of organization culture 'with special emphasis on the formal work-tearn — with the assistance of a change agent, or catalyst and the use of the theory and technology of applied behaviourai science and action research' (French and Bell, 1984).

The central theme discernible in the definition is the changing or organization culture. This effort has essential constituents or planning organization-wide impact, increased effectiveness and health through planned interventions in organization processes using behavioural science. The process has to have a continued commitment from the top.

A review of OD literature (Perras and Robertson, 1987; Porras, 1987) reveals its multiple foci: (a) concepts dealing with change implementation which mainly revolve around the change-agents — their roles and activities and guidelines to them; (b) concepts dealing with the processes highlighting the movement in the organizational variables subjected to intervention. The first set is further elaborated in terms of considerations of strategy, procedure and technique in changing.

Drawing from these resources, described below is a case of change implementation indicating the major strategy, procedure and techniques followed. For our OD work, we followed a conceptual model integrating some of the ideas discussed before.

OD Model Framed for TCIL

Our OD model (Fig 2) has the following major components:

(i) The inner core of the model is the self of the individuals in the organization
(ii) Self is surrounded by Group
(iii) Centripetal (collaborative, convergent) forces and centrifugal (divergent, destructive, conflictive, political) forces which engulf the self and the group and are embedded in the organization culture.
(iv) The organization culture seeks to derive strength by internal integration Organization environment can be viewed as a techno-economic political culture embedded in broad social milieu and culture. The culture of social milieu permeates within the organization, group, and individual and goes right into the heart of organization.
(v) The structural elements of the model are self, group, organization and society.
(vi) The process elements are the nature and dynamics of centripetal and centrifugal forces created by individuals in the organization, internal integration and external adaptation and the pesent state of organizational and social culture.
(vii) Organizational configuration elements are: direction (entrepreneurial), efficiency (mechanistic), proficiency (professional), concentration (differentiated), innovation (adhocracy) and preservation (conservation). The choice, blend and relative importance exert a determining influence on the nature and mode of functioning ofthe organization (modified after Mintzberg, 1991).

We believe, as indicated in the model, that the general culture of the society, comprising a composite of sub-cultures, integrated or differentiated, and the particular culture of the organization which may also be a composite of sub-cultures, operate at all spheres in the organization. These two sets of coexisting cultures can be mutually reinforcing or discounting, constructive or destructive. The resultant consequence will depend on the magnitude of the content of life force and death force that they promote and the intensity of the interaction between them. As the culture of one single organization cannot have a determining effect on the societal culture, though collectively considered they can and they do (Even and Damanpour, 1988), the organization remains primarily at the receiving end. Since in OD we are basically preoccupied with one organization at a time, the task becomes changing the internal culture of the organization.

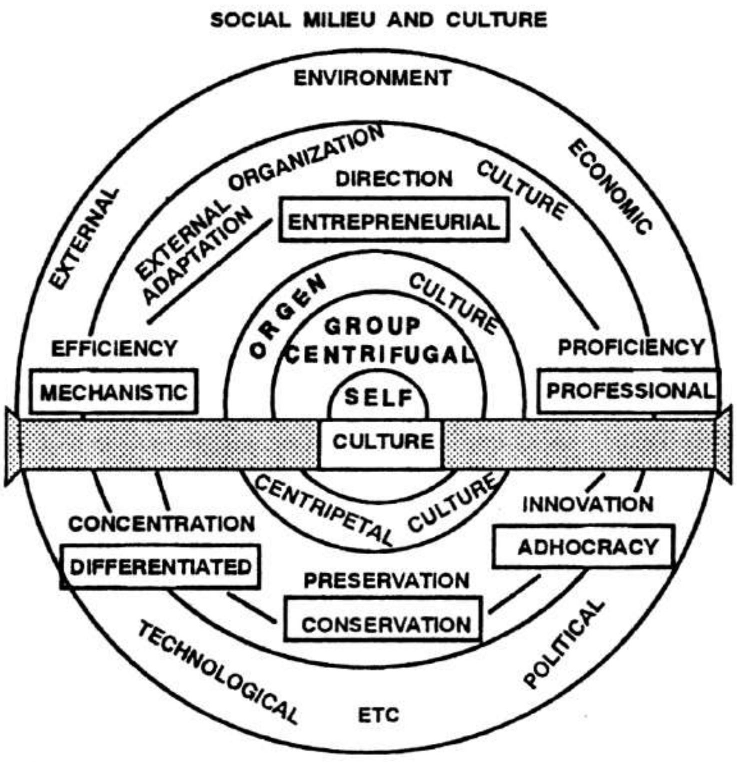

Fig 2 Model directing approach to OD intervention at TCIL

INTERVENTIONS AIMED AT GENERATING ORGANIZATIONAL CHANGE

I now present the case of the organization I have been associated with for the last five years.

Brief History of the Organization

The Tinplate Co of India Ltd was set up in 1922. It was a joint venture between Burmah Oil Co and Tata Steel. The management was through a managing agency of Shaw Wallace & Co. The company had very successful run for decades.

Even though the company management was aware that the technology had gone obsolete, for reasons of their own, they decided not to invest in the company when it was required during 60's.

During 70's the company decided to revamp its technology. Electrolytic tinning plant was set up. Due to delays in implementation project cost went high. Raw materials had not been tied up. It ran into serious troubles when its very existence was threatened. It accumulated heavy losses. The downward slide in its wake pushed employees' morale to a low level, discipline suffered and management lost its rightful role.

I had a brief stint in the company as its chief executive during 1982-83. I moved back to this company in 1987. During this period, steps were taken to bring up production levels, to change the product mix and also to ensure continued supplies of raw materials and bring about ready acceptance of the company's products in the market.

After initial discussions and interaction with executives and officials at various levels, I had a feeling that if the company was to go ahead, the organization would have to be renewed. It was good enough for subsistence but not for growth.

Initial Uneasiness

The reasons that led me to this evaluation were: (i) low cohensiveness, (ii) general apathy, (iii) lack of trust and confidence, (iv) work carried out by dictat, (v) little openness, and (vi) 'Yes' culture, whether it was intended to be fulfilled or not. Power and authority were sought for but not the fulfilment. It was at this stage, I decided to initiate a survey, to diagnose key factors of the organization culture and identify the weaknesses where effort would have to be focused on.

Diagnostic Survey

A survey to explore the present state of internal organizational environment and motivational climate was conducted employing survey feedback method. The entire management staff was involved.

The cultural exploration are conducted by prolonged individual and group discussions. The result of the organization environment is presented in Table 1.

TABLE 1 ORGANIZATION ENVIRONMENT

Dimension	Actual (A)	Rank	Desired (D)	Rank	Difference (D—A)	Mean scores level-wise				
						L1	L2	L3	L4	L5
Personal Development	43.50	10	86.75	1	43.25	51	50	47	42	40
Decision Making	40.00	12	81.50	9	41.50	43	43	44	40	37
Recognition	44.50	8	85.50	3	41.00	51	50	50	42	42
Team Work	43.50	11	83.00	7	39.50	48	48	47	44	39
Managing Problems	44.25	9	83.75	4	39.50	56	43	50	43	39
Communication	45.50	6	82.00	8	36.50	51	48	48	43	45
Trust	53.50	2	86.50	2	33.00	53	59	59	49	53
Innovation	45.25	7	77.50	10	32.50	49	45	50	43	46
Structure	51.50	3	83.25	6	32.00	53	50	55	50	51
Overall Identity	55.50	1	83.50	5	28.00	63	53	60	53	53
Supervision	46.00	5	72.50	11	26.50	47	50	49	44	45
Performance	50.25	4	48.50	12	—1.75	56	49	55	48	48

TABLE 2 MOTIVATIONAL CLIMATE IN TCIL

Managerial Practices	MOTIVATION: Dependancy	Achievement	Control	Affiliation	Extension	Expert Influence
Orientation		H			L	
Industrial Relations	H				L	
Supervision	H				L	
Communication	H					L
Decision Making			H	L		
Trust	L			H		
Managing Problems	H				L	
Managing Mistakes	H					L
Managing Conflicts					H	L
Rewards				H	L	

H indicates the highest impact of a practice on fostering a motivation
L indicates the lowest impact of a practice on fostering a motivation

Continuous Interventions

The continuous interventions are those that do not depend upon a particular event, episode, programme nor sometimes a visible activity. They include from certain regular practices to the stances and preferences that employees assume the top management has or even to the myths that circulate. A few such interventions are given here.

Emphasis on Certain Core Values and Belief

As Deal and Kennedy (1982) and likewise others state that strong cultures have strong values and beliefs; we also think it is necessary. But how does one create it? We thing thatslogan like proclamations, or socially desirable, pleasant to listen phrases and sentences do not create values. We had a two-pronged strategy: one focused on the organization and the other on individuals. Some of corporate beliefs and values rested on the understanding that we were the best in the country; our products were the best; we were the market leaders; we had the required entrepreneurship, etc. These positions were not stated as a pep talk but settings were ceated, formally and informally for people to discuss and debate. Data search was encouraged for people to test realities. Similarly, for individuals their own views about themselves were subjected to reality testing where cognitive redefinition was possible. Attempts were made to usher in the notions amongst the executives, old and young, that each one of them is important and central to the organization, there was no end to their learning leading to greater personal growth and development, everyone was a scientistmanager: their analytical ability, their proactive stances, relentless pursuance were important. The double loop learning (Argris, Argyris and Shon, Argyris 1991) was of immense help. Modelling, critiqueing, non-directive counselling, even somtimes goading, providing opportunities for testing and creating numerous opportunities for training, debating and discussing were some of the means employed.

Generation of Hope

When production is in a tail spin, atmosphere is moribund, vitality of the individuals is eroded by an overall sense of alienation. One of major intervention that we attempted was generation of hope. Creating a vision of the superordinate goal for the organization in which activity of individual employees got opportunity to be a participant and a partner as well where his contribution and his goal were values, was one step.

Entrepreneurship demonstrated by the top management group in venturing new business, new markets and creating new opportunities and even in securing resources and inputs was another step. At the same time helping individuals focus attention to the superordinate goals in their own lives was resorted. Attempts were made to generate a view based on reality, that they could attain worthwhileness which in essence was a part of the spiritual search of man. Many individuals felt that it was possible to derive more meaning of existence working in the organization. We derived some help from the propositions of transformational leadership (Bass, 1989) on one hand. Substantive help was also received from the Bihar School of Yoga which helped individuals to take an inward look to locate their potentialities and resources.

Keeping the framework in the background, the results of the survey (which served also as a bench-mark for subsequent comparison) guided us in designing the intervention strategy in an OD programme that is being executed for the last three years.

Strategically we decided to have two sets of interventions one that is continuous, repetitive and regular, and the other is discontinuous, episodic and phasic.

We tried to stabilize and refreeze. Thus there is no separate refreezing stage. We believe that movement-refreezing forms a continuous upward spiral.

We present below first the interventions of stage 1.

Developing of Internal OD Facilities

It was necessary to create the internal facilitators (IF) who would help external consultants in implementing the OD plan. Their role is to carry on the work even after the departure of external consultants. We created 25 internal 00 facilitators. They were trained. The thrust of the training was ability to look into self and roles, to differentiate between cause and effect, identify problems search for set of solution, decide on an optimal one, prepare action plans and resolve them. We tried to develop in them high level of expertise in process consultation (Schein, 1991). Through repeated exposures to intramural training, live practice in the organization, action research and in phases.

Group Process In Communication

All officers were exposed to group dynamics, role of members, intragroup communications and build in cohensiveness through repeated cycles of exposure to Theory-Action-Critiqueing- Theory model of learning.

Task Force

In addition to individual level interventions, task forces were appointed in the areas of decision making communication, reward and recognition, personal development and team work. These areas were chosen as they were considered by the group as needing attention and corroborated by the surveys conducted. Task forces besides the contents that dealt had learning focus to build expertise in managing temporary systems.

Total Quality Management

It was also realized that in order to serve our external customers, we needed to develop in-depth quality culture in the organization. To guide the functions, Quality Group (core group) was formed and the group which started initial work on creation of awareness moved on to internal custom eruption.

Roll Task Specification — Review — Support

The efforts were therefore directed to energize the positive forces in each one of the areas. The first steps taken were to have an agreed role classification with all the functionaries, also focus on aweed key result areas which one operated in his group. They were also encouraged to accept objectives within broadly defined annual plans for each of their teams. Within a team the specific responsibilities that each executive took upon himself was broken up into quarterly action plans with a clearly defined objective during the period.

At the end of each quarter, each team presented its performance which included its gains and losses, problems accounted, solved successfully and not so successfully and the areas where support areas were brought into focus. The area in which a group or the individual needed support was identified and support extended.

Training and development of subordinates and Quality became the integral responsibility of all line functionaries.

Phasic Intervention

Phasic interventions were basically different kinds of programmes, events or episodes which were brought in once or a few times, with specific objectives in mind at regular intervals. Often a number of interventions is conducted simultaneous with a clear cut start and termination of the intervention. For easier comprehension they are arranged in a tabular form and presented below.

TABLE 3 OD PROCESSES IN TCIL

First Stage	Second Stage	Third Stage
IF Selection and Training	IF Training and Working as Change Agents	IF Taking up New Roles
Task Forces on Weak Areas	Task Forces in New Areas	Task Forces in New Areas
Group Process and Communication Programme for JR Level Officers	Achievement Motivation for all Officers	Achievement Motivation for Supervisors Team Building for Officers
Quality Core Group	Total Quality Management	Quality Circle
	Redefinition of Mission and Objectives	Strategic Plan

IF stands for internal facilitator

It will be seen that interventions are classified in the three stages. The stages are sequenced on time. Organically stage 1 corresponds to the 'unfreezing stage' in Levinian model, stage 2 and stage 3 are on the 'movement state'. In the movement stage itself, after some movement along any dimension.

At about the same time we considered what Bernstein and Burke (1989) termed as 'Belief Comains' that depict 'the potential classes of variables to be relevant for predicting organizational and individual performance'. (1) Mission and strategy, (2) Structure, (3) Task requirements, (4) Leadership, (5) Management practices, (6) Work unit climate, (7) Organization culture, (8) Formal policies and procedures, (9) Individual views, needs and values — all leading to develop and (10) Motivation that determines ultimately individual and organizational performance.

Inter-departmental memoranda of understanding was generated on mutual discussion. Expectation of each department from others and viceversa was documented. Deviations were discussed and corrected by the group at review sessions. The next step was to introduce small group activities.

In this work we tried out to the deeper levels of motivation beliefs and assumptions that individuals and groups hold without even being aware of them and created opportunities for bringing these up.tor conscious charity and articulation.

Now we present interventions of stage 2.

Action Learning of Internal Facilitators

The internal facilitators were drafted to work with the external trainers as co-traininers.

Achievement Motivation Training Programme

All executives including those in the corporate level were exposed to 'Achievement Motivation' and its role in achieving organizational excellence. The programme was spread nearly over a year.

Second Survey of Organization Environment

At this stage, a survey of organization environment and activational climate was conducted once again. The survey revealed progress in areas focused on. The findings were supported by the operational results the organization had been achieving.

Initiation of Work on Strategic Management — Mission and Objectives

It was, therefore, felt appropriate at this point of time that the group could start looking at its corporate mission, define objective as a part of the strategic business plan. External support was obtained from an academician.

The group defined the corporate mission, set out the objectives and has prepared a strategic business plan which projects growth quantitative and qualitative over the coming years.

I now present the interventions at stage 3.

Internal Facilitators in Their Emerging Roles

We are currently in the third phase of development. TheAnternal facilitators are being given roles towards all dependent functioning. There has been a shift of 00, effort being internally driven rather than externally directed .

Broadening the Scope for Personal Growing

Thrust on individual development continues with emphasis on personal growth. It has now been extended to supervisors and workers. For executives, the thrust has moved on the effective team building as operating in TCIL work intention.

Creative Supports Structure

In order to ensure that certain key functions permeate in the organization culture throughout, groups have been assigned to promote, introduce and encourage work in the following areas: (i) Energy Conservation, (ii) Productivity Growth, (iii) (Dost Reduction, (iv) TQM, (v) OD, and (vi) Management Information System.

The steering group constituted by members in the corporate team oversee functioning of all the groups with a continuous feedback on the chievements done, metrb laction provides for new directions to be taken.

Review

We reviewed the progress every now and then formally and informally individually and in groups. The diagnosis-interventions-review and evaluation cycle were repeated.

The process is on-going and continuous. As some of the areas get covered, new areas are added, Organizational effectiveness enhancement goes on.

Supervisors as the Added Focus on OD

So far focus had been on executive and will continue. Supervisors are now being exposed to similar programmes, They form a key link between policy planning and execution.

During the course of current year they would have been covered by the intervention modules which expose them to the concept of self, group dynamics, motivations, communication and understanding of human behaviour.

Workmen as the Added Focus on OD

Simultaneously 'employee awareness' programme has been set into motion. Groups of workmen join a 6-day residential programme. To many, this is the first exposure to the programme of learning of this nature.

These programmes are independent of skill, knowledge and technology and management development exposures which are essentially linked to direct operational needs.

Gains

Apart from healthy indicators revealed by attitude and organizational climate, gains are discern able. Some of these are tangible quantifiable and some qualitative. First, we indicate below the quantitative gains. The indicators of change that are essentially qualitative in nature are presented below:

Qualitative Gains

The qualitative gains are indicated in a few key areas:

1. Morale: One single transforming pay-off is high morale of team and individuals. Besides, OD intervention, continuous dialogue with men, supervisors and executives, have brought openness in the organization. Open door policy provides accesibility at all levels.

2. Team Work: There is cohesiveness in the teams. Ability of teams to identify problems, diagnose, decide on solution and execute is of high order.

3. Communication: Information sharing, inter-group and intra-groups are facile. Conduits function well. Distortions are few.

4. Motivation: Achievement culture has generally permeated into the organization. It is not uniform throughout. Groups are self actualising. While recognition and reward provide stimulus, largely it is the sense of fulfilment which spurs employee team to perform.

5. Decision Making: There is a lot of sharing of knowledge and opinions in decision making. This has led to ownership of many decisions and as such improved implementation.

6. Urge to take more responsibility and be more proactive.

7. Drive towards creativity and innovativeness.

TABLE 4 DATA OF PRODUCTION

Mills	1990-91	1991-92	1992-93
Mills	87 245	99 417	132 000
ETP	51 892	31 828	

TABLE 5 DATA OF PRODUCTIVITY

Mills	1990-91	1991-92	1992-93
Mill yields,%	68.0	69.92	70.5
ETP yields, %	83.0	87.0	89.0
Production, man-year	83.00	87.0	89.0
Energy conservation, million kilo.cal/t	4.024	2.71	2.50
Zinc consumption, kg/t	73.5	70.7	67.0

COST EFFECTIVENESS

Saving	Consumption		Savings	
	1990-91	1992-93	Quantity	Cost, Rs/t
Hot mill rolls, kg/t	13.86	10.05	3.81	180
			Rs 23.8 million/ annum	
Fuel coal equivalent, kg/t	596	430	166	166
			Rs 21.9 million/annum	
Power, kWh/t	294	263	31	51
			Rs 6.7 million/annum	

VOLUME INCRESE (HDP)

	1990-91	1991-92	1992-93
Volume	100 035	125 498	132 000
Fixed Cost, Mt	3 528	2 812	2674

Other Productivity Measures

1. Coal conversion into briquettes
2. Improved handling of coils
3. Mechanization of areas with repetition manual handling

TCIL ORGANIZATION ENVIRONMENT (1989-91)

Rank	Dimension	Mean Score	Perceived as Actual 1989 Mean Score		1991 Rank
1	Overall Identity	53.50	73	+17.5	1
2	Trust	53.50	73	+55	5
3	Structure	51.25	56	+47	6
4	Performance	58.25	64	+137	4
5	Supervision	46.00	51	+5	11
6	Communication	45.50	55	+85	25
7	Innovation	45.25	49	+37	12
8	Recognition	44.50	55	+10.5	7.5
9	Managing Problems	44.25	65	+20.7	3
10	Personal Development	43.00	69	+25.5	2
11	Team Work	43.50	53	+9.5	9.5
12	Decision Making	40.00	53	+13	9.5

TCIL ORGANIZATION ENVIRONMENT (1989-1991)
PERCEIVED AS ACTUAL, DESIRED AND DIFFERENCE

		1989			1991			
Rank	Dimension	Actual (A)	Desired (D)	(D-A)	Actual (A)	Desired (D)	(D-A)	Rank 1991
1	Personal Development	43.50	86.75	43.25	69	92	23	8.5
2	Decision Making	40.00	81.50	41.50	53	85	32	3.5
3	Recognition	44.50	85.50	41.00	55	87	32	3.5
4	Team Work	43.50	83.00	39.50	53	87	34	2
5	Manging Problems	44.25	83.75	39.50	65	89	24	7
6	Communication	45.50	92.00	36.50	55	85	30	5.5
7	Trust	53.50	86.50	33.00	59	89	30	5.5
8	Innovation	45.25	77.75	32.50	49	72	23	8.5
9	Structure	51.25	83.25	32.00	56	71	15	11
10	Overall Identity	55.50	83.50	28.00	73	91	18	10
11	Supervision	46.00	72.50	26.50	51	87	36	1
12	Performance	50.25	48.50	-1.75	64	76	12	12

TCIL MOTIVATIONAL CLIMATE (1989-1991)

1989		1991	
1989 Rank	Motivation	Motivation	1991 Rank
1	Dependency	Achievement	1
2	Achievement	Expert Influence	2.5
3	Control	Dependency	2.5
4	Affiliation	Control	4
5	Extension	Affiliation	5
6	Expert Influence	Extension	6

CONCLUSION

While I have given salient features of the OD process in Tinplate, I have had the opportunity to undertake similar exercises in a Division of Tata Steel and company - wide in Bharat Coking Coal, where I was the Chief Executive.

For enhancement and even sustenance of an organization the process, must be on-going. It never ends. It will continue leading organizations to the path of excellence. This will call for tatal commitment of the chief executive officer and his top team.

In all cases, on ceasation of the process slippages start taking place. Even if individuals teams subscribe to the continuity, changed organizational climate, lack of support dampens and many of the gains get lost.

In the current dynamics of changing business and industrial climate, to me, organizational effectiveness will be the key factor. This must be nursed, kept on improvement path.

Effectiveness is a must for success of an organization. Every organization is expected to set out its goals clearly, provide organizational structure which will be apt for fulfilment of its goals. Personnel, to man, various posttions would be selected based on their qualifications, relevant experience and commitment to goals. It is also expected operating system to run an organization as an efficient group will be installed.

Despite all normative provisions, organizations have been found wanting. Their responses to demands of changing environment have not been adequate or fast enough. learning and re-Iearning processes have been sluggish.

I have focused on actions which have been practised by me and my colleagues in a number of organizations. These were aimed to diagnose organizational cultural inadequacies and measures to strengthen. The core work has focused on understanding of self, group dynamics, roles within organization, identification of key result areas, jointly agreed plans and action for fulfilment. It is achievement which has been in focus and not activities.

Expert external support to me is a must. Likewise, development of internal facilities to take over change-agent functions is important. The process of cultural alteration is slow and needs investment of time and commitment of teams.

The pay-off is not linear but stepwise. After every measurable gain. With continued fresh input progress is not visible. This connotes the period of assimulation of new ideas, their amalgom with earlier success factor, till next step becomes visible and so on.

In my presentation, I have given background in which organization development was undertaken. I have also shared with you the logic of I structuring; OD work.

To be able to utilize opening opportunities from globalization, our industrial products and businesses must be effective organizations to play a vital role.

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REFERENCES

1. R W Woodman and W A Pasmore (ed). 'Research in Organizational Change and Development".'Reasoning, Action Strategiesand Defensive Routines' by CArgyris. Jai Press, Greenwich, Conn, 1987. .

2. C Argyris. 'Overcoming Organizational Defenses'. Allyn and Bacon, Boston, 1990.

3. C Argyris and A Schon. 'Organizational learning: a Theory of Action perspective'. Addison-Wesley, Reading, Man, 1987.

4. B V Bass. 'Leadership and Performance Beyond Expectations'. Free Press, New York, 1965.

5. R W Woodman and W A Pasmore (ed). 'Research in Organizational Change and Development'. 'Modelling Organizational Meaning System' by W M Bernstein and W W Burke. Jai Press, Greenwich, Conn, 1989.

6. J M Beyer and H M Trice. 'How an Organization's Rites Reveal Its Culture'. Organization Dynamics, vol 15, n04, Spring 1987, p 5.

7. M Bower. 'The Will to Manage'. McGraw-Hili, New York, 1966.

8. W W Burke and H A Hornstein (ed). 'The Social Technology or Orgartization Development'. University Associates, San Diego, Cali, 1972.

9. P N Khandwall (ed). 'Social Development'. 'Societal Culture, Organizational Culture and Societal Development' by T E Deal and F Damanpour. Sage, New Delhi, 1988.

10. W L French and C H Bell. 'Organization Development: Behavioral Science Intervention for Organization Improvement'. Prentice-Hall, 3rd edition, 1984.

11. C Handy. 'The Age of Ur:reason'. Harvard Business School Press, Boston, Mass, 1990.

12. G L Uppitt. 'Organizational Renewal'. Prentice-Hall, 2nd edition, 1982.

Engineers — The Agents of Change

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Since July 1991, Indian perception about national development has undergone a sea change. Mounting foreign debt and our inability to borrow more has been the prime mover in bringing about this sharp and abrupt change of heart by the Government. It has been now decided to chart an entirely new course, moving away from its commitment to a mixed economy and its thrust on liberal socialism. With the collapse of the erstwhile Soviet Union and the stunning exposure of the hollow claims and the empty coffers of the Eastern block countries who earlier swore by the Soviet model, there was little that our country could do but to fall in line with what the lenders want us to do.

It goes to the credit of the present Government and specially its Finance Minister, that Government made its decision to liberalise and globalise the economy to appear as its own new revolutionary economic strategy in dealing with the fast changing world economic scenario. During the last 46 years, the Government had unfortunately, allowed liberal and unmonitored public spending, helped create an inefficient and closed economy, politicised social inequalities and encouraged political opportunism. In those formative years of a newly liberated nation, inapt policies obliged rural people to migrate to urban regions either just for their survival or for having opportunities to improve their lot. Successive governments fostered a large, inefficient and irresponsible bureaucracy and allowed an unholy nexus to develop between the bureaucrats and the business community which in turn, created a special class of prosperous elite and urban middle class who have been cornering and consuming a large portion of the country's resources. Durihg these years we. created an unique kind of industrial infrastructure based on a license - permit regime that prevented competition even within the country, encouraged debilitating, all-pervasive corruption and paved the way for a quickly deteriorating business ethos where cunningness and craftiness overwhelmed the sense of creativity and courageous entrepreneurship. Also to the great dismay of those who care, we neglected to effectively control the population growth. The pollution of at least the river waters, should have been avoided with appropriate laws and strict enforcement. We failed to avoid creating new illiterates leave alone doing anything substantive about adult illiteracy. Over these last 45 years forest resources have depleted at 3.6 % per annum. Delhi failed miserably in creating a disciplined cadre of officials to effectively implement what was pronounced in their economic and developmental plans structured by the National Planning Commission and through the political pronouncements in party manifestos.

Now after these decades of gross neglect, we have, as a nation, committed ourselves to globalisation, to get rid of licenses and permits, to disinvest in public sector units and turn over ownership to the real public rather than the Government. We also have promised to allocate additional resources for stimulating the rural economy. What is happening presently, seems to be done with a reasonable earnestness, thanks to the Finance Minister Action today, however, is limited to cleansing of the fiscal, economic and commercial spheres of national governance. Still missing are the measures to combat social, ecological, cultural and ethical aspects of national decline. Unfortunately all these are interdependent and do directly affect the success or otherwise of the economic and industrial reforms. There has to be a concurrent thrust and awareness for bringing about a comprehensive change. Efforts need to be collaborative. For this, a much larger group of changeagents has to share the responsibility to bring about the transformation.

We, my friends, are the engiheers, the Indian engineers. Engineers, professionally, are indeed well recognised as the agents of change. Historically it is the engineers who have been using the logic of science to achieve practical solutions .. Unlike a scientist, an engineer is more of a grass roots person. He uses science to seek solutions but is generally free from the associated scientific dogma. A good engineer relies on passions, impulses, urges and intuitions in addition to his scientific knowledge. His thrust is on providing solutions than on just satisfying curiosity. That's why we, engineers, pride ourselves to be the 'change agents.' A practising engineer is not a mechanic or a technician. He is a provider of solutions through a process of creative designing. Engineering, in that sense, is the art or science of making practical application of the knowledge of pure sciences.

Engineers, during the whole of the 20th century, have unveiled for the world, month after month, technological marvels making the prospects for mankind increasingly bright. Take the case of transportation. Engineers gave to the community, trains, ocean liners, subways, automobiles and aeroplanes. For comm unication, our predecessors and contemporaries invented telegraph, telephone, phonograph, movies, radio, television, video recorder, teleconferencing, global paging and whole new world of computers which get with each passing year, more powerful, more compact, more' portable and more affordable. Bridges, tunnels, dams and skyscrappers came as construction marvels. For the common man, engineers offered sewing machines, typewriters, bicycles, matches,. cameras, refrigerators, electric light and heater, airconditioners, washing machines and so forth.

Such is the history and legacy left for us by our professional predecessors. That imposes on us a moral responsibility to be 'the Change Agents' for supporting the liberal, competitive, global industrial scence that is unfolding in India. A large and populous country like India will also have a large and profitable service industry. But to survive it has no other choice than to establish an efficient manufacturing industry within the country. We can't help ourselves but become an attractive source for manufactured goods and information products for the world community. That is the challenge before us. The task, however, is formidable. We are immediately being pitched against China and also the pacific-rim countries. Most of these countries have a great advantage over us. They are disciplined societies and discipline is an ideal fertiliser for any manufacturing Industry to ensure higher productivity and consistent promised quality. Japan, with its highly involved and self-disciplined workforce is a formidable production machine. So is Korea & Taiwan, who learnt their engineering alphabets from the Japanese under whose dominance they were for 40 years and later, for another 40 years, they worked under military dictatorial rule. In the People's Republic of China, People can't revolt or strike work. Whatever may be the reason for the general lack of discipline in the country, our main handicap is going to be the Trade Unions who are sensitive about the short-term employee benefits but care nothing abouta either the producitivity or the quality responsibility. The managements, who are equally unimaginative, and self-centred, carry on and live with this cold war. The casualty is productivity and quality.

Sometimes, there is a tendency to. belittle engineers who are involved in creative manufacturing. I recollect a story when in 1962, Chairman of Philco Corporation, then a leading manufacturer of transistors in the US, said in an lEE meeting that they should "let Japan produce transistors. Let the Japanese crank them out. The more they make and sell, the more the royalties will pour into U.S. Coffers". He concluded by saying "let us not seek to reproduce objects. Let us seek to produce knowledge". Result of this attitude in the US then is for everyone to see today. Research in isolation never really thrives. One would need a strong manufacturing base to derive commercial benefits out of the laboratory research.

Our other handicap lies in the quality or rather lack of it, in engineering education. Institutions here are breeding engineering graduates and diploma holders without training them adequately and properly. Rapid expansion and commercial approach has aided in the further and faster devaluation of engineering training.

The thrust, if at all, is on providing scientific facts to be reproduced in examinations. Very little hands-on work is included in the training curriculum and that too is delivered without any excitement or involvement. Practical training has become an unlikable formality. In various Institutions, such ill-trained engineering graduates, in many instances, are becoming faculty members immediately after graduation without any experience in the industry. All engineering training is from the books. It is academic, uninspiring and dull.

To use these youngsters and to chisel out of them, the hidden engineer by chipping off the misconceptions, the diffidence, the fear of enterprise, is not difficult. But we must work at it. Merely accepting or rejecting them on the basis of what they know would be not only wrong but also unjust to the young lads who have been misdirected and denied their right to learn. Those who are managing these engineering colleges must wake up and realise what they are doing to our younger generation. In fact, I wonder why the students don't revolt, rather than being unjustly condemned by the elders and prospective employers as 'useless'. The blame lies squarely with those who have made education merely a business to make money and exploit the young aspirants and their parents.

After 46 years of cumulative decline, we can't hope to switch as rapidly as the world bank or IMF may want us to. But independent of these external pressures, we need to speed up as far as possible, to catch up with our competitors. I for one will keep China under a close watch and try to reach their position as soon as possible. We can't isolate ourselves without severe handicaps. We did that in the past and so did China. Both of us have suffered. We should, however, be alarmed today when China attracts 40 times higher foreign investment and exports 40 times more than India does. Their larg'e export volume is particularly significant because, China has already become an attractive source of merchandise for the world whereas India has remained the least preferred source on any count.

We, engineers' have in front of us serious challenges indeed. We must respond to this opportunity to create an efficient manufacturing industry which utilizes minimum of every resource, monetary, manpower as well as time. This will ensure competitiveness and profitability. Many engineers today, after graduation, join a business school. Unfortunately that takes them even further from the shop- floor. Business Management courses, at best, train one to be a manager in a service Industry. It prepares one to wear a white collar and involve in trading. It is significant to note that Japan & Taiwan have hardly any business schools. In fact, Japan has none. All Japanese manufacturing and trading engineers are company braid managers.

We also cannot hope to fashion our growth on the North American pattern but should evolve our own model that is closer to Taiwan or Korea which are primarily manufacturing economies. Yale or Harward Business School graduates are good for America. India needs thorough braid, hands-on bluecolloured stuff that loves to soil the hands and rub shoulders with the team. We need practising engineers who take pleasure in solving technical problems and can successfully complete constructive projects. Prof John Lehmann has said it with a sense of euphoria 'Engineers cause comfort, leisure and equality amongst the people and that has imbued men with confidence- in themselves and in the objectives of their society. Engineers have their own pride. In 1978, I read an article in The Japan Times in Tokyo by Dr Hatoyama of Sony Corporation which ended on a very confident note. He said 'The difficult we do immediately, the impossible takes a little longer.'

While our need to face the fiercely competitive world by converting our inward looking and rather inefficient manufacturing infrastructure into one that can deliver high quality products at competitive prices could be accomplished with some effort, there is yet another challenge which we can't overlook. In the wake of a new realisation of the environmental crisis, a reappraisal of the engineer's role in the society as a solution provider would need sober reflection and earnest intellectual effort. These are the times when everyone wants to make money fastand cheap. Even the existing laws and regulations to prevent pollution and avoid potential hazards are being blatantly violated. Pollution of river waters with poisonous effluents and waste products from industries go unpunished. Here, in Delhi itself, Lt. Governor P K Dave who runs the municipal administration has recently said that garbage dumping in the once pristine Yamuna river has gone to such an extent that it now consists of 70 % sewage. Engineers of today are primarily responsible for this. Corruption, callousness, connivance with politicians and money bags is wide-spread amongst engineers working for a regulatory body like the Government. There is need for us to self-examine and understand what our casual approach to work means and leads to. We have to examine whether it is right for us to overwhelm professional duty towards the public. People, we must remember, are today defenceless against retaliation or neglect by the service provider, may it be a public body like a municipal corporation or a private pharmaceutical industry violating the FDA directives. It's now time for us, engineers, to take to 'whistle blowing'. Blowing the whistle on anyone, when the public benefit is at stake, will reaffirm and uphold our professional obligation to the society. We can, of course, overlook the fact that engineers are after all, people made of the same clay as others. We also would have amongst us radicals, hawks, doves, idealists, pragmatists and such like. But more and more amongst us will have to take to whistle blowing on industries who pollute, bureaucrats and officials who turn a blind eye to actions which would harm the innocent and on politicians who perpetuate ecologically undesirable projects. I am aware that pledges of virtue have never solved any problems. Problems will not get solved through such appeals. Technical truths, like the moral truths, are elusive and, therefore, we have to rely on an aggressive process. One can only hope that those engineers in public service will choose to be public spirited. I am told that over 80 % of the towns in India which are lucky to have water, get it polluted enough to be classified as 'potentially dangerous'. Outbreaks of disease attributed to drinking water are happening practically every week.That we have 'safe drinking water' as one of the Technology Missions pronounced by the Central Government is, of course, of no consequence.

We must remember that Technologists and Engineers have solutions. In the 'limits to Growth', the club of Rome's report of 1971, it has been noted that "Technological Advance would be both necessary and welcome in the Equilibrium State". Indeed conservation itself is an engineering solution to promote forestry, horticulture, sanitary engineering and other endeavours dear to the heart of environmentalists.

I think, in a sense, our democracy is on trial, not the engineers. Politicians, anxious to retain power, pander to the lazy and selfish desires of the society elites. Leaders dare not call for sacrifice except when a crisis makes such a posture politically populist. Inspite of the successive Five Year Plans, there has been little concern for preservation of natural resources. Government's lack of foresight is not limited to environment. It is also reflected in its passivity towards the crisis of population, casteism, crime, education and many others. As a refreshingly new change, however, crisis in economy is being tackled with certain finesse and imagination. We as engineers must see this as an opportunity and not as a threat. It is time to use our strengths and overcome weaknesses.

I have personally always enjoyed being an engineer. The engineering profession is closely linked with the activities of man and the laws of nature. I have indulged in poetry occasionally, but it was usually when logic failed to explain circumstances. When one works in. Delhi and that too with the politicians and bureaucrats, such a thing can happen. It's inevitable then to turn to poetry.

But still there is a potential in engineering to give us a sense of tranquillity and peace as we switch in our work between creation and contemplation. We, as professionals, have, to revive these intrinsic resources of an engineer. An essential element of the profession of engineering is the concept of 'creativity'. Whether we are civil, mechanical, electrical, chemical, electronic or computer engineers, we all design things. But the word 'Design' covers a variety of functions ranging from calculating the size of the beam to support a certain load, or adjusting a capacitor value to achieve higher bandwidth of an amplifier, upto inventing a transistor or developing a vehicle to land on the moon. By oneself or in a team, an engineer always has the opportunity to be creative. Some of us are directly involved in research and development, some others are involved in 'planning, directing, advising, consulting and teaching. There are also many of us who are selling, producing, constructing, maintaining, testing and so on. However, one way or the other, there are challenges in our profession requiring us to be creative. That, in fact, is the centrai mission of every professional engineer. With the new important role that we have to assume to help our Industry compete worldwide and be a source of high class merchandise to the world. we need to invoke these inner strengths and win back our reputation to be agents of change. That is today's challenge.

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Small Industry and Technology

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THE SMALL ENTERPRISE

A small enterprise can be broadly defined as one which is owned independently, without the association of the Government or a sizeable industrial group, and which is not a dominant operator in its field. The small enterprise is, therefore, a logical step in the development process of businesses from the level of the enterprising artisan to that of a very large enterprise. This definition would indicate that small enterprises do encompass areas other than manufacturing and, indeed small enterprises do playa very strong and influential role in areas such as agriculture, trade and service industries. However, organized data regarding the evolution of the small enterprise in the non-manufacturing area are difficult to access. Consequently, in this paper, thediscussion has been restricted to the industrial sector within the field of small enterprises.

Many significant developments took place during the early part of the century. Two, among these, are the development of industrial engineering as a science and the establishment of job specialization as a discipline. These two developments have, over time, combined to give rise to mass production techniques, with particular initial application in the automobile industry. As a consequence, large-scale enterprises have rapidly overtaken the other sectors in the industrial world so far as the value of output is concerned. These mass production techniques enabled the Allies to overhaul the initial advantage enjoyed by the Axis during the Second World War and the resultant acceleration in the speed and penetra tion of their applica tion has lasted well into this day. Nevertheless, just as the small farmer has successfully survived the onslaught of organized farming, the small-scale decentralized enterprises too continue to playa vital role in all the developed economies. In recognition of this fact, most countries have provided a well-defined legal and procedural framework for the encouragement and development of sma II enterprises.

In the Indian economy, the small-scale sector constitutes a sub-set within the decentralized industrial sector. The contribution of this sector to the Indian economy is indeed considerable. The estimated 2.4 million units provide employment to over 14 million people and, apart from dominating the Khadi and Village Industries sector, it contributes over a third of the overall gross output of the entire manufacturing sector. The output from small enterprises, which now stands at Rs 236500 crores, has been growing at a rate of 8% per annum. This compares quite well with the progress of the manufacturing sector in its entirety. This sector is also reputed to contribute abort a third of the country's exports, although it is doubtful whether the export-oriented units for garments and leather products would really qualify for small industry status.

The development of Government Policy regarding the small industry sector was conditioned in almost equal measure by the stated preference of the Congress Party for the khadi and village industries, by the limited availability of investment capital in the severely depleted post-war economy in India and by the lessons learnt from the Great Depression in the USA and the post-war resettlement programme in Europe. The policy environment was laid down in the remarkably farsighted recommendations of the Karve Committee in 1955, but these have been considerably embellished, distorted and encroached upon by the vested interests which have gradually developed in the intervening years. The concept of reservation was first introduced in 1967, possibly under the influence of Dr E F Schumacher's thinking, with a list of 44 items which rapidly grew to nearly 900 items until it was pruned to its present range of 836 items. The reservation policy has not been able to influence the growth of small industry segment. The past policies regarding licensing and capacity limitations in the organized industrial sector have combined with the reservation policy and excise duty concessions for the smallscale sector to create a situation of mutual competition and mistrust between the two segments. Therefore, the situation in India is one of small versus large, rather than coexisting small and large sectors. A hostile rela tionship of this nature between different segments of manufacturing industry disrupts the continuum, and is rarely, if ever, experienced in any of the developed economies.

SMALL ENTERPRISES IN DEVELOPED ECONOMIES

The importance of the small enterprise in a developed economy is derived mainly from its ability to generate employment in the decentralized sector, which assumes particular relevance during the cyclical downturns in the economy. It is true that the construction, trade and services segments generate far more employment than the manufacturing segment. While the transforma tion from small manufacturing enterprises to medium and large industries has continued apace in product categories which are amenable to mass production economies which are efficient in energy and material conservation, new small enterprises continue to appear and to flourish in a host of products such as metal working, food, electronics, textiles, and leather among others, where efficiencies have been generated through the deployment of knowledge, skill and craftsmanship.

The continued vitality of small enterprises in the largest industrial economies such as Japan, Germany and the USA, even while these were undergoing structural changes of a fundamental nature, can be traced to three concurrent sets of developments which we shall briefly discuss because they will serve to illustrate the changes which we ourselves are likely to experience in the coming years.

The first of these factors was the rapid escalation of fixed costs, arising from increasing capital intensity as well as higher wage rates in the large manufacturing sector. The necessity of combining the energy and ma trials conserving fea tures of mass production with the need to introduce zero defect manufacturing at affordable prices, has led to a progressive increase in the level of investments required in such industries. At the same time, the rapid pace of technology developmentand transformation has substantially increased the rate of obsolescence of manufacturing hardware. The steady growth of per capita incomes and the reduction in unemployment rates experienced by the develop~d economies over a sustained period, lasting over a quarter century, has resulted in a very sharp rise of wage rates, particularly in the manufacturing sector. Therefore, the competition offered during the last decade by the more efficient production systems, which were developed initially in Japan and later spread among the other Asian Tiger Economies, has forced the large western enterprises to seek economies through subcontracting as well as through decentralization

The second important influence was the emergence of product categories such as electronics and software, which easily lend themselves to small-scale, decentralized production. The importance of knowledge and skills development, as well as the need for creativity among the managers, make such product categories far more amenable to entrepreneurial systems, using profit-sharing as a motivation. Even in more traditional areas such as processed foods, garments and leather products, the emergence of geographically localized population centres has given rise to relatively smaller enterprises which can effectively take advantage of the shorter distribution chain. The third important development, which has worked in favour of small enterprises, is the rapid evolution of consumer markets across the world, leading to appreciably shorter product life cycles. The emergence of differentiated product categories, aimed at fulfilling the preferences of segmented population groups, has meant shorter production runs which neutralize scale economies. These shifts have brought about profound changes in the processes employed for manufacturing not only directly consumable items, such as food organnents, but also consumerdurables, such as automobiles. In response to this shifting pattern of consumption, an entirely new discipline, broadly known as flexible manufacturing, is gradually gaining importance and Japan is playing a leading role in this development. Flexible manufacturing practices tend to even out the cost differences between the small and the large enterprises much more effectively than differentiated wage rates could ever do.

RELEVANCE OF TECHNOLOGY TO SMALL ENTERPRISES

A study of the role of small enterprises in developed industrial economies, conducted by S Nanjundan, clearly demonstrates that small, medium and large enterprises coexist in a dynamic equilibrium depending upon the particula r characteristics of the market and the product. As Peter Drucker had said in 1989, 'Size follows function' rather than political philosophy. In certain industry groups, the small enterprises are now able to participate on equal terms in a globally competitive market and are able to offer working conditions and productivity almost on par with large industries. Nanjundan has identified two major factors as being responsible for the sturdy nature of small enterprises in the developed economies. The first, of course, is the support extended by the Government, both at the State and at the local level. The nature and quantum of assistance varies from country to country but, invariably, such assistance is aimed at making the small enterprise self-susta ining, rather than being perennially dependent upon, and addicted to, such help. A not inconsiderable degree of further assistance is provided by simplifying the legal, labour and social welfare procedures to render them user-friendly for the small enterprise. The second and very important reason is the development of collective and collaborative action programmes which serve to neutralize the disadvantages suffered by the small enterprises in obtaining adequate finance, suitable technology and assured supplies of materials and services. As a result of such initiatives, specialized consultancy agencies have developed to provide services such as a data bank on suppliers and customers, joint purchasing or marketing efforts, and generally providing facilitating services, particularly where a number of sma II enterprises are loca ted in an agglomeration, such as an industrial estate.

The ability of the small enterprise to coexist with the large, organized sector is derived in no small measure from the developments that have taken place in the technology field. We have seen that certain new industries, arising from the computation and information revolution, require the intensive application of knowledge-base and specialized skills and these are particularly accessible to small entrepreneurs. Even in more traditional industries, such as metal and wood-working, recent developments in micro-circuitry and electronic controls have enabled the small enterprise to bring world-class quality and competitive costs within the shopfloor at a relatively moderate expense. Further, the rapid evolution of capabilities for data processing, data transmission and parallel processing have now made it possible for large industries to develop long-term relationships with small enterprises for sub-contracting significant portions of the supply chain and with ancillaries which produce quality components and sub-assemblies. The benefits of agglomeration derived by the Italian small enterprise, for example, in the garment industry or the leather industry is often, and very rightly, held out as an example worthy of emulation. But it is rarely noticed that the post-war revival of Japanese industry has been due, in no small measure, to the development of an interlocking structure of large, medium and small enterprises in which subcontracting and ancilliarization act as the cementing force. The recent revival of certain sectors of the US industry also involves similar high-technology inter-sectoral collaborative efforts even in such mundane items as garments. This trend is going to be further accentuated in the future.

A second important reason behind the progress of small enterprises in the developed economies has to do with people and their motivation. The hierarchical organization structure of the large industries does not provide enough room for experimentation and innovation by the creative people and offers limited avenues for career growth for the upwardly mobile and footloose managerial tribe. As Peter Drucker has pointed out, a large industry has responded to his situation by 'farming out activities that do not offer opportunities for advancement into fairly senior management and professional positions.' Indeed, in such countries, the small enterprises provide ample proof that economic democracy survives, even in oligopolistic regimes, through the expression of the spirit of free enterprise and that the capitalist system is provided a very broad and stable base by spreading the ownership of capital assets through the decentralized sector.

THE SMALL INDUSTRIAL ENTERPRISE IN INDIA

It has been mentioned earlier that the small enterpnse plays a vital and progressive role in the Indian economy. The rapid growth in the services sector of the economy is derived in great measure from the development of small enterprises, particularly in areas such as trade, transportation, construction and ancillary services. Such rapid development of the small enterprises is perhaps because they have been left entirely to the private entrepreneurs, free from the shifting effects of Government interference or patronage. Although these enterprises have been relatively successful and prosperous, they have been thankfully left outside the purview of numerous regulations or, even better, the probing eyes of various learned commissions of enquiry. Consequently, their achievements have remained outside the chronicles of economic literature.

The small industrial enterprises, however, have been less fortunate in this regard. The first organized enquiry was commissioned as early as 1955 and the cascading bounty of public funds into this sector since then has been a shining beacon to a multitude of economic parasites. It is tempting to speculate that our enormous preoccupation with small industry owes its origin to a guilt complex about abandoned ideals. When the National Movement shifted gears after the First World War, patronage to small and village industries became a cornerstone of its ideological platform. Yet, in the aftermath of the Quit India struggle, when the recommendations of the National Planning Committee came to be discussed in 1944, it was impossible to avoid the conclusion that the development of a large-scale industry was an essential priority in our search for economic growth. It is possible that we tried to assuage our collective guilt, first, by appropriating as large a share of this growth as possible for the Government sector and, secondly, by enshrining small and village industries as items of economic and political priority. Over the years, this priority has manifested itself in innumerable forms, some of which are clearly absurd. For example, among 836 items reserved solely for manufacture by small industrial enterprises, are included as many as 233 items which are not at all produced in this sector. The continued survival and, indeed, the remarkable progress achieved by certain segments of the small-scale industry, in spite of such benevolent anxiety and fawning attention, is a tribute to the innate strength and resilience of this sector.

Under the protective umbrella of State patronage, the small industry segment has grown and diversified extensively to encompass as many as 7449 articles of manufacture. According to a relatively recent study conducted by the National Council of Applied Economic Research, in collaboration with the Friedrich-Normann-Stiftung, in the year 1987-88, we had 15.93 lakh small-scale industries responsible for an output of Rs 136860 crores, corresponding to an average annual outputof Rs 8.55 lakh/unit. According to the last official count in 1987-88, the employment in this segment was about 9.5 million, and growing at a rate of 5.4% per annum. Around two-thirds of the employment generated was in the urban sector. Its share in the country's exports was estimated at around 30% and growing. This export growth has coincided with the rising importance of gems and jewellery, garments, leather and marine products within the overall exports from India. It may be argued that many of the export-oriented units and export-processing zone units are, in reality, large enterprises according to the definition but, even so, the substantial contribution of the small industries to exports cannot be gainsaid. While the growth in the export sector will continue further, new opportunities for small enterprises will ensue from the steady increase in rural incomes generated by the sturdy progress of our agriculture as well as the anticipated thrust in the export of processed agriculture and food products.

It would be reasonable to conclude, therefore, that small industries are not only playing an important role in the nation's economy but that it is set on a path of further growth and prosperity. While it is true that over half of the units employ entirely manual processes and that only 5% of the units operate with automa ted equipment, a cursory exa rnination does not reveal any pressing reason for upgrading the technology employed in small industries. We need to look below the surface in order to understand the need for such change. The progress of the small industries sector is due largely to the success of the three pronged strategy underlying Government policy initiatives since Independence; these being subsidized infrastructure and finance, exemption from excise duties as well as labour and pollution regulations and, finally, reserva tion of items for manufacture and preference in Govemmentpurchases. Each of these policy initiatives is now being reviewed and re-evaluated in the context of the need to improve the productive efficiency of our economy and to contain the burgeoning growth of direct and indirect subsidies. We need to consider the induction of technology in the small industries segment precisely because we are conunitted to preserving its importance within the country's manufacturing sector even in the changed context of globally competitive quality, cost and speed of delivery.

TECHNOLOGY UPGRADATION IN SMALL INDUSTRIES

Despite the growing awareness of the level of sophistication and technology which is now available in articles of daily use, technology in the abstract is still associated in our minds with a large-scale industry supported by major investments. Yet, as Schumacher had put it so aptly, the primary task of technology is to lighten the burden of work and this applies as much to the small industries sector as to the larger, mechanized and automated industries.

The modem small enterprises in the garments and textile industry provide an excellent example ofthe application of technology for achieving greater competitiveness. The availability of highly adaptable design software has combined with computer-aided design systems to bring the customer and the producer very close to each other through short production runs and quick changes of style and design. Automated small looms are changing the very dimensions ofthe knitted garment industry. Specialization of units in an interlinked system has been made possible through the application of informa tion technology to the management of the supply chain. The multi-faceted application of technology has enabled Haggar Apparel in Dallas to reduce its response time from seven weeks to three days whereas the more traditional and mass productionoriented garment industry in Hong Kong requires as longas three months to fulfil new orders.

We need to transplant such developments to India as early as possible. In addition, we need to develop technological solutions to some of our own pressing problems. For example, looking back to the early development of automation in the textile industry, it is not difficult to visualize that the principles underlying the Jacquard loom can be combined with modem numerical control technology to revolutionalize the hand-knotted carpet industry. Such innovations are immediately necessary not only to still the clamour against the exploitation of child labour and the insanitary working conditions which are so audible in Germany and the United States, but also to match the quality, consistency and value offered by the. Chinese hand-knotted carpets.

Admittedly, the average Indian small industry will find it difficult to upgrade the level of technology, particularly in the dominant number of very small units with investment of Rs 5 lakh or less which offer little better than independent wage employment Such units account for 87% of the number, 59% of the employment and 45% of the output from the small industry sector. However, technology is already infiltrating this segment and this process is best exemplified by those 5% of the units which are already automated and the other 40% which are semi-automated now and are likely to progress further down the road with the passage of time. Upgradation of technology has been high on the agenda of various promotional agencies since the sixties but to-date it has met with only limited success, principally because the target sectors have not been adequately prioritized, the right type of technology packages has not been made available and the fact that neither the promotional agency nor the adopters had a clear idea about the appropriate application of technology. However, a greater degree of focus is being brought to bear on this issue through the search fora small manufacturing industry which is economically as well as technically viable.

STRUCTURAL HURDLES

The search for modernization and upgradationinsmall industry will have to contend with several hurdless, some of which, paradoxically enough, arise from the very policy measures which have so far significantly contributed to its growth. For example, the very definition of small enterprises, which limits entry, as well as promotional benefits to an investment of Rs 65 lakh or less in plant and machinery, is going to severely restrict any investment in technology upgradation for meeting competitive requirements of quality and cost. Similarly, the facts that excise exemptions are available to only those enterprises whose value of output does not exceed Rs 75 lakh could well reduce the benefits from increased output that can be derived from technological improvements. Again, the immunity from internal competition afforded by the reservation policy makes the small enterprise oblivious to the ultimate, but inevitable, arrival of external competition on the scene. The-anachronism of reservation is a ghost which cannot be exorcized but, most certainly, the investment limits could be raised without hurting vested interests.

The second set of hurdles are those which are embedded within the structure of small industry itself. As we have observed, the small industry is involved in the manufacture of nearly 7500 items out of which 836 items are reserved solely for manufacture in the small sector. Even if we restrict our activities to the top 200 items which account for as much as 60% of the output, and it is doubtful whether such focussing will be at all permitted by the various special interest groups operating in this sector, the list of targets will still be too wide to yield any quick results. Technology upgradation will, therefore, depend upon the availability of an interested, and influential, sponsor.

The third type of difficulty will arise from the necessity of planning for and procurement of resources, If we take the case of capital as an example, the poor debt servicing record of the average small industry will continue to discourage the lending institutions from extending a helping hand. The gradual deregulation of the financial sector, and the consequent emphasis upon generating a surplus while operating with a reduced spread, supplemented by the environmental pressures against any exercise of selectivity on the part of the lenders, will make the lending Institutions extremely cautious about extending credits for technological upgrada tion, in spite of the refinancing support available from the SIDBI. This log-jam can be broken only if a credible counter guarantee becomes available.

Finally, we must remember that the selection, adoption and skilful application of technology is by no means an easy task. Very few, if any, among the small industries will have access to the necessary knowledge base or skilled manpower, which is taken for granted in large-scale enterprises. Even if the selection and adoption part is successfully accomplished, the full benefits of technology application can be derived only through the development of the necessary skills among the operating personnel. The ability of the small industry sector to attract and to retain skilled personnel has always been suspect and is unlikely to improve in a dramatic fashion, unless the compensation package is improved. Of course, this will eliminate the most significant competitive advantage which a small industry has today.

MANAGEMENT AS A CATALYST

I am aware that even the preliminary list of hurdles which I have attempted to visualize is long enough to discourage even the most stout-hearted among the protagonists of technology. But we cannot afford to turn away from this urgent task because the pressures of globalization will inevitably create even greater challenges. Globalization has already introduced new uncertainties and has significantly enhanced the complexity of the situation by increasing the degrees of freedom. The current industrial restructuring ushered in by the rapid accretion to the knowledge base, the ongoing compression of the innovation cycle and the new business systems arising from the information revolution will generate major new challenges. These can be resolved only by establishing mastery over technology and by ensuring that technology becomes deeply embedded not only in the products and the processes but the work systems as well.

No one will seriously question the assertion that then paradigm shifts take place, we are left with little time to blame others, least of all the Government Engineering as a discipline, with its solid grounding in hierarchical logic, assumes centre-stage when we have to act in our defence. I believe that our training in mathematical systems and ourskills in logical thought processes will enable engineers to successfully essay the first, and the most basic, task of prioritization. We simply cannot take up all the 7449 categories at the same time. The next step will be to identify the cutting edge technology in the selected fields and, thereafter, to destructure these technologies to segregate the key success factors, which are not dependent upon scale. The third major step will be to juxtapose these success factors with the competitive factor advantages that are inherent in the economy, or the envirorunent, in order to arrive at the best combination. The penultimate stage will be reached when we put together these logically derived and tested elements into an engineering or technology package for adoption by the small industries. These are the ingredients which go towards developing appropriate technology and, believe me, appropriate technology is not a dirty phrase. To quote Schumacher, 'we need methods and equipment which are cheap enough so that they are accessible, suitable for small-scale application and compatible with man's need for creativity.' The final stage in the process will be the fine tuning of the technology package in real-life application followed by the development of training modules so that the technology is adequately maintained and updated by the operating personnel.

ROLE FOR LARGE INDUSTRIES

The task of technological upgradation in the small industry segment is certainly amenable to resolution through the systematic application of engineering knowledge and management skills. However, the technology effort is quite considerable and requires a significant resource base which is normally available only in the large-scale sector. It is no accident that the major successes by the small industry in developed economies have been achieved in.those cases where large-scale organizations have played a collaborative role in various ways, for example, by subcontracting and ancilliarization, by promoting small-scale ventures or by providing a marketing umbrella.

Our policy framework has, perhaps unwittingly, created an unfortunate conflict of interests between the small and the large industry sectors which preclude such collaboration. Possibly, the first step towards resolving this conflict has been taken by permitting the organized sector to participate in the equity of small enterprises. Many more such steps will be needed before the mutual, and unproductive, hostility prevailing today is finally put at rest.

The need for technology inputs in the small industry segment was understood quite early and, at least during the last four decades, technical extension services have been an integral part of the multitude of promotional and support services which have been available to this sector. As a matter of fact, the SISIs and the DIes were given particular responsibility in this regard. In spite of this effort, the results achieved so far have been discouraging and the small entrepreneurs have a very poor opinion of their utility. One does not have to go far to find the reasons for such poor perforuauce. Apart from the classic infirmities of the public sector such as the remoteness between stra tegy development and its implementation or the absence of direct correlation between reward and performance, these service institutions further suffer from a total of involvement in the clients' performance and very little, if any, knowledge of technology.

Considering the structure of the task involved, it is evident that efforts to induct technology into the small industry sector would not succeed unless they are linked to some form of commercial reward. The Government, therefore, cannot fulfil the functions of a change agent. On the other hand, the investment needed for developing suitable technology packages is so large, that it can be afforded only by large-scale commercial organizations which would, naturally, expect adequate returns from such investments. Such retums could certainly arise through traditional supply chain linkages such ss ancilliarization and partial processing. In such instances, the mutual distrust between the two sectors could perhaps be minimized bycreatinga truly symbiotic relationship through financial and technical collaboration. An interesting a Iternative could also emerge by developing the collaborative agglomeration principle which has evolved so successfully in Italy. For example, the large-scale enterprise could set up an umbrella corporation, in which itwould have a substantial stake, in order to develop an associated network of specialized small enterprises operating in the same product area, such as garments or electronics. The relationships could be further reinforced by giving each small enterprise an equity holding in the umbrella enterprise which in turn would hold equity in the individual small enterprises. This model is, in fact, a commercia lIy oriented altema tive to the not very successful cooperative model. The main thrust of the argument is that a number of such interesting alternatives could be constructed, provided we are prepared to shift from the rigid mindset that not only all assistance but also all organizational efforts must flow only through a Government agency, preferably through the disbursement of subsidies. Industrial applications of technology become successful only when they operate within a commercial framework and small industrial enterprises present no exception to this paradigm. Such a framework can be created only through the active involvement of prosperous commercial organizations in the efforts to upgrade the small industry sector.

THE WAY FORWARD

The plans for accelerating India's economicgrowth depend quite heavily upon a faster development of the manufacturing sector. About one-third of the gross manufacturing output is drawn from the small industry sector which has, in the past, grown in line with the rest of the manufacturing output. Hence, it is reasonable to expect that the small industry sector will receive its due share of attention when growth promotion strategies are formulated. Such attention would naturally include technology upgradation measures in order to improve its global competitiveness. The bulk of the small industry units operates with a fixed asset investment of Rs 5 lakh or less. These are no better than independent wage employment units and would not readily respond to technology inputs.

However, they do create a. significant employment potential. Therefore, their needs would be best served through employment generation schemes, such as Jawahar Rozgar Yojana. The remaining units numbering about 300000 are the ones which should be seriously considered for technology upgradation schemes.

These industrial units can be broadly divided into three categories. The first category would include items such as handicrafts, and gems and jewellery, which are artisanal in nature and would, therefore, not be readily amenable to the application of technology. The second category would include products like hosiery, knitted and stitched garments, etc where examples of beneficial application of the technology are already available elsewhere in the world. In such cases, these technology models will need to be adapted to suit Indian circumstances before they are released for application. Finally, there would be a third category of items such as carpets, small diesel engines, etc which would certainly benefit from technology upgradation but where technology packages are not readily available. In such cases, research and development effort will be necessary in order to evolve such packages.

Whether the issue is one of technology adaptation or one of technology development, the task will call for the deployment of considerable resources. In order to ensure timeliness and efficacy, the engineering and technology effort should be harnessed within a commercial framework of risks and rewards. Therefore, large-scale commercial enterprises would be far better equipped to undertake such activities than promotional measures introduced by the Government This would indeed mark a radical departure from the action programme followed hitherto. It is heartening to note that our policy-makers are not averse to considering such new and productive ideas, although they run counter to the enormous ideological baggage which has been acquired over the years.

Self-Regulation and Professional Organizations

Shri V Ramachandran

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I do not know why the prestigious Institution of Engineers (India) has asked a layman like me to deliver the Sir Rajendra Nath Mookerjee Memorial Lecture. Perhaps the Institution is responding to the general call around the world and in our country that the Iymen should be heard by governments, experts and professionals. If it is so, I heartily welcome it and thank you all most sincerely for giving me this opportunity to speak to such a galaxy of engineers from all over the country.

As a layman I see that there are two major trends in recent developments in India regarding economy and governance. One is that through economic reforms Indian economy is sought to be linked more and more with the global economy, which itself is getting more and more integrated. The other is that within the country governance is sought to be decentralized, through a comprehensive system of constitutionally-mandated local governments. These two trends appear to be contradictory, but are not actually so. Both involve more powers to a larger number of units (economic or administrative). The notion of a monolithic state, which can deal with, control, plan and develop all aspects of the people's lives is giving place to the need for a decentralized, responsive and flexible system of economic development and governance.

The essence of the recent economic reforms is that while the basic functions of security, law and order, human resources development, urban and rural development, programmes for the poor and the weak and development of infrastructure will remain with government and will indeed get better attention, government will leave investment in industry largely to the private sector (as has always been the case in our country in agriculture) and cease to be a major investor, owner and manager of enterprises. Government will not also be playing the role of allocation of resources in the case of private sector investment. Government's responsibility for macro-economic stability and management will become important. It will also have to play the role of an umpire, in public interest, in monitoring standards of safety, quality, environmental protection, consumer protection, fair play in business and financial transaction, avoidance of monopoly and promotion of competition.

In the exercise of these last set of functions, government has, willy-nilly, to get laws enacted through the legislature (central parliament and state legislatures, as the case may be). It has itself to issue regulations and lay down procedures which are implemented through different wings of the bureaucracy. It is in doing this that several problems arise. In a rapidly changing business and technological environment, the time-consuming process of law-making means that the laws lag far behind the changes. When made, they are frequently out of tune with the reality-either in terms of business practices or due to technological change or both. This happens even when they are issued as ordinances which, as you know, are emergency law-making by the executive pending ratification by the legislature. The Cable TV Regulation Ordinance 1994 has already become obsolete in many respects, because of changes in technology and due to fierce competition in the business. There is the added confusion that regarding the same broad subject-matter there are laws of varying vintage. In a culture in which obedience to law is not all that ingrained-one need only look at our roads to be reminded that we cannot even follow the elementary rules of the road this leads to a bizarre situation. There are thousands of laws and regulations but few are enforced and fewer still are followed.

Yet another problem is that since such laws exist on the statute book, they are invoked, from time to time, not to achieve the objectives of the law, but to harass those whom you do not like for one reason or other.

A vicious cycle develops. People are unable to follow the law in many respects. They devise means to circumvent or beat the law in all respects! Governments enact new laws or introduce more stringent (on paper) provisions in old laws, to plug the loopholes. The process goes on. Instead of there being cooperation between the people and the law-makers for the public good, an adversarial relationship develops. Apart from the negative social and cultural effects of such a development, the transaction costs — as the economists call it — of the economy increases as a result of all this. It becomes less efficient and economical and, therefore, less competitive. Nothing gets done on time, disputes arise in plenty, recourse to courts becomes frequent and common, courts get clogged with cases leading to delays and thus starts another vicious cycle of disputes and delayed justice.

In this situation, what I fear is that as we try to proceed with the reforms, there would paradoxically be greater confusion, affecting the pace of the reforms and the smoothness of the transition. Why do I say this? Because, what reforms require is that we deregulate in certain respects and regulate in certain others. This process of deregulation-neo-regulation is not an easy one. Take the infrastructure sector, which is the main theme of your Congress this year. In areas of State monopoly like power, telecommunications, air services, ports and even roads, we are thinking of negotiating and renegotiating and finalising (hopefully) projects involving private investment. New business relationships will arise as a result of all this. It was easy to deal with relationships between government agencies-those who do not pay generally got away with it! You and I, as general tax-payers, where the losers; but some groups or others benefitted. We all loved with it. But the relationships between private power producers, for example, and public distributors have to be worked out. In addition to business relations, there are also technical requirements and discipline regarding frequency, peak demand, voltage and the like.

Regarding roads, we are thinking of BOT, BOLT and the like. Complicated contractual and other arrangements have to be there, since these private segments will be parts of large public systems. One can give examples from other areas of infrastructure. The phased deregulation of the financial sector will create similar problems. We have already referred to the complications introduced by rapid technological change. To repeat, it is easy if everything is either in the public or the private domain. When both have to not merely coexist (as in the case of industrial units), but also interface and be parts of the same physical system, things become difficult. I suspect that in our reforms, we will have a fairly long period of this kind of cohabitation of the same sector by public and private enterprises. How are we to ensure a smooth, working legal framework which facilitates growth and change?

Students of comparative law tell us that there are two major processes of law-making. One builds on the common law tradition of social norms from which much of English law, for example, was found by judges. The latter did not 'lay down' laws or rules, rather they looked at the prevailing practices and picked out and enforced those which were in larger interest. This was much the practice for many years of the Industrial Revolution also. Most of commercial law was built up initially following this method. The second one is the method by which the State-Napolean in the case of the famous Napoleonic Codes or the parliament or legislature in democracies- enacts the law, based on what is considered best for the public good. In modern times, the gap between the two is sought to be filled through Law Commissions and the like as well as through such parliamentary devices like Select Committees which hear and take evidence from interested individuals and groups. Yet, we see a lot of mismatch because the former turn out to be 'expert studies' with normative considerations of what is best, while in the case of the latter, the individuals and groups are largely content with stating their special interests and pleading for them rather than in assisting in the formulation of or negotiating a good law. Most laws are passed almost entirely in the same form as presented by theqovernment, that is, as prepared by the officials and approved by the Cabinet.

Dealing with these problems, in a recent talk at Delhi, on 'Market Modernization of Law' Prof Robert Cooter of the University of California, summarized his solution as follow:

"As an economy develops, specialization steadily increases the information deficit of central officials. To overcome this deficit, law and economics must decentralize. 'Market modernization' is my name for the decentralized development of business law. Decentralization of law requires the evolution of norms in communities and intermediate institutions, including the internalization of norms of members of the community. Social norms give content to general legal principles, which is fundamental to legality. By supplementing social norms in intermediate institutions, officials of the State can solve problems of motivation and information that are insurmountable otherwise According to my theory, norms arise when individual benefits from representing himself as conforming to a practice that benefits other people. In other words, norms arise when everyone's self-interest is served signalling that he will supply a local public good. Business norms tend to be efficient within a community in which they arise, although under-enforced. However, the spontaneous enforcement of norms falls short of optimal enforcement. Enforcement of a social norm by the State can increase efficiency, provided that the norm does not have harmful spillovers to communities other than the one in which it evolved. Scholars should rehabilitate the old conception the State should find law, not divorce it. The active aspect of market modernization involves the state receiving impediments to competition, which is the engine driving the evolution of business norms and the State selectively enforcing the norms that arise in business communities."

That was an extension of Adam Smith's 'hidden hand' to law making and a call to rely more on the common law tradition. Even if one has unflinching faith in the market as the source for all economic solutions, one can think of this only as an ideal at best. At most, one can think of greater confusion than what we feared earlier. This is particularly so in a cultural environment in which self-discipline is very low and commitment to common cause is even lower.

By now you most have decided that there has been some mistake in calling me to speak to you. You must be wondering: "What has all this to do with us, engineers?" And so, I now come to the main point of my argument.

Following the practice in the United Kingdom, from where we have adopted not only the system of governance but also many of the institutions and laws, professional organizations of engineers, doctors, accountants and auditors, lawyers and so on were formed in India. Many of them have functioned for several decades. Your own organization is over 75 years old and has rendered yeoman service. The main functions of professional organizations were to uphold professional standards and lay down technical norms for doing that as also to adopt ethical norms for the conduct of its members in the pursuit of the profession. They have done both to some extent and the Institution of Engineers has undertaken education and training also in a big way.

Over the years, two things seem to have happened and you should excuse me if what I say is not correct. One is that with a large number of government agencies in the economic sphere and the domination of even higher and professional education by government (either by running them or through approvals and funding), professional organizations have compromised a great deal with quality. As Chairman of the Electricity Board (a monopoly producer and distribution of electricity) I found that a Superintending Engineer of the Board was also the Chief Electrical Inspector, implementing the Indian Electricity Act and Rules. It was not surprising that the technical quality standards prescribed were not applied to the Board and its activities. Since it was not applied to the public body, its application to private users also became perfunctory and sporadic. There was the dual result of poor quality and corruption. I believe one could give examples from other sphears, especially in respect of quality of education. Hundreds of professional institutions of 'higher learning' have been started and are 'functioning' in the country, which do not come anywhere near the standards adopted by the national professional organization concerned.

Secondly, somewhat deprived of their role — involuntarfly orvoluntarily — as enforcers of discipline on others' part, they seem to have relaxed the norms of self-discipline also. Ethical norms seem to have been .abandoned to a greater or lesser degree in different professions. The self-serving logic that "It I do not do it, someone else will do it. So, why not I?" has been carried too far, to the detriment of public interest. Not that there are not individual exceptions in each profession. There are many. That is way, we have managed to survive.

But, as a natural corollary to these trends, professional organizations have tended to act as special interest groups and lobbies, trying to protect the perceived interests of their constituents rather than function as watchdogs of professional integrity and standards. Many of them have become almost trade unions and indulge in g8ild-like activities desperately trying to preserve the status quo, on the mistaken assumption that is the continuance will ensure their current level of benefits for ever. I would not like to name the professions, much less to grade them. Suffice it to say that it is a general tendency, but is perhaps the least among engineers. And that is why I am raising this with you.You can set an example to others, including the one to which I belonged!

There is another reason. There is no branch of economic activity (or human life forthat matter) in which 'engineering' does not have a place. So when we are reforming different aspects of economic activity, obviously engineers would have to playa very important role. My plea is that in addition to restoring the lost ground, if any, in the matter of professional integrity and standard engineers should play an active part in evolving norms of self-regulation in their respective fields. The point briefly is this:

In the context of technological and economic transformation and transition, new institutions, relationships and instruments will emerge. Many old regulations will have to go and new ones have to come in. If this is left to be done only govemment, several defects arise, as we have seen. On the other hand, it cannot be left to the economic actors and the state coming in later, as has been suggested by some scholars. To neutralize the natural, selfserving nature of most economic actors and to bridge the 'information deficit' and overskill or futile control by the government, professional bodies' should find norms of self-regulation, which as professionals involved in economic activity, they would make economic actors adopt in their operations. Since most modern economic activities will have a large technical component, the span of self-regulation can be quite large indeed. And to the extent there is self-regulation, the span of State legislation will be less, better and more to the point. My plea is that, as a premier professional body, the Institution of Engineers (India) should take up the challenge of self-regulation and contribute significantly to the evolution of economic law in our country in the coming years.

Thank you.

Intelligent Robotic Systems in the Indian Context

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Abstract

In this talk, a brief overview is given of the history of robotics, and the relevance of robotics to India is discussed. It is argued that unless robotic systems are equipped with "intelligence", further progress in robotics will not be possible. Finally, it is argued that, even in the Indian context, there is considerable scopefor the use of intelligent robotic systems.

A Brief History of the Evolution of Robotics

What is a robot? The "official" definition I given by the Robot Institute of America is :

> A robot is a reprogramniable multifunctional manipulator designed to move material, parts, tools, or specialized devices through variable programmable motions for a variety of tasks. (emphasis added).

Note that some emphasis has been added on various phrases in the definition. The key point to note is that not all automation is robotics. In particular, "hard" automation consisting of mechanical devices that are not reprogrammable does not count as robotics. The Table 1 gives a brief summary of the evolution of robotics.

Table 1 : Some Key Events in the Evolution of Robotics

Year	Event
1954	First programmable robot is developed.
1961	First robot (Unimate) is installed in Trenton, New Jersey (USA).
1971	The Stanford arm is developed (First research robot).
1975	Unimation Inc. registers a profit for the first time.
1983	General Motors installs automated assembly line.
1986	General Motors *removes* automated assembly line.

There are several noteworthy points about this table. First, Unimation Ine. had to wait forfourteen years before registering a profit for the first time. Thus, getting into the robotics industry is not for the faint of heart. Second, after having installed a fully automated assembly line at a cost of about $ 800 million in 1983, General Motors (GM) was sufficiently disillusioned by the non-performance of this automated assembly line to remove it just three years later.

Why did this misadventure take place? In those days, GM had a linear assembly line that was several miles long. The robots of that era were reasonably sound mechanically, but had very little intelligence by way of sensory capability. Most of the robots in the automated assembly line were welding robots. These robots merely executed point-to-point motion without any sensory feedback. As a result, these robots merely moved to a predesignated set of coordinates in space and performed "welding", whether or not there was any part to be welded at that point. The misadventure of GM caused a considerable setback to industrial robotics, as can be imagined.

Current Robot Population

Details of the robot population in the world (for the latest year in which statistics are available) are shown in Table 2.

Table 2 : World Robot Population (As of 1992)

Country	No. of Robots
Japan	3,50,000
USA	50,000
Germany	47,000
China	400
India	100

Thus, it can be seen that India is considerably behind the advanced nations (as can be expected). The surprise is that India is so far behind China as well.

The Table 3 shows the rate of increase in the robot population in the world from 1991to 1992.

A study of the robot population over the years, both in the world as a whole as well as in Japan, the USA and Germany, shows that the rate of increase of the robot population, even in advanced countries, has come down considerably in recent years.

The predicted "boom" in the robot population has simply not taken place. What is the reason for this? The author's opinion is that the robot population has not taken off mostly because present day robots are not sufficiently "intelligent".

Table 3 : Rate of Increase of the Robot Population From 1991 to 1992

Country	Rate of Increase
Japan	7.6%
USA	7.0%
Germany	15.0%
Sweden	11.0%
UK	9.0%

What is Robot Intelligence?

The aim of intelligent robotics is to build robotic systems that are as "human-like" as possible. In particular, a human operates on the basis of a very small set of high-level instructions, whereas a non-intelligent robot would require a large number of very specific, low-level. and inflexible instructions. Thus intelligence on the part of a robot consists of the following attributes, among others:

• The ability to sense the environment through various sensors; e.g., vision, proximity, tactile, force/torque, etc.

• The ability to reason about its tasks; e.g.,

• Determining its own action on the basis of a high-level task specification, for example, assembly motionplanning given a description of the part to be assembled and its constituent sub-parts.

• Identifying which part is which, in its workplace, and further, determining the position and orientation of the parts that are to be picked and manipulated further.

• Identifying the obstacles to its own motion, and computing a feasible path that avoids all obstacles and reaches the specified destination. Since some of these obstacles might consist of other robots sharing its workspace, the obstacle-avoidance and path-planning would have to be performed in real-time.

• Ability to learn on the basis of experience; e.g., improving its own positional accuracy and repeatability after repeatedly performing the same task and being given sensory feedback about its performance.

Of course, these are only a few examples of robot intelligence, and others can also be given.

As of today, most commercially available robots are only capable of executing point-to-point motion. Some robots are equipped with sensors such as force/ torque and proximity sensors, which would be of use in performing somewhat localized tasks with precision such as populating printed circuit boards (PCB's). While there are several research robotic systems that incorporate various attributes of intelligence, such systems are for the most part not commercially available. For this reason, robot programming languages for commercially available robots are somewhat like computer as embly languages of decades past. In contrast, an intelligent robot should, in principle, be capable of executing task-based commands. For example, an intelligent robot should be able to :

• Examine the workplace and identify the part to be picked up.
• Determine the location and orientation of the part.
• Pick up the part.
• Manipulate the part.

What Advances in Robot Technology are Needed in order to Build Intelligent Robots?

As mentioned above, various research laboratories around the world contain robotic systems that display some attributes of intelligence. However, given the tendency of researchers to specialize in a particular topic or set of topics, it is not surprising that there are very few fully integrated intelligent robotic systems, even in research laboratories. In order for such systems to become widely-used, several advances in robot technology are needed. Some of these are listed below.

• High-level programming languages that enable a robot to accept and respond to "human-like" commands. These high-level commands would then be 'partitioned' into lower-level tasks automatically by the programming language, without further human intervention.

• Versatile and expandable robot operating systems. Since an intelligent robot makes use of a variety of sensors, some of which might be added after the robot is commissioned, it is necessary for the operating system running on the control computer to be versatile and expandable, so as to accept further (and previously unforeseen) tasks as time goes on.

• Integration of diverse sensory information. This is a special case of a standard problem in Artificial Intelligence known as 'blackboard architecture', whereby information coming from several sources is integrated. The main challenge in this topic is that the information is not always reliable nor accurate (for example, force/torque measurements are ultimately based on strain-gauge measurements, which are prone to drift and other forms of inaccuracy).

• Tools for animation and CAD-based modelling. The idea here is that one should make all one's mistakes in software, and perfect the design before commencing to 'cut metal'.

Interestingly, all these ingredients already exist in an advanced state in various research laboratories around the world. However, the developers of these various tools do not always communicate with each other, owing to'the tendency of researchers to specialize. Thus, what is really needed is mostly an integration of existing tools rather than the development of entirely new technologies.

How Relevant are Robotics to India?

It is often argued that robotics are irrelevant to the Indian context because of

• High unemployment
• Low labour cost
• Poor quality-consciousness among consumers
• Low purchasing power of consumers

These points are all valid, and it will be a long time before Indian industry sees the widespread use of robots for routine assembly operations. Nevertheless, there is considerable scope for robotics in India. Some of the possible applications of robotics in India include:

• Hazardous environments, such nuclear reactors, ordnance factories, handling toxic substances such as chemicals, paint factories.
• High-precision applications such as those in defence and space-related applications.
• Export-oriented factories where the quality of the finished goods is more important than cost.
• Retrofitting ("piecemeal") automation.

Thus, it can be seen that there are a great many applications, but these are rather diverse.

Prescription for India: Custom Robotics

In introducing robotics in India, we should not blindly follow the road taken earlier by industrialized nations. Rather, we must take into account the unique features of the Indian scene. Some of these are as follows:

• Low labour cost but commensurately lower productivity.
• High cost of capital.
• Large investment in existing plants.
• Diversity of opportunities for automation.
• Limited demand for each specific robot model.

Because of the high cost of capital and the large investment in existing plants and facilities, there is relatively little scope in India for buildingjully automated factories starting from scratch. Rather, robots have to be introduced into a workplace which cannot be altered very much to accommodate the robot. This process is usually referred to 'retro-fitting', and can be thought of as a 'piecemeal' approach to automation. Since the various tasks that need to be automated will be rather diverse, it will be necessary to design many different models of robots. However, the demand for each model of robot will be very small. This situation can be referred to as 'custom robotics'. Under normal circumstances, a designer would be able to amortize the cost of designing a robotic system by spreading it over a large volume of units sold. However, in cases where it is necessary to produce a great many models of robots, each model being produced in rather small numbers (fewer than 10), how is it possible to keep the unit cost within reasonable limits? It is here that the Indian robotics community has a clear cost advantage. Producing custom-designed robots in a cost-effective manner requires good design and fabrication capability. Design costs account for up to 70% of the cost of even mass-produced robots. Thus design costs would take up an even larger fraction of the cost for custom-designed robots. Fortunately, in India the manpower cost is very low, and it is precisely in such "one of a kind" or "few of a kind" applications that Indian designers can potentially offer a cost advantage. Unfortunately, even though thefabrication capability in India is adequate for most purposes, the design capability needs to be built up considerably. This is one of the objectives of CAIR. Another difficulty faced by robot designers is that, while precision manufacturing in the country is in fairly good shape, it is difficult to interest such manufacturers in fabricating parts in small lots, as would be required by those designing and building prototypes of intelligent robotic systems.

Components of Custom Robotics Design

In order to design customized robots, an organization requires the following skills:

- Task-level modelling, that is, identifying the task(s) to be performed from the standpoint of robot design.
- Identification and optimization of robot geometry and robot dimensions.
- Motion planning (including obstacle avoidance, assembly planning) and trajectory control.
- Animation of robot motion and control.
- Automatic generation of controller code.

While some of these capabilities are currently available in CAIR, much work remains to be done.

Conclusion

Unless some "intelligence" is incorporated into robots, the field of robotics will remain stagnant. Making robots more intelligent involve many interesting research problems, some of which are being pursued in India. In spite of the low level of development of Indian industry, there is considerable scope for introducing robotics into the Indian workplace. The potential applications of robotics in India are many, but each application would require a relatively small number of robots. In order to develop' many different models of robots, each in very small numbers, it is necessary for the Indian community to develop the design skills needed to carry out custom design of robots in a cost-effective manner.

Indian Steel Industry in the Context of Globalisation

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Globalisation

The 1990s have ushered the era of globalisation. National boundaries are losing their relevance as economies world over are getting integrated through higher trade flows and increasing mobility of capital and investments. The flow of private capital to the emerging markets of the world increased sixfolds, from $50 billion in 1990 to $336 billion in 1996, signifying an ever increasing movement of capital across borders. Similarly the volume of total world exports to total world output has increased from around 7% in 1950 to 15% in 1996. This has been facilitated by a progressive reduction of tariffs and quantitative restrictions, earlier under GATT [General Agreement on Trade and Tariffs], and now under its successor organisation WTO [World Trade Organisation], which has extended its scope to cover services as well.

It is generally agreed that global integration has been facilitated by tremendous advances in the area of communication and computing which has transformed national societies to a world society. There has been a growing interdependence across regions and the intraregional trade in European Union, NAFTAand ASEANhas shown an increasing trend. The developing countries have changed their attitude towards FDI (ForeignDirect Investments) and Multi National Corporations. There has also been an increased focus on strategic alliances and co-partnership, facilitating technology transfer and improved product quality and services.

The Indian economy has not remained insulated from global trends. Although the driving force of reforms in India were the compelling circumstances in the aftermath of the Gulf war, there has been a broad consensus to integrate India with the world economy through accelerated growth in exports and freer imports. The share of imports and exports as a percentage of GDP in India has increased to 17% in the post 1991 period, in comparison to 12% during the period 1986 to 1991. Foreign direct investment which was a meagre $ 97 million in 1990-91 has increased to around $ 2.7 billion in 1996-97, and since 1992-93, GDRs and portfolio investment by Foreign Institutional Investors [FIIs] have increasingly contributed to foreign private capital inflows.

World Steel Trends

Some discrete trends have become visible in the world steel sector.

• Although the output has remained more or less stagnant for the past decade or so, there has been an increasing trend in the world steel trade. Exports as a percentage of world steel production increased from 28% in late 1980s to 40% by mid 1990s.

• It is projected that the global demand for steel will increase by 2% per annum up to the turn of the century, and that the developing world would increase its presence in world trade together with Eastern Europe and Russia, while the role of European Union and Japan would diminish.

• The technological trends indicate that the competitive global players, will increasingly access new technologies such as thin slab casting and "compact strip production", which can reduce per ton capital cost, by as much as 75%. The viable size of new hot strip making capacity, has come down, to 1.2 million tonnes. The processes to be employed in steel industry in future will have lesser number of discrete steps. This would reduce scrap and skull generation and would require less man-hours per tonne. Continuous steel making, continuous rolling of long products from the caster, and integrated process of pickling — cold rolling and continuous annealing would be increasingly used.

• Major international steel companies, such as Nippon Steel Corporation, pasco, British Steel, (to name a few), are setting up units in other countries, through joint ventures, with steel companies from third countries. In other cases, as with Thyssen, and Krupp, in Germany, mergers are being proposed, to mutually supplement the strength of each unit.

• Privatisation of the steel works is the other phenomenon cutting across the globe. It may be noted, that, two successful Asian steel companies, namely, pasco in South Korea (the second largest steel producer in the world, after Nippon Steel Corporation), and China Steel Corporation in Taiwan, were established by the respective governments, in 1968, and 1971, respectively. In each case, privatisation has been introduced progressively. Government shareholding, has come down, to 34%, in 1995, and 29%, in 1994, respectively, in the case of pasco, and China Steel Corporation. In the case of China Steel Corporation, the company is combining with Taiwan's Kuie Yu Industrial Co., to build Taiwan's second largest integrated steel mill. Other recent cases of privatisation of government-owned steel companies, include USINORof France, and ILVAof Italy, both being companies with a global presence. USINORhad shut down or divested its loss-making units as British Steel had done earlier, in the process of privatising in the late eighties.

The Indian Scene

Inspite of the current slump, India is one of the fewcountries where the steel industry is believed to be poised for a rapid growth. India's share in the world production of crude steel increased from l.5% in 1981 to 2.9% in 1996. World steel dynamics had earlier predicted a consumption of 31 million tonnes of steel in India by 2000 with an internal availability of 28 million tonnes. The 9th plan approach paper had assumed a growth rate of steel demand during the 9^{th} and 10th plan as 8.85% and 8.25% respectively. The present economic slowdown perhaps will delay this happening a bit.

With expansion of the capacities in the integrated plants and new capacities like Lloyd Steel, Essar Gujarat, Nippon Dendro, Jindal Vijaynagar, Malavika Steel and NINL being operational or under implementation, supply of steel in Indian market place has considerably increased. This has created an intense competition in the domestic market in the short run. Export of steel therefore has seen a big boost in recent years and had moved up from a mere 373,000 tonnes in 1991-92 to nearly 2 million tonnes in 1996-97. Nearly 3 million tonnes of steel export has been planned from India during 1997-98. Pig iron is also being exported since 1993-94.

Globalisation of Indian Steel Industry

Globalisation of the Indian steel industry would basically need the industry to be internationally competitive both in terms of quality and cost of production. Otherwise, reduction of tariff barrier as a part of Government of India's plan of opening of economy can mean a disaster for the domestic industry.

After endless debate on cost competitiveness of Indian steel, the World Steel Dynamics figures indicate that Indian steel- SAILsteel, at least, is competitive in terms of cost. In iron ore, India has a distinct advantage at $20/tonne of saleable steel against $61 in USA, $70 in UK and $57 in Japan. Indigeneous coking coal is available at an average landed cost at about US $55/tonne as compared to US$70 C&F value of imported coal. The total material cost works out favourably. In SAILfor example, it is US $ 106/ tonne of saleable steel against US $ 226 in USA and US $ 232 in UK and US$ 236 in Japan. Labour cost inspite of low labour productivity, works out to be US$ 55/tonne of saleable steel against $ 153 in USA and US $ 104 in UK and US $ 148 in Japan. For India the energy costs per tonne of saleable steel is however very high at US $ 136/t against US $ 98 in USA, US $ 76 in UK and US $ 88/t in Japan. The comparison of costs as worked out by WSD in 1996 is given in the enclosure. Since the comparison is based on per tonne of saleable steel, the value mix of different products in the saleable steel is relevant for comparison and indicates the competitiveness of Indian steel in at least low valued items.

It should be however remembered that the cost advantage that Indian steel enjoys today, is threatened by steep escalation in the input prices.The costs of coal, power and transportation have risen since and continue to rise. In contrast, developed counties have the benefit of a steady or at some time declining input costs. The cheap labour in India is also not going to stay for a long time. Developed countries which traditionally had a high component of labour in the total cost of steel have been able to reduce the % component steadily by increasing automation, closing down units with lower efficiency and reduction of the total working force. In contrast, no such thing has been attempted in India so far and to compound the problem the spectre of regularisation of contract labour is before the Indian PSUs. The labour cost component in Indian steel industry is on the rise and need to be checked if the industry has to be globally competitive.

The competitive edge of technology

Much of the competitive edge for the Indian steel industry would come from the technology employed and the efficiency with which the available technology is being put to use. Currently, the steel industry is not on a very strong footing but the process of modernisation through which many of the old plants are currently undergoing is rapidly changing the position.

The present technological gap is quite apparent which would only get partly bridged by the turn of the century. The lowest energy consuming integrated plant of SAIL today is Bhilai. But it consumes about 55% higher energy per tonne of crude steel than the international norm. The by-product energy recovery at Bhilai is one of the best, but still is 16%below international norm. The unit rate of energy which basically depends on the landed cost of coal is lower in plants which incidentally continue to consume more specific energy per tonne of saleable steel. This trend is being corrected now.

Parameter	**World average**	**India-'96-97**
		Actual
Steel making by process	%	%
BOF	60.1	54.4
EAF	32.8	25.9
OH	6.9	19.7
Others	0.1	0
% crude steel cast by continuous casting	78	34
Energy rate in integrated plants GCal/TCS	4.5-5	7.8-9

The basic structure of the steel industry in India in the near future (say by 2000) would be the core integrated plants (accounting for 69% of the carbon crude steel production) employing the traditional BF - BOF/OH route and the electric arc furnace sector which would cater to practically the entire alloy and special steel output plus the remaining 31% of the carbon steel output. Variations of the two traditional types are also coming up. JVSL plant at Tornagallu in Karnataka uses COREX process instead of Blast furnace for hot metal production and is based on noncoking coal. In Ispat's Dolvi plant, twin shell electric arc process would be used where liquid iron would replace partly the solid charge of scrap and DRI. The traditional EAF installations would continue to look for scrap substitute (DRI/HBI/Liquid iron) due to scarcity of scrap in India and the highly volatile price of scrap linked with exchange rates. Electricity charge would remain a perennial problem in India and Electric Arc furnace operators would have to introduce all power saving devices to remain competitive.

Till recently, all the integrated plants with the exception of RINL had been using the technology of the 60's. This sector would continue to be enjoying the advantage of lower operating cost but then continuous thrust of modernisation would be required here if Indian steel is to be made globally competitive. Fortunately, during the last fiveyears, a series of modernisation measures have been taken in all the integrated plants except lISCO Burnpur. These actions have now started bearing fruit. Burnpur modernisation planned since the late 80s is getting delayed due to a number of reasons but there are hopes now that this plant would not be left behind.

I may mention a few major technological changes introduced recently.

• The facility of agglomeration has been strengthened along with new facilities of raw material bedding and blending. This has enabled the integrated plant to use more fines to cut down the cost ofusable iron ore and improve the consistency in composition of raw material used. It has helped to reduce coal to hot metal ratio and has helped in production of lower silicon levels in hot metal, facilitating subsequent steel making. New Sintering facilities have been added at Durgapur (198 m^2), Rourkela (192 m^2) under modernisation and has come in TISCO (180 m^2) during the phase -1 of modernisation itself. In all these plants, sinter capacity exists to charge over 70% sinter in the blast furnace burden. A new sinter plant is under construction at Bhilai with a capacity of over 3 million tonnes per annum to be started in 1998 and this facility would make Bhilai also capable of using over 70% sinter in the burden.

• The use of imported coal in the coking coal blend has gone to over 45% in SAIL plants to counter the lower availability and poor quality of the indigenous coking coal. TISeO however gets the benefit of a better quality captive coal and use of stamp charging technology which could keep the imported coal at a lower level. RINLbeing a shore based plant currently uses 72% of imported coal.

• Modernisation of blast furnaces. From 1984-85, several modern technologies have been adopted in blast furnaces for improving productivity and decreasing coke rate. Some of these are :

- High pressure operation in BF2&4 of Durgapur. It would be introduced in BF-4 of RSP also.

- BLTin four blast furnaces of Bhilai, five furnaces of Bokaro and three furnaces of Rourkela.

- Movable throat arm ours in BF2&4 of Durgapur.

- Cast house granulation in a total seven blast furnaces of SAIL.

- Increase in the hot blast temperature in all the plants through modification of the stoves.

- Provision of coal dust injection in one blast furnace each at Bhilai and Bokaro is under implementation.

- In TISCO the new G furnace has all these facilities. TISCO has implemented CDI in three of their furnaces and has provided liquid fuel injection in the other two.

As a result of these measures, the productivity of Indian Blast furnaces has increased. Individual blast furnaces like BF-7 of Bhilai and G furnace of TISCO have given a productivity of over 2t/ m^3/ day. Blast furnace shop productivity has increased by nearly 27% during the last five years as shown below:

BF Productivity t/m³/day (on working volume basis)

Plant	1992-93	1996-97
BSP	1.33	1.47
DSP	0.52	1.03
RSP	0.83	0.92
BSL	1.28	1.49
TISCO	1.28	1.49
RINL	0.85	1.59

There had been also a significant decrease of coke rate in SAIL plants, TISCO and RINLduring this period. In SAIL,at Bhilai and Bokaro the coke rates are below 600 Kg/THM and 525 kg/THM at RINL.At TISCO where auxiliary injection is practiced, the skip coke rate has come down to 546 Kg/THM with 64 Kg of injection of coal/ tar. These figures however are still far below what is internationally achieved. A productivity of around 2 t/m^3/day and a coke rate of less than 500 kg/THM without any auxiliary addition is considered as an acceptable norm. These figures may be difficult to achieve if significant quantity of Indian coals are to be used. Still thanks to lower cost of ore and low labour rate, the current cost of hot metal from Bhilai and Bokaro at around US $ 122/t is internationally competitive and has enabled SAIL to export pig iron also for the first time.

• Closing down of the open hearth furnace route in Rourkela and Durgapur. In both the plants new converter shops with continuous casting facility have been installed. At Rourkela, the project report envisages ingot casting for a small percentage of the total crude steel. But Rourkela is making trial for continuous casting of silicon steel heats and would introduce rimming substitute heats also for continuous casting so that 100% continuous casting can be achieved by the next financial year. At Durgapur, product mix requirement has dictated retention of ingot casting to the extent of 60%. This is an area which I hope would be able to improve in the coming years by rationalisation of the product mix. Continuous casting has been introduced at the steel melting shop No.2 of Bokaro (1/2 × 300 t) and the trial production has just started. Wehope to bring CCratio at Bokaro to over 50% in about a year's time. There are further plans to introduce Slab casting in the Steel melting shop No.1 of Bokaro also during the 9th plan making ingot casting totally redundant by early 2000. TISCO under the Phase-4 of modernisation is commissioning the third 150 t converter and the new slab caster. A bloom caster is also going to be installed to cater to the long product mills and increase the overall CC ratio. TISCO is operating openhearths in a limited way which is also likely to phased out soon.

• Modernisation of Hot strip rolling facility. The hot strip mills installed recently by TISCO, Essar, JVSL and at Salem (unit of SAIL)are of the state of the art technology while the hot strip mills in SAIL (RSP and BSL) lack many of the modern facility. Replacement of the older pusher type furnaces with walking beam furnaces are currently going on and the new walking beam furnace No.4 has already been commissioned at Bokaro. In the mill proper, steps are being taken to improve the quality of the hot strip in terms of dimension accuracy, surface finish and shape of the coils. The coil weight of RSP will soon be increased to international standard.

Product Mix:

The global trend today is to go for economy in usage of steel. The need is for material which is stronger, corrosion resistant and sized. Such material should reduce wastages at the consumer end. On the long product side availability of increased number of sizes facilitates economic design of load bearing structures. Avariety of coated products capable of being processed through automatic machines are also much in vogue. In this area the situation in Indian steel industry is not comfortable. Excepting TISeO, the other integrated steel plants generally produce traditional products in conventional qualities. However with the completion of modernisation and installation of facilities like VAD/LF /Wire feeding for deoxidation, the position is changing. Most of the special steel products are through Electric arc furnace route which globally is being made through BOF route. Only recently, VISL a special steels plant - subsidiary of SAIL which was earlier using only EAF route for alloy and special steels has started making these grades through BF-BOF-LRF route. I understand some other companies in the private sector will also follow.

On the flat product side, the proportion of EDD quality steel for automobiles, higher strength sheets / coils for making higher grades of APP pipes, corrosion resistant sheets and increased quantity of galvanised products will be produced in future. On the long product side, lowalloy steel billets for further processing, wire rods for special applications and thermally treated and corrosion resistant reinforced bars will be produced in increasing quantities to cater to domestic market. But the possibilities of export ofthese commodities except to neighbouring countries does not seem likely today unless the exportable yield of these items are increased substantially. Special long product sections like universal beams, thin flanged sections are difficult to produce in integrated plants in India due to lower aggregate demand which prevents economy of scale. Some of these have been produced in a limited quantity in the secondary sector. Production of these would be feasible only with export of substantial quantity at a competitive cost.

Alloy and Special Steel

The alloy and special steels sector of the Indian Steel Industry is primarily based on Electric Arc and induction furnaces and is plagued with over capacity. Against an annual demand of nearly 1.5 million tonnes, the available capacity is around 3 million tonnes. 50% of this capacity is from 14 major producers out of which TIseo is the only integrated plant. Most of the major producers have modernised their facilities and use continuous casting along with ingot casting. Use of VAD/VOD/AOD/LF for steel making and EMS in the continuous casting is becoming increasingly common. Largest proportion of the alloy steel is stainless steel (demand about 600,000 t) 10% of which only is required in industrial quality (in AISI 304 and 310). Rest are for utensils for the consumer market which accepts material with nickel ranging from 0.5% to 4% and are produced in a large number of small scale installations. The high power tariff combined with the cost of electrodes and the uncertainties of the international scrap price make the production cost of alloy and special steels high in India. Export of stainless steel as being done from the Salem plant of SAILis only possible now by importing slabs (duty free for export purposes) and doing subsequent hot and cold rolling. In advanced countries, the proportion of alloy and special steels in the total steel consumption is steadily rising, but in India it is of the order of 3.5% and largely limited to the lower valued carbon construction steels, spring steels and nickel substituted austenitic stainless steels. In the developed countries, the cost of production of 18:8 stainless steel at the steel making stage has drastically fallen by use of AOD/VOD and even using dephosphorised hot metal as a raw material without sacrificing quality. In India, basically because of lack of domestic market' for large volume of quality stainless steel such efforts are yet to gain momentum.

Infrastructure

The infrastructure limitations are a serious threat to the growth of the Indian Steel industry. The Railways are likely to continue to affect the cost and freight structure of the steel industry. Alternate road movement will depend on development of roads and the extent of private investment in this sector. Export of products and import of bulk raw material like coal will get constrained on account of poor facilities at ports and will call for modernisation and development of ports. If the steel industry is to invest in these infrastructure facilities, its growth will be slower. The support therefore has to come from Government.

Concluding, I may say that the steel industry has now been exposed to new challenges in the form of tough competition from both within and out side the country. The industry needs to change the work culture developed over the years under a protected regime. The maximum emphasis will have to be given on cost reduction and accompanied by simultaneous improvement in quality of products with the needed technology and skill for achieving international competitiveness with sustained growth.

Table-1 : Major Steel Producing Countries 1995 and 1996

(Million metric tons crude steel production)

Country	1996		1995	
	Rank	Tonnage	Rank	Tonnage
PR China	1	100.0	2	95.4
Japan	2	98.8	1	101.6
United States	3	94.7	3	95.2
Russia	4	49.2	4	51.3
FR Germany	5	39.8	5	42.1
Republic of Korea	6	38.9	6	36.8
Brazil	7	25.2	8	25.1
Italy	8	24.3	7	27.8
Ukraine	9	23.3	9	22.3
India	10	21.8	10	20.8
United Kingdom	11	18.0	12	17.6
France	12	17.6	11	18.1
Canada	13	14.7	13	14.4
Turkey	14	13.4	15	13.2
Mexico	15	13.2	16	12.1
Taiwan(RoC)	16	12.3	18	11.6
Spain	17	12.2	14	13.8
Belgium	18	10.8	19	11.6
Poland	19	10.4	17	11.9
Australia	20	8.4	21	8.5
South Africa	21	8.0	20	8.7
Czech Republic	22	6.5	22	7.2
Netherlands	23	6.3	24	6.4
Romania	24	6.1	23	6.6
DPR Korea (E)	25	6.0	25	6.0
Iran	26	5.4	28	4.7
Sweden	27	4.9	27	5.0
Austria	28	4.4	26	5.0
Indonesia (E:1996)	29	4.3	29	4.1
Argentina	30	4.1	31	3.6
Venezuela	31	3.7	32	3.6
Slovak Republic	32	3.6	30	3.9
Finland	33	3.3	33	3.2
Kazakhstan	34	3.1	34	3.0
Saudi Arabia	35	2.7	38	2.5
Egypt	36	2.6	36	2.6
Luxembourg	37	2.5	37	2.6
Malaysia (E:1996)	38	2.5	39	2.5
Bulgaria	39	2.5	35	2.7
Thailand (E:1996)	40	2.3	40	2.1
Other Countries	–	19.8	–	19.2
World Total	–	751.7	–	756.2

(This table lists all countries producing more than two million metric tons of crude steel in either year shown)

Source : IISI

Table-2 : CRUDE STEEL PRODUCTION BY PROCESS - 1996

Country	Prodn. Million M. Tons	Oxygen %	Electric %	Open Hearth %	Other %	Total %
Austria	4.4	90.9	9.1	0.0	0.0	100.0
Belgium	10.8	85.2	14.8	0.0	0.0	100.0
Finland	3.3	77.4	22.6	0.0	0.0	100.0
France	17.6	62.0	38.0	0.0	0.0	100.0
FR Germany	39.8	74.0	26.0	0.0	0.0	100.0
Italy	24.3	43.0	57.0	0.0	0.0	100.0
Luxembourg	2.5	46.7	53.3	0.0	0.0	100.0
Netherlands	6.3	97.5	2.5	0.0	0.0	100.0
Spain	12.2	34.6	65.4	0.0	0.0	100.0
Sweden	4.9	65.2	34.8	0.0	0.0	100.0
United Kingdom	18.0	76.5	23.5	0.0	0.0	100.0
Other EU	2.8	16.1	83.9	0.0	0.0	100.0
European Union(15)	**147.0**	**65.0**	**35.0**	**0.0**	**0.0**	**100.0**
Czech Republic	6.5	87.4	11.7	0.9	0.0	100.0
Hungary	1.9	95.1	4.9	0.0	0.0	100.0
Poland (E: 1996)	10.4	64.8	24.5	10.7	0.0	100.0
Romania	6.1	63.3	21.3	15.4	0.0	100.0
Slovak Rebublic	3.6	94.1	5.9	0.0	0.0	100.0
Turkey	13.4	32.3	62.3	5.4	0.0	100.0
Others	4.7	47.3	52.7	0.0	0.0	100.0
Other Europe	**46.6**	**60.1**	**33.8**	**6.1**	**0.0**	**100.0**
Russia	49.2	51.6	12.5	35.9	0.0	100.0
Ukraine (E: 1996)	23.3	44.0	5.7	50.4	0.0	100.0
Other former USSR	4.6	55.3	22.7	22.0	0.0	100.0
Former USSR	**77.1**	**49.5**	**11.0**	**39.4**	**0.0**	**100.0**
Canada	14.7	62.4	37.6	0.0	0.0	100.0
Mexico	13.2	35.9	64.1	0.0	0.0	100.0
United States	94.7	57.9	42.1	0.0	0.0	100.0
NAFTA	**122.6**	**56.1**	**43.9**	**0.0**	**0.0**	**100.0**
Argentina (E: 1996)	4.1	42.6	57.4	0.0	0.0	100.0
Brazil	25.2	79.6	18.9	0.0	1.5	100.0
Chile	1.2	93.6	6.4	0.0	0.0	100.0
Venezuela	3.7	0.0	100.0	0.0	0.0	100.0
Others	2.3	26.8	73.2	0.0	0.0	100.0
Central and South America	**36.6**	**64.4**	**34.5**	**0.0**	**1.1**	**100.0**
Egypt (E: 1996)	2.6	41.5	55.6	2.9	0.0	100.0
South Africa	8.0	63.6	35.3	0.0	1.1	100.0
Other Africa	1.9	49.9	50.1	0.0	0.0	100.0
Africa	**12.5**	**56.9**	**41.8**	**0.6**	**0.7**	**100.0**
Iran	5.4	31.9	68.1	0.0	0.0	100.0
Saudi Arabia	2.7	0.0	100.0	0.0	0.0	100.0
Other Middle East	0.8	0.0	100.0	0.0	0.0	100.0
Middle East	**8.9**	**19.4**	**80.6**	**0.0**	**0.0**	**100.0**
PR China	100.0	70.4	16.8	12.5	0.3	100.0
India	21.8	54.4	25.9	19.7	0.0	100.0
Japan	98.8	66.7	33.3	0.0	0.0	100.0
Republic of Korea	38.9	60.5	39.5	0.0	0.0	100.0
Taiwan (RoC)	12.3	53.3	46.7	0.0	0.0	100.0
Other Asia	17.2	8.7	80.3	11.0	0.0	100.0
Asia	**289.0**	**62.2**	**31.2**	**6.5**	**0.1**	**100.0**
Australia	8.4	87.9	12.1	0.0	0.0	100.0
New Zealand	0.8	66.7	33.3	0.0	0.0	100.0
World	**749.4**	**60.1**	**32.8**	**6.9**	**0.1**	**100.0**

E-estimate ***Source : IISI***

Table-3 : Continuously Cast Steel Output

Country	% Crude Steel Output		
	1994	1995	1996
Austria	96.0	96.3	96.8
Belgium	94.5	97.2	97.8
Finland	99.4	99.2	99.4
France	94.7	94.2	94.6
FR Germany	95.6	95.4	95.8
Italy	96.6	96.4	96.6
Luxembourg	29.5	46.2	52.8
Netherlands	96.4	95.9	97.5
Spain	95.6	95.5	95.8
Sweden	87.5	86.3	88.2
United Kingdom	87.2	86.6	88.4
Other EU	99.0	98.9	98.9
European Union(15)	**93.2**	**93.7**	**94.3**
Czech Republic	22.6	32.5	47.2
Hungary	90.5	91.2	95.6
Poland(E: 1996)	11.8	21.3	21.3
Romania	47.1	47.9	49.3
Slovak Rebublic	66.1	88.5	101.4
Turkey	90.5	92.3	93.0
Others	55.7	52.7	57.3
Other Europe	**50.9**	**56.5**	**61.9**
Russia	31.7	37.1	40.8
Ukraine (E: 1996)	8.1	11.6	12.4
Other former USSR	38.1	37.3	39.7
Former USSR	**24.9**	**29.9**	**32.2**
Canada	96.0	96.4	97.0
United States	89.5	91.1	93.2
NAFTA	**89.0**	**90.3**	**91.9**
Argentina (E: 1996)	94.5	95.9	96.0
Brazil	59.2	63.4	71.6
Mexico (E:1996)	74.9	76.9	76.8
Venezuela (E: 1996)	94.0	93.5	93.4
Other Latin America	67.9	69.7	68.3
Central and South America	**66.7**	**70.3**	**76.2**
Egypt (E: 1996)	88.0	93.1	94.0
South Africa	90.7	92.4	94.4
Other Africa	84.6	91.9	92.8
Africa	**89.4**	**92.5**	**94.2**
Iran	100.0	100.0	100.0
Saudi Arabia	100.0	100.0	100.0
Other Middle East	92.0	87.9	100.0
Middle East	**99.2**	**98.7**	**100.0**
PR China	39.5	46.5	51.2
India (E: 1996)	21.7	33.8	33.8
Japan	95.8	95.8	96.4
Republic of Korea	97.8	98.2	98.3
Taiwan (RoC)	99.1	100.2	99.8
Other Asia	98.1	97.0	96.9
Asia	**71.0**	**74.7**	**76.0**
Australia (E: 1996)	99.4	99.3	99.3
New Zealand	100.0	100.0	100.0
World	**73.0**	**75.9**	**77.6**

E-estimate77.6 ***Source : IISI***

Table-4 : Major importers and exporters of steel 1995

(Million metric tons)

Rank	Total Exports		Rank	Total imports	
1	Russia	27.4	1	United States	22.3
2	Japan	22.1	2	FR Germany	19.1
3	FR Germany	20.3	3	FR China	14.6
4	Belgium- Luxembourg	14.2	4	Taiwan(RoC)	13.6
5	France	12.8	5	Italy	13.1
6	FR China	10.5	6	France	11.9
7	Italy	10.2	7	Republic of Korea	10.8
8	Republic of Korea	9.8	8	Thailand	9.7
9	Brazil	9.7	9	Japan	7.0
10	United Kingdom	8.8	10	United Kingdom	6.7
11	Ukraine	7.3	11	Belgium-Luxembourg	6.3
12	United States	6.5	12	Malaysia	6.2
13	Netherlands	6.3	13	Netherlands	5.7
14	Mexico	6.3	14	Spain	5.3
15	Turkey	6.2	15	Canada	5.3
16	Spain	4.9	16	Hong Kong	5.2
17	Canada	4.7	17	Singapore	4.4
18	Czech Republic	3.7	18	Russia	4.0
19	Poland	3.5	19	Indonesia	3.7
20	Slovak Republic	3.5	20	Philippines	3.7

Source: IISI

Table-5 : Export of Iron & Steel from India

('000 tonnes)

Product	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97 (Prov.)	1997-98 (Plan)
Pig Iron	–	16	620	466	503	471	500
DRI/Sponge Iron	–	200	700	660	850	373	350
Semis	5	154	585	399	391	300	392
Non-Flat	202	528	632	487	729	774	900
Flat	166	213	388	386	546	848	1675
Total Steel (Carbon)	373	895	1605	1272	1666	1922	2967

Source: JPC

Table-6 : Indian Steel Export to Major Consuming Countries 1996-97

(in thousand tonnes)

Country	Semis	Plates	Structural/ Wire Rods/Bars	Sheets/ Coils
Indonesia	43.0	–	94.2	48.1
Italy	–	13.8	–	33.7
Bangladesh	10.4	–	–	6.1
Japan	–	110.9	33.9	29.6
Malaysia	25.0	4.0	16.5	63.4
U.S.A	–	108.6	–	12.5
United Kingdom	–	37.5	–	15.2
China	–	–	236.7	1.9
Nepal	74.6	–	28.0	13.3
Taiwan	76.45	–	53.9	–

Source: JPC

Table-7 : Export of Iron steel from Indian Steel Plants 1996-97

Plant	Pig iron	Steel Items
BSP	–	443
DSP		10
RSP	–	–
BSL	–	9.2
TISCO		400.4
RINL	406	482

Table-8 : Production Performance of the Indian Iron and Steel Industry 1996-97

(In Million tonnes)

Item	Main producers	Secondary producers	Total
Crude Steel	16.36	7.33	23.69
Semis	3.582	4.39	7.972
Non Flats	4.414	7.1	11.54
Flats	6.122	5.084	11.206
Pig Iron	1.733	1.547	3.28
DRI	3.668	1.352	5.02

Table-9 : Technoeconomic Indices for the Integrated Steel plants in India. 1996-97

SlIndex	Unit	BSP	DSP	RSP	BSL	TISCO	RINL
1. Use of agglomerates in Blast furnace Burden	%	52	57	52	74	62	82
2. Av. Blast Furnace productivity	T/m3/day	1.29 1.47*	0.96 1.03*	0.8 0.92*	1.25 1.43*	1.49*	1.59*
3. Skip Coke rate	Kg/THM	596	679	699	598	483	525
4. BF Auxiliary fuel injection rate	Kg/THM	#	–	–	#	64	–
4 CC ratio	%	43	31	**	**	56	100
5 Crude to saleable yield	%	85.6	86.3	84.9	79.7	90.75	91.27
6 Specific Energy Consumption	GCal/TCS	7.5	8.93	10.38	8.56	8.717	7.834
7 Labour Productivity	Tonne/ man/year	126	65	53	109	119	181

* Productivity based on working volume.

\# BSP and BSL will have Cold Dust Injection in one Blast Furnace each from 1998 onwards.

** Continuous casting has started in RSP from 1997-98 onwards and the current ratio is 70-80%.

Table-10 : Break-up of Cost of Production of Saleable Steel - 1996

[US$/T]

Components	Japan	Germany	USA	UK	India [SAIL]
Iron ore	57	79	61	70	20
Other Material	179	163	165	162	86
Total Material Cost	**236**	**242**	**226**	**232**	**106**
Energy	88	93	98	76	136
Labour	148	179	153	104	55
Operating Cost	**472**	**514**	**477**	**412**	**297**
Depreciation	63	39	27	26	20
Interest	**22**	**11**	**9**	**5**	**29**
Total Cost	**557**	**564**	**513**	**443**	**346**

Source : World Steel Dynamics and SAIL
SAIL figure pertains to FY97
US $ = INR 35.5

Abreviations :

BSP	–	Bhilai Steel Plant
DSP	–	Durgapur Steel Plant
RSP	–	Rourkela Steel Plant
BSL	–	Bokaro Steel Plant
IISCO	–	Indian Iron & Steel Co.Ltd.
VISL	–	Visvesvaraya Iron & Steel Ltd.
RINL	–	Rashtriya Ispat Nigam Ltd.
NINL	–	Neelachal Ispat Nigam Ltd.
LRF	–	Ladle Refining Furnace
EDD	–	Extra Deep Drawing
VAD	–	Vaccum Arc Degassing
AOD	–	Argon Oxygen Decarbonisation
VOD	–	Vaccum Oxygen Degassing

Engineering for Sustainability — Preparing for the Next Millennium

Lt Gen J S Ahluwalia, *PVSM*

Vice President, Institute of Directors, New Delhi

"Nature has enough for everyone's needs but not for anyone's greed".

— Mahatma Gandhi

I am grateful to the prestigious Institution of Engineers (India) for giving me this opportunity to deliver the Sir Rajendra Nath Mookerjee Memorial Lecture today to such a galaxy of engineers from all over the country. Sir R. N. Mookerjee was the first President of the Institution of Engineers (India) during the session 1920-21. He was the president of the Science Congress in 1921 and was knighted after his successful construction of the beautiful Victoria Memorial building at Calcutta.

GLOBAL ENVIRONMENT SIGNIFICANCE

When humanity harnessed the power of fire, a momentous dichotomy came to light: man as engineer, environment as enemy. As the millennia passed our manipulation of the 'material world' intensified with grandiose technological strides forward. But what happens when this malleable 'material world' begins to fight back acid rain, rising sea levels, desertification, and dramatic climatic change?

Today six years beyond the Rio Earth Summit, humankind's greatest Challenge is to provide an equitable standard of living for everyone in this and future generations: adequate food, clean water and energy, safe shelter, a healthy environment, education and satisfying work for all. Today, the major global environmental threats are climate change, biodiversity loss, stratospheric ozone depletion, desertification and land degradation, degradation of fresh and marine waters, and the destruction of forests. The more than 150 countries that gathered at Rio six years ago considered these threats significant enough to negotiate global Conventions for four of them — climate, ozone, biodiversity and desertification.

In spite of countries' commitment to clean up the environment, it continues to degrade because of the increased demand for water, biological resources and energy services as a result of economic and population growth; the failure of markets and government in national income accounting to recognize the true value of natural resources and the cost of environmental degradation; the failure to appropriate the regional and global values of natural resources to the local levels; the failure to internalize environmental externalities into market prices; the failure of government to regulate the use of water, biological resources and energy; and lastly, the failure to consider the long-term consequences of economic development activities.

Much remains to be done; only by fully integrating economic and environmental concerns into- the development process at the local, national and regional levels will the vision of environmentally and socially sustainable development at the global level be realized.

India is gradually changing from a predominantly rural society to one with substantial urban population. Indian cities are going through a process of metamorphosis since independence. Urbanization, thus, leads to rise in income, change in lifestyle and superior quality of services, and amenities for increased population. However, if it takes place in an uncontrolled and unplanned manner, it can also have severe negative effects on the inhabitants of urban areas and their environment.

The change in the way of life of the people has resulted in an increase in the pollution levels inmajor Indian cities in terms of air, water, soil and noise pollution. Water pollution has been caused by traditional organic waste, industrial waste, excessive use of fertilizers and pesticides for crop protection and silt from degraded catchments. It is estimated that more than 70% of the waste are generated from the municipal sources. Industrial waste, though small in volume contributes for larger amount of pollutants which in several cases are highly toxic. The gap between demand and supply of infrastructure services has been continuously widening.

Urban environment problems include high level of water pollution on account of poor waste disposal, inadequate drainage and improper disposal of industrial effluents. High levels of air pollution resulting from congested streets, poorly maintained vehicles and fuel burning and untreated emissions from industrial activities add to the deteriorating quality of air in these areas. The levels of suspended particulate matter are higher than the prescribed standards. In addition, the high levels of noise pollution due to loudspeakers, traffic congestion and industrial operations add to the annoyance of city dwellers. Worse of all is the congested unhygienic condition of the squatter settlements which creates innumerable problems for the urbanities. The only way to achieve sustainable development is to internalize environmental concerns in the development process right from the inception of various projects.

GLOBAL CLIMATE CHANGE

The burning of fossil fuels (coal, oil and natural gas) and cleaning and burning of natural forest are the source of increasing CO_2 level in atmosphere which may change the Earth's climate. It was 315 ppm in 1985 and become 356 ppm in 1992. CO_2 in the atmosphere allows solar radiation to pass through but does not allow heat to radiate back into space. Instead, the heat is radiated back to earth surface. As CO_2 accumulates in the Earth's atmosphere, enough heat may be trapped to gradually warm the Earth.

Environmental scientist have stated that if trends are not changed the earth's mean temperature could rise by 1.5° to 45°C by the middle of next century, making the atmosphere warmer than it has been at any time in the last 100,000 years. This might produce major shifts in patterns of rainfall and might initiate melting of the west Antarctic ice sheet. This melting would cause ocean levels to rise by 50 cm, which is alarming as it might put many of the Earth's major cities at least partly under water.

The UN Climate Convention, which has been ratified by the governments of 174 countries around the world, has as one of its principles that precautionary measures should be taken to anticipate, prevent or minimize the cause of climate change and mitigate it's adverse effects. Apart from Kyoto Declaration very little real action has taken place in terms of policies and measures for the mitigation of, or adaptation to, global climate change. Policy makers seem unwilling to lead where they fear others will be reluctant to follow. Voluntary and other cooperative initiatives by industry can result in the reduction of CO_2 emissions at relatively low cost and achieve the benefits of flexibility. In particular, the energy industry can take the lead in developing and applying appropriate technologies.

WATER

Water dominates all environment discussions, not surprisingly, since without water there would be no life. The two themes that emerge are the need to provide adequate supplies without exhausting the sources and the need to make more efficient use of what we already have. The demand for water doubles every 21 years. Seventy per cent of all water used went into irrigation, though less than half of this actually reached the crop. While this had led to a 50% increase in production, it had also resulted in salinity and the loss of good agricultural land. Industry used 20% of water, but often polluted supplies for others, thus reducing the quantity of useable water available. Only 10% of fresh water used went to individuals for drinking, washing, hygiene and so on. Too often abstraction left insufficient flow in rivers, and without a minimum amount of water within the ecosystem the environment downstream would be seriously damaged. This meant that there would have to be cooperative action when river basins are shared between different countries or different authorities within the same country. There would have to be adequate storage to take advantage of heavy rainfall and floods when they occurred, better planned groundwater use and better means of disposing off industrial waste without contaminating water flows.

Better techniques for drainage and irrigation management in saline groundwater areas are needed, and water conservation is essential. Techniques should be simple, appropriate and affordable, and should utilize local knowledge and technologies. Action should be community based, and good planning would address local issues in a local context. Education in the use of water for health and hygiene is an essential complement to the provision of good water and sanitation, and it is also essential to involve women, traditionally the providers of water and the protectors of family health.

Finally, all concerned should encourage community participation in the planning and development of water resources, otherwise new facilities would break down or be abused and finally abandoned. In many of the developing parts of the world a training element is needed to change attitudes and provide knowledge and skills, particularly in arid and semi-arid lands, where the environment is fragile and could easily break down entirely.

AIR

There are three major environmental impacts of concern, arising from airborne emissions: first, extensive indoor and urban air pollution; second, sulphur and nitrogen emissions and their potential contribution to regional acidification; and third greenhouse gas emissions, in particular CO_2 and their potential contribution to global warming.

Due to cooking on open wood fireplaces, indoor air pollution in poor rural areas is more than 20 times higher than in industrialised countries. Local environmental problems should thus have first priority for us. The most effective solutions will be those that are most comprehensive, relying on a mix of efficiency improvements, cleaner fuels, and "end-of -pipe" control technologies. Both efficiency improvements and the shift to cleaner fuels will yield triple dividends: lower resource use, lower overall energy system costs, and lower emissions.

ENERGY

It is well known that energy is a basic component of economy. Until recently energy consumption was directly linked with economic growth. Integrating environmental concerns into development indicators is essential. More countries are seeking to incorporate environmental and social concerns into their national accounts. Government regulation is not the only solution to pollution. There is now an expanding tool-kit of innovative and flexible incentives which can be used to get polluters to clean up their act. While there is no substitute for meaningful regulatory frameworks and information about the environment, these new tools. which rely on persuasions, social pressure and market forces to help push for improved environmental performance, can often succeed where regulations cannot. Local communities and market forces can significantly influence polluting industries to comply with environmental regulations. Renewable sources of energy have been appropriately demonstrated for their cost-effective environment-friendly application. One concept is of solar roofs. A national programme may be launched for building 1.5 million solar roofs. Other renewable energy sources may also be appropriately utilized.

DISASTER MANAGEMENT

Disaster mitigation measures are important for ensuring sustainable development in long-term planning perspective. National policy on disaster management, focusing on preventive and post disaster management need to be developed and implemented.

WASTE

Not surprisingly, the main threat to human health comes from human waste disposal. Two billion people lack adequate sewage disposal facilities. Half the population of poor countries live in cities. With a rapid change in the life style of population there has been tremendous increase in the domestic as well as industrial waste. Though a major part of the waste generated are of non-hazardous type, substantial quantities of hazardous waste has also been generated. In spite of several efforts, only a small proportion of solid waste are being properly utilized or disposed off.

The golden rules on waste management generally are to avoid creation of waste; to reuse unavoidable waste where possible; to recover wastes for reprocessing where this was economically viable and did not need the excessive use of energy; to use it for fuel where re-processing was not environmentally sensible, thereby recovering the latent energy; otherwise, if none of these. were possible, to dispose off the waste in an environmentally sound fashion. Waste to energy plants for urban areas were often the most economic way of dealing with the vast quantities of waste produced by affluent societies, but they needed to be strictly controlled and might well not be suitable for developing countries which produced much less domestic waste anyway.

POPULATION GROWTH·

The global environmental decline was recognized nearly thirty years ago at the UN Conference on Environment in Stockholm. If we consider forecast for the next thirty years, concerns increase rather than reduce. In this period, population is forecast to rise fifty percent, and two thirds will be in cities, water demand will be up six times, and food output will need to rise by 60 to 70 per cent. If we look for reasons for this "fudged" response by political leadership, we can find several possible reasons. Five years on , it is apparent that, despite these public affirmations and commitments, the basic structures for implementing sustainability are not well understood and have not been put in place.

The United Nations Conference on Population and Development, held in Cairo in September 1994, as a follow up to the Earth submit held in June 1992, properly emphasized the need of worldwide attention to family planning as a pre-requisite to any meaningful approach to global stability which is a must. In this conference, it was documented that 300 million women in the world do not have access to modern contraceptives. It will be a great achievement if we can make the modern contraceptives available to them, it may be possible to level off population at 8.5 billion. Pessimism is worthless as our attitude or a strategy. Rather, knowledge must be used to provide the key to effective action in a future that may only dimly resemble to familiar past. Hence, we should take the kind of meaningful actions on which our common future so clearly depends. It took thousand of years for the human population to reach

1 billion, 130 years to reach 2 billions and 12year to reach 5 billions. More than 2,76,000 people are added to world's population each day, i.e. 192 every minute. At this rate there will be 6.2 billions by 2000 AD.

GLOBAL IMPERATIVES

Trans-boundary pollution, once considered only a problem in the industrialized world, are increasingly apparent in many developing regions. In many poorer regions of the world, persistent poverty contributes to accelerating degradation of productive natural resources, and desertification has spread. Inadequate and unsafe water supplies are affecting an increasing number of people worldwide, aggravating problems of ill health and food insecurity among the poor. Natural areas and fragile ecosystems are still deteriorating in all regions of the world-with attendant reductions in biological diversity. At the global level, renewable resources, notably fresh water, forests, topsoil and marine fish stocks, continue to be used at rates beyond their natural rates of regeneration, a situation which is clearly unsustainable.

So far, the progress on the global level has been disappointing. The atmospheric concentrations of greenhouse gases have continued to increase (about 1% per year), natural habitats continue to be lost (wetlands and forests are still being lost at about 0.5 to 1% per year), and soil and water continue to be degraded. Except for the phase-out of ozone depleting substances which destroy the earth's protective ozone shield, at the global level we are not achieving our objectives.

The conditions of our global ecosystems need to be viewed in the context of every country's national and sub-national agendas. They reflect the aggregation of local practices and national policies, and manifest themselves locally, nationally, and regionally. The bulk of the work required to respond to these global problems, reflected in the global treaties, must happen at the sub-regional, country, and local levels. Until this happens, the global environment will continue to degrade, and local communities will feel the impact. Unfortunately, in most cases developing countries are more vulnerable to these global environmental issues than developed countries.

AGENDA 21

Five years after the UNCED, the Special UN General Assembly acknowledged that progress has been inadequate. Those who hoped for the clear targets, commitments, and specific initiatives that the reporting would have justified, were disappointed. Instead, the General Assembly, adopted a "programme for the further implementation of Agenda 21", containing organization and policy decisions to promote progress. These included:

• Reaffirmation of political commitments to SD, and the role of the UN.

• Clarification of the roles of UN organs and institutions.

• Reconfirmation of the CSD as the central policy forum for action on SD.

• Reaffirmation that Overseas Development Aid is essential for SD.

• Initiation of intergovernmental processes on freshwater and energy.

• Promoting a better understanding of the importance of and commitment to tourism, transport, changing consumption patterns and eco-efficiency.

• Promotion of practical agreements in specific areas, like worldwide phase-out of lead in gasoline.

• Recognising the importance of learning from practical country level experience in implementing the concept of sustainable development.

ENVIRONMENTAL REVOLUTION

Building an environmentally sustainable future depends on restructuring global economy, major shifts in human reproductive behaviour, dramatic changes in values and life styles. The addition of these changes will lead to a revolution. This will be known as "Environmental Revolution". It will certainly bring great economic and social transformation in human history.

These changes totally cannot be achieved by individual actions. Some of the conditions of environmental stability can be achieved by individual effort but the major part of environmental revolution can be expected on formation of national or international policies to be framed by Government. Phasing out chlorofluorocarbons, replacing fossil fuels with solar energy, protecting biodiversity need national Government policy decisions. Without this, it is not possible to change environmentally destructive business practices.

Environmental protection is primarily a process, not an investment. It calls for planning and coordinating, regulatory and enforcement activities, public education and awareness, and bringing environmental concerns into all government ministries. Some investments may be needed, often to mitigate past mistakes, but the fundamental thrust of environmental management is to create effective policies, regulations and procedures.

South Asian countries are working to meet this challenge through more clearly defined and understood priorities for action, leading to more targeted action with more measurable results. Last year, the World Bank supported a year-long priority-setting activities in Bangladesh, leading to a Priority Framework for Implementing the National Environmental Management Action Plan.

More efficient policies. not only for the environmental authorities themselves, but for industry, agriculture, transport, and other agencies have an impact on the environment. In India, macroeconomic analysis is being used to show the economy-wide impacts of environmental degradation 4-8% of GDP a year, and to quantify the enormous economic benefits of policies that could prevent degradation in the first place. Through improved implementation of policies and regulations, by incentives, information: and increasingly focusing on institutional strengthening, environmental concerns can be addressed effectively.

The World Bank Group is supporting a number of initiatives to bring together industries, local regulators and community groups to discuss local priorities and improve their environmental performance. The first is to more proactively prevent pollution, rather than focusing on treatment and clean-up. There will always be a need for regulation, quality standards and clearly defined limits on certain discharges, but this proactive approach shifts the emphasis to improvements in process and management to reduce the volumes of pollution generated

The second approach is to establish a careful balance between central standards and locally negotiated environmental requirements. Uniform national standards have the advantage of being clear and equitable. On the other hand, local regulatory bodies can set more efficient plant — specific requirements based on real costs and specific local environmental conditions.

South Asian countries understand better than ever before the close linkages between economic growth, poverty alleviation, and environmental degradation, The sentiment that "the environment can wait" is less prevalent now than it was during the 1980s, a decade of lower growth. This increasing awareness, found across governments, communities, academia, and the private sector, is the basis for acriievinq greater improvements in environmental management during the last five years.

To build upon this opportunity, overall approach in the region is to support two levels of action. The first is to support the awareness raising, public participation and policy analysis required at the national level to agree on policies. The next step is to support on-the ground activities that show that concrete environmental successes are within reach. The challenge remains to move forward on both fronts, national and local, top-down and bottom-up, and to keep up momentum that has been slowly building since the Rio Summit.

SUSTAINABILITY: AN ENGINEER'S VIEWPOINT

World Commission on Environment and Development (1987) defined Sustainable Development (SO) as :

"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" and that "SO is a process of change in which the exploitation of resources, the orientation of technological development, and institutional change are made consistent with future as well as present needs."

Sustainable technology is the finding of practical solutions to help achieve the goals of economic growth that are in harmony with the environment and related to' improvements in quality of life. These include:

• Maximizing natural economies, effectiveness and efficiency:

- development as a compatible part of the Earth's systems;
- emulating nature in the production and use of resources; and
- removing barriers to human goodwill, cooperation and capacity enhancement.

• attaining necessary balance:

- resource accessibility;
- requirements of communities; and
- capacity of communities to meet their requirements.

• Implementing guidance principles to meet the effectiveness, efficiency and balance requirements of communities:

• Renewable energy utilization:

- solar energy;
- wind energy;
- geothermal energy;
- bio-mass energy.

• Pollution prevention:

- chemical selectivity (minimize by -products);
- CFC replacement; and
- chemical reformulation.

INTEGRATED APPROACH

The concept of environmental sustainability and the imperative for maintaining biological diversity have arisen following the realisation that the earth's resources are indeed finite and that the rapidly growing human population is increasingly competing for what little remains.

There are technical challenges in developing appropriate and sustainable infrastructure, there are many more social, economic and political problems. Engineers are realizing the need to broaden their perspective beyond the simply technical. If engineers are to maintain the principal role in social infrastructure development, it must be through leading and guiding an integrated team addressing the whole range of issues that are fundamental to successful provision, operation and maintenance of the infrastructure.

It is clear that infrastructure development cannot be treated as a purely technical challenge. Although the technology must be right, sustainable infrastructure development is just as much a political, economic and social issue as technical. Engineers must be knowledgeable, understanding and sympathetic to the needs of the other disciplines with which they work and the communities that they are trying to help. Engineering profession can continue to be leaders in the multi-disciplinary field which is attempting to address the greatest inequality in the world: the quality of life.

Clearly, sustainable development remains the most important challenge facing humanity as it approaches the twenty-first century. The critical issue is whether we can continue to provide food, shelter and the other needs of a growing world population without destroying the natural resource base on which the existence of that population depends. Many polluting emissions, notably toxic substances, greenhouse gases and waste volumes, continue to rise in industrialized countries, and their wasteful. production and consumption patterns remain fundamentally unchanged.

ROLE OF ENGINEERS FOR SUSTAINABLE DEVELOPMENT

The World Federation of Engineering Organisation's (WFEO) submission to the Earth Summit in 1992 stated that:

"Engineers have the potential and the duty to be a major influence in the achievement of the primary goals of the future: a sustainable habitat for all life, and one that continues to allow mankind to achieve his potential and to enjoy the process of living."

"That Council acknowledge the leadership role the engineering profession must play in attainment of sustainable development and that Council develop special plans to achieve this leadership role and report regularly to the members."

"To advance the profession of engineering by providing leadership in the sustainable use of earth's resources".

The EC/UK nine-point Code of Professional Practice on Environmental Issues states that engineers should:

• work to enhance the quality of the environment;

• maintain a balanced, disciplined and comprehensive approach;

• make systematic reviews on environmental issues;

• balance economic, environmentai, and social benefits;

• encourage management to follow positive environmental policies;

• act in accordance with the codes of conduct;

• know about and comply with the law;

• keep up to date by seeking education and training; and

• encourage understanding of environmental issues.

Sustainability is the way of the future. Our vision should be that by the year 2010, all engineers should adopt and implement the concepts of sustainability as a normal part of their professional activities. To achieve this vision, a paradigm shift is required on the part of engineers. It is essential to achieve a shift from unsustainable development to sustainable use of the Earth's resources, which will require the linking of development with protection of the environment. The basis for this paradigm shift must be an "attitudinal and behavioural change" by engineers. Change must occur at all levels within the profession, that is, in professional organisations, practicing engineers, educators and students. Attitudinal change must be the focus of current activities, for without it the move toward sustainability will not occur.

The vision will not be achieved without considerable effort from professional orqanisations, education institutions, companies and individuals. The problem is too complex to expect individuals to be able to embrace sustainability and implement the concepts within their own work environment. Professional organisations need to provide a leadership role for the profession in achieving the above vision and moving towards sustainability.

For engineers to take for granted the integration of environmental concems and sustainability into engineering practice by the year 2010, a major continuing education programme will be necessary for practising engineers who have not been exposed to these issues and concepts in formal engineering degrees. This is an important group, as many are making significant decisions about projects that affect the environment.

It is the responsibility of all engineers to understand and accept the need for sustainability and, hence, the practice of engineering that leads to sustainability. It is unacceptable to say that sustainability is too general a concept that cannot be translated into specific actions. Although there are technical challenges in developing appropriate and sustainable infrastructure, there are many more social, economic and political problems. Engineers are realising the need to broaden their perspective beyond the simply technical. If engineers are to maintain the principal role in social infrastructure development it must be through leading and guiding an integrated team addressing the whole range of issues that are fundamental to successful provision, operation and maintenance of that infrastructure.

Professional engineering organizations also need to provide input into environmental education. This may be through guidelines for environmental engineering courses and the inclusion of environment content into single-discipline courses. All of this must be focussed to achieve attitudinal and behavioural change, after which the move toward sustainability will become easier.

Engineers must be knowledgeable, understanding and sympathetic to the needs of the other disciplines with which they work and the communities that they are trying to help. Failure to do so will result in governments and funding agencies handing this leading role to professionals of other disciplines.

It is my belief that, as a consequence of their basic qualities and practical aptitude, engineers are quite capable and potentially well qualified to retain their key role. A growing number of engineering companies, government departments and individual engineers are accepting the need to deal with infrastructural improvements in an integrated way. The engineering profession can continue to be leaders in the multi-disciplinary field which is attempting to address the greatest inequality in the world: the quality of life.

ENVIRONMENTAL ENGINEERING — A BASIC DISCIPLINE

There is growing imperative for engineers to be environmentally aware and of the need to respond to the demands of societies throughout the world for greater environmental sensitivity. Technology has to be environmentally appropriate. Clearly, more emphasis has to be put on the environmental education of engineers and engineering students. Complexity is a characteristic of management, of matters involving safety and risk, and of many other aspects of professional engineering. Yet virtually all the early-level training of the professional engineer deals with simpie physical models. For this, adding environmental courses to existing engineering curricula would not be enough.

All engineers, no matter what their primary discipline, need to be environmentally educated to the extent that they understand the issues involved in, say, sustainable management and cleaner production. Environmental involved engineers, on the other hand, would be those dealing with engineering matters that specifically and directly interacted with the natural and social environments.

As the environmental problems facing the world become increasingly grave, the world's communities, who are ultimately our "customers", need increasingly effective action for engineers to take positions of leadership. There is a lack of a direct interface between engineers and the majority of their "customers". That is, links with the community are indirect, through clients and employers. This results in:

• inadequate recognition of engineers by the community; and

• inadequate understanding of the needs of the community by the engineers.

Therefore:

• The interaction and communication between engineers and their "customers· needs to improve. The new engineer needs strong communication skills, an ability to deal with large, complex and ill-defined systems, and a clear and far-sighted world view, together with a well-developed ethical stance. Professional engineers have the opportunity and challenge to be leaders in creating a better world for the future.

• Additional skills and capabilities are required of engineers. Environmental awareness should be a prime subject of education and training at all levels, commencing at primary school and going on to Continuing Professional Development. The education and training for the student, graduate and professional engineer at any level must be designed to provide an appropriate and mature understanding of environmental matters and the relevance of the work that engineers do and the likely impact on the environment. In planning for sustainable development, engineers need to examine fully and systematically the aggregate long-term consequences of decisions, in terms of both time and space, and the alternatives which may lead to more environmentally sustainable choices."

• All engineers need to be environmentally educated. Engineering education must give the professional engineers of today and tomorrow broad-based skills in environmental and social sciences, economics, technology, communication, leadership and ethics. It must be a process of continuing professional development apd life-long learning.

• Specialist environmental engineering courses are required. A proportion of engineers must be generalists. The environment must be seen as holistic, recognizing the interdependence and interaction of people and the natural and physical environment. Engineering must recognize the obligations of the professional engineer to the global community in its widest sense, to the client employer and colleagues.

The practicing engineer must know the duties, requirements and intention of resource legislation as never before: Legislation and policy that guides environment and resource use worldwide continues to expand, strengthen and broaden its control. This is the umbrella under which technology is applied. At this present time, it is growing rapidly because countries are in the process of ratifying the climate change and bio-diversity conventions and shaping the policies that will reduce greenhouse gas emissions under the Climate Change Convention.

ENGINEERING OPPORTUNITIES DEVELOPMENT FOR SUSTAINABLE

Within the environmental sector in emerging markets, a large number of areas offer favourable business prospects for environmental engineers. The markets for reprocessing of domestic and industrial wastes offer considerable growth opportunities. This is also true of water markets, where an increasing number of projects are underway because of droughts, floods, and required treatment of waste and drinking water.

As government, business and industry adopt the concepts of sustainable development, engineers are developing new equipment and processes to meet the changing needs of their customers. Look at clean technology (processes, machinery and equipment which avoid waste and emissions); recycling (design for recycling, disassembly or separation techniques, using' recycled materials in new products); eco-integration (use of wastes or by-products from one process as feed stock for another process or industry); examples of new designs and retrofits to existing equipment; tools and techniques which are being used to assist designers or managers assess the environmental impact of alternatives and choose the most sustainable option.

Since the 1997 UN Special General Assembly, the Commission for Sustainable Development has published a number of issue summaries to inform on the agreements reached. A number of these have major implications for engineering. These include;

• An initiative in eco-efficiency — to consider setting a target (for industrialized countries) of achieving a tenfold improvement in production in the long term, with a possible fourfold increase in the next two or three decades.

• Fresh water to be given "highest priority". A dialogue beginning with the 1998 session of the Commission for Sustainable Development to consider a strategic approach to preserve and protect freshwater supplies.

• A compromise agreement to consider "legally binding, targets" for developed countries that will result in significant reductions in green house gas emissions within specified time frames, such as AD 2005, 2010 and 2020.

• Promote internalization of environmental costs in energy prices.

• "Evolving commitments" for the transfer of clean technologies to developing countries.

• Safe substitute for toxic chemicals should be developed.

• Increase in the efficient use of materials and energy.

Some of the industries producing environmentally non-friendly products have to change prospectively to produce eco-friendly items. Manufacturers of electrical appliances can concentrate on designing them to be more energy efficient. Auto makers are to change to electric or hydrogen powered models. Producers of incandescent light bulbs can easily shift to proper efficient compact fluorescence. Beverage producers can use refillable containers. Product like photovoHaic cells, thermally efficient building materials, wind electric generators, high speed rail cars, roof top solar water heater, solar light, solar cookers, water efficient plumbing appliances etc., are to be encouraged.

Manufacturing goods in terms of varieties and quantities is the present day index of advancement. Resource base is not necessarily an aid in putting the country in the higher value of civilization. If that was so then, Japan could not have competed with. the USA as Japan is one tenth of, USA in terms of size arid with a very negligible raw material resource base. Manufacturing leaves a major fraction of the raw materials as left-over residue. For every 100 t of paper produced 40 t of lime sludge is generated as residue. For making 100 t of steel the process produces 150 t of solid waste and so on.

Economic prosperity and quality of life for all depend to a great extent on the innovative capacity of our engineers. The short term focus of engineenng effort is required to cover:

a) An initiative in eco-efficiency leading to fourfold increase in the efficient use of materials and energy .

b) Development of a strategic approach to the prevention of fresh water supplies.

c) Devetopment and use of safer substitutes for toxic chemicals. Development and application of clean up technologies. Clean up contaminated sites.

d) A major effort in reducing green gas emissions.

ENVIRONMENT IMPACT ASSESSMENT (EIA)

The search for innovation and cost-effective ways to improve industries environmental performance has led to the development of a wide array of environmental tools.

Assessment of environmental impacts is an essential pre-requisite for ensuring sustainable development - the primary objective of which is to meet the needs of present generation without foreclosing the further options. Hence, it requires prudent use along with protection of ecological assets. Over the years, in addition to techno-economic evaluation, environmental impact assessment (EIA) has developed as a tool for investment decisions in regard to developmental projects. Even after a lengthy and expensive EIA process for individual projects, the queries as to whether the objectives of environmental protection and sustainable use of ecological assets are duly addressed, remain unresolved.

In parallel with the adoption by governments of emission standards for industrial facilities, environmental impact assessment (EIA) was one of the first specific environmental management tool. EIA was developed to predict the impacts of, new industrial plant or infrastructure project on the local environment. In many countries including India, EIA studies are now prescribed by law, with the aim of:

a) Encouraging better siting of industrial facilities;

b) Helping governments to prescribe emission standards in operating permits;

c) Stimulating industry to compare alternative technologies and to adopt pollution prevention and control measures.

The need of rigorous identification of project risk factors and the necessity of risk allocation and management are now part of overall corporate governance. EIA predicts and mitigates the environmental impacts of proposed development schemes to make informed decisions.

In January 1994, Government of India has made prior environmental clearance necessary in respect of 29 project categories. This is another important regulation brought out with the aim of integrating environmental concerns at planning level. A detailed environmental impact assessment study has to be carried out for submission to the MOEF. The demand of EIA expertise is growing significantly with this regulation. Moreover, trends indicates that financial institutions would also be taking into account Environmental Risk Assessment as a part of their total lending risk assessment procedure for future project financing.

EDUCATIONAL REFORMS

Reform of education is fundamental, but necessarily within a whole of profession strategy which brings a professional focus to bear on ecoefficiency, fresh water, reduction of greenhouse gases, energy efficiency, and truth in environmental costs. It is essential that engineers become advocates for sustainable development. This education question, the key to our future as a profession, has been a matter of rising concern, to employers as well as engineers, over several years. It seems to me that a major effort in new education at both the undergraduate, graduate, and professional development level needs to include:

• A platform of education about sustainable development and the environment.

• Integrated teaching of SD and environment in all engineering courses.

• A systems focus.

• Accreditation requirements that encourage faculties to build teaching capacity in these matters, and insist on basic SD and environment content.

• Eco-efficiency, environmental impact assessment, and life cycle anaiysis.

• The use of information technology.

ENVIRONMENT MANAGEMENT SYSTEM (EMS)

An important step in combining business and environmental issues came in 1987 with the report 'Our Common Future' being published by the independent commission on environment and development (Brundtland Commission). It introduced the term 'sustainable development' and urged industry to develop effective environmental management systems. The UN conference on Environment and development (UNCED) held in Rio de Janeiro in 1992 soon followed.

At about the same time the international chamber of commerce (ICC) developed it's business charter for sustainable development, which was launched in 1991. The charter contains 16 principles of sound environmental management. Along similar lines the chemical industry, concerned about its deteriorating public image, had earlier launchad its 'Responsible Care' program in 1984. 'Responsible care' is now a condition for membership of the Chemical Industry Association.

Traditionally environmental problems were addressed through the installation of pollution control equipment in plants and factories. However, such 'end-of -pipe' solutions do not provide long-term answers given the changing business and regulatory climate. An enterprise needs a system that will help to address" its legal, commercial and other challenges related to the environment. Persuasion can achieve much, and building a social consensus around achieving key environmental objectives provides a good foundation for making even more proqress. Far-reaching environmental improvements of existing processes, products and services or the design of entirely new product chains are needed, if we desire to increase the eco-efficiency substantially and thereby take a large step towards a sustainable society.

Environmental Management Systems (EMS) can fill these needs. They are intended to provide a systematic, comprehensive, but above all, flexible framework around which an organization can develop measurable action programmes to minimize or remove threats to the environment. Better environmental management will save raw materials, increase production efficiency, provide a greater return on investments, lower compliance costs, increase stakeholder confidence and lead to improved environmental performance.

EMS is concerned with the integration of environmental requirements into the existing organizational structures, practices, procedures and resources. EMS is required to strategically review the environmental issues affecting business; set objectives and targets to minimize those impacts; devise and implement an action program to achieve the set targets; measure performance in achieving those targets; and then periodically review the overall adequacy of the system.

In broad terms, ISO 14001 fills two requirements in an organization. The first is the internal need for a system that will help the organization address the legal, commercial and other challenges related to the environment that it faces. The second is the need to be able to assure those outside of the company that it is meeting its stated environmental policy.

ISO 14001 is an international standard outlining one such system as a common basis (the European EMAS is a similar standard and steps are underway to harmonize the two). Both ISO 14001 and EMAS also identify those steps, which can be audited and independently verified, providing a basis for certification.

Nationally Indian industry's response to environmental challenges have ranged from doing nothing - to crisis responses - to integration of environmental management into the overall management structure via a well-defined environment management system. Industry is now recognizing that sound environmental management can enhance the corporate image, increase profits and competitiveness, reduce costs and obviate the need for further legislative measures by authorities. The above factors have led to an enthusiastic response to Environment Management Systems (EMS) since first introduced in the country in the form of a draft standard in 1995.

It helps to sustain export market access especially in the light of the likelihood of it becoming a pre-requisite for doing business with the developed economies. It provides a platform for discussion with the regulators. It is an expression of due diligence as it is a signal to investors, lenders, regulators and other stake holders that the comoany is systematically managing its environmental risk and liability. It improves public image and community relations. It aiso improves access into financial markets through enhanced investor confidence and access to capital, and provision of access to preferential insurance rates. Achieving ISO 14001 implies institutionalizing pollution prevention practices and continual improvement in environmental performance in the organization – a relevant and important step towards sustainable development.

Environmental management systems suffer from image problems, They often are thought of as an expensive extra or of little practical business benefit. For example, the application of environmental management systems to design procedures, when coupled with life cycle costing, gives the client the opportunity to assess the best environmental option. The building operator gets financial benefits from systems that are designed to use minimal energy and raw materials.

ECONOMICS AND ENVIRONMENTAL CONCERNS

If economic development is to become truly sustainable, a great shift is required. It will require fundamentally new ways of accounting for the environment as an economic good and reflecting this in national accounts. Governments arid industries must recognize that there is no ultimate dichotomy between sustainable economic growth and environmental protection, and that the environment can no longer be viewed as a luxury. Government needs to stimulate environmentally sound market behaviour by creating an enabling policy environment and .an appropriate national and international regulatory framework. Citizens need to be empowered, partnership need to be created. Knowledge needs to be developed and shared, and financial resources need to be mobilized. Much remains to be done; only by fully integrating economics and environmental concerns into the development process at the local, national and regional levels will the vision of environmentally and socially sustainable development at the global level be realized.

The Challenge of creating and maintaining a sustainable environment is probably the single most pressing issue in the world to day. We all should have knowledge of how ecosystem. work, how matter and energy move through ecosystem and how population dynamic affects and is affected by ecosystem. We need to know the principles that are involved, and each of us must strive to understand the fundamental issues that are presented by environmental pollution so that we can make informed decisions about appropriate action to take. Our future way of life will be based. Ultimately, on our ability to deal with the earth intelligently.

It is interesting to note that everything is cyclic in nature. The well known bio-geochemical cycles like CO_2 - O_2 cycle, nitrogen cycle, phosphorous cycle, sulphur cycle are too well known. As a result, non-interfered by externalities all items in the cycle are renewable and hence do not get exhausted. The famous hydrologic cycle tells us of never exhaustible water resources. Whereas all our production systems are linear. Iron ore to steel, steel to pieces of furniture – a furniture does not go back to produce iron ore. Of course, production of steel from scraps satisfies the cyclic order to some extent. In the same ecosystem species do not compete for the same raw material.

Engineers need to question the process of manufacturing they are planning to adopt and reveal not only the line of production but also the residues - solid, liquid or gaseous in nature - and their scope for recycling recovering and final disposal. Any process of synthesis or manufacturing any product invented today must be subjected to three basic questions or scrutiny before it is cleared for synthesis or manufacturing. The synthesised or manufactured product must get disintegrated as soon as it comes in contact with nature. For the same reason, pesticides like DOT known as organochlorine compounds got replaced by groups of chemical called organophosphorus as the latter groups of the chemical could get easily disintegrated in contact with nature.

The process of synthesis of manufacturing should be so chosen as to maximise conversion of raw materials into products and thus minimising the residues. This question is relevant not only from the view point of environmental protection but also for the economics of the process. If residues of one industry can become the raw materials of another industry why not those two industries be sited together. This concept can be, named as Compatible Industrial Cluster.

The new ethos proposed for development is itself an approach to environmental protection. Environmental protection is to be recognized as a part of development, just as economic viability of a development project is always desired. Development without environmental degradation should therefore, mean internalization of environmental protection in the process of development. Engineers and scientists in each discipline need to recognize this fact and take up the challenge to work towards that goal.

CONCLUSIONS

Environmental Pollution is now a serious threat to very existence of lives on earth. Sir Winston Churchill said-"It will be a tragedy if the Sunrise of technology were to be the Sunset of mankind."

Sustainability is the way of the future. Our vision should be that by the year 2010, all engineers should adopt and implement the concepts of sustalnability as a normal part of their professional activities.

To achieve this vision, a paradigm shift is required on the part of engineers. It is essential to achieve a shift from unsustainable development to sustainable use ot the Earth's resources, which will require the linking of development with the protection of the environment. The basis of this paradigm shift must be an "attitudinal and behavioural change" by engineers. Change must occur at all levels within the profession, that is, in professional organizations, practicing engineers, educators and students. Attitudinal change must be the focus of current activities, for without it the move towards sustainability will not occur.

The vision will not be achieved without considerable effort from professional organizations, education institutions, companies and individuals. The problem is too complex to expect individuals to be able to embrace sustainability and implement the concepts within their own work environment. Professional organizations like the Institution of Engineers (India), need to provide a leadership role for the profession in achieving the above vision and moving towards sustainability.

Reform of education is fundamental, but necessarily within a whole of profession strategy which brings a professional focus to bear on ecoefficiency, fresh water, reduction of greenhouse gases, energy efficiency, and truth in environmental costs. It is essential that engineers become advocates of sustainable development, and responsible contributors to the formation of technological law and policy.

We have the vision. What we need is the resolve and effort to make it happen. Finally, we should allcheck whether the sun is on our face and if not, turn toward it.

Ocean — A Source of Energy

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Dignitaries on the dais, Ladies and Gentlemen, I have great pleasure in delivering today 'The 21st Sir R N Mookerjee Memorial Lecture', being organised by 'The Institution of Engineers (India)'. The theme, I would like to address in this lecture is 'Ocean — A Source of Energy'.

The ocean is our last frontier on earth with huge potential for deriving socio-economic benefit and for sustaining life in our planet Earth: In recognition of the importance of oceans, the year 1998 was celebrated as 'The International Year of the Oceans' world over. It created awareness among all sections of the society about the potential and uses of the ocean. The ocean occupies about 71% of the globe and it influences the weather and climate significantly. Ocean is a source of wealth. It provides fish for food; oil, gas, minerals and energy for the economic development; and promotes revenue earnings through tourism and shipping. It is a natural source for atmospheric gas regulation and an inexpensive dumping site for land based domestic and industrial waste. It plays a major role in national security. Skill and expertise in a wide range of fields is essential for exploration, the sustained and rational utilisation of the resources, and to improve our quality of life.

The direction of ocean technology in the next millennium should be based on the primary objective of improving the quality of life on our planet Earth. The world population is expected to double in size from 5 to 10 billion in the next 50 years or so. This steady increase in population leads to less land per person, more rapid consumption of food, energy and-natural resources, and a significant impact on our environment. The three most important and fundamental areas requiring all our attention are food, energy and environment. Of these let us consider the energy, particularly ocean energy, which is derived from the ocean and is a source of non-polluting inexhaustible energy.

ENERGY RESOURCES

First let us examine the present energy resources. At present, the main sources of energy are the combustion of hydrocarbons, followed by nuclear power , in addition to hydro and solar resources. Oil and gas reserves appear to be sufficient to supply power plants for about 40 more years, and coal reserves can extend into the 22nd Century. Nuclear-generated electrical power ranges from 17% in the US, to 35% in Japan, and to 65% in France. Today, fossil fuel and nuclear power comprise over 90% of the total power produced, with the balance of 10% mainly from hydropower and solar-derived energy.

There is a growing concern about the pollution damage by fossil fuel combustion, including, greenhouse gases causing global warming, acid rain, and air, land, and water pollution. Carbon dioxide emissions from fossil fuel combustion are the main contributors to greenhouse gases in the atmosphere. The environment's ability to assimilate CO_2 is being reduced because of deforestation and loss of vegetation, the natural assimilators of carbon dioxide. The Intergovernmental Panel on Climate Change concluded that the balance of evidence suggests that there is a discernible human influence on global climate.

There is also concern about the problems associated with nuclear power, such as contamination and health problems due to operational and waste storage leaks. The public is concerned about the risk of accidents such as Those at three Mile Island in the USA, Chernobyl in Russia, sunken Russian submarine reactors in the Kara Sea, and the controversies about the safe storage of nuclear waste. World-wide, nuclear waste clean-up is costing tens of billions of dollars.

Gas hydrates, methane bearing ice-like-material formed by ocean sediment over the millennia, is stable at low temperature and high pressure in deep water. Raising temperature or reducing pressure can release the gas and allow it to escape into the atmosphere. It represents an energy source that is much larger than the remaining known oil and gas supplies on earth. Research involves surveying and characterizing existing resources, assessing sea floor stability problems, developing cost effective means for extraction, and understanding the effects of increasing greenhouse gases. This huge potential energy source also has the environmental problem of contributing to global warming.

Solar energy is an inexhaustible, non-polluting source that has great potential as an alternate energy for the future. The oceans are the world's largest solar energy collector 'and storage system. On an average day, 60 million km^2 of tropical seas absorb an enormous amount of solar radiation. If less than 0.1 % of this stored solar energy could be converted into electric power, it could supply the.equivalent about ten times the current world consumption.

This incident solar energy is stored either directly, or indirectly, in various forms within the ocean system. Specifically, this solar power is stored directly in the form of thermal heat created by the temperature differences between surface and deep ocean waters; and indirectly as wind, waves, and currents. Among the ocean energy systems, ocean thermal energy conversion (OTEC), tidal and wave, are the more promising ones, which I wish to address in this Memorial lecture.

OCEAN THERMAL ENERGY CONVERSION

The basic concept of ocean thermal energy conversion (OTEC) is to extract energy from the temperature difference between surface and deep ocean waters. Solar energy has been absorbed and stored as heat in the upper layer of the ocean. Cooler water transported from the polar regions lies below. In tropic and subtropic regions the temperature difference between the surface layer and the water 1,000 meters deep is 20°C or more. Further north or south, the maximum temperature difference is less and it varies throughout the year. However, the availability of huge quantities of ocean thermal resource allows the possibility of very large OTEC base load plants. OTEC plant concepts range from shore mounted plants with ocean intake pipes, to fixed and moored offshore plants, to grazing plantships.

OTEC techniques are based on either the closed or open-cycle concept, with some interest in hybrid combinations, and special cycles such as the Uehara cycle. In the closed-cycle plant, warm surface water is used to evaporate an auxiliary working fluid such as ammonia or Freon. The vaporized working fluid drives a turbine which, in turn, drives an electrical generator. Cold water from a depth of about 1000 m is used to condense the vapour after it has passed through the turbine. The working fluid returns to the evaporator to be recycled.

The open-cycle system, first demonstrated by George Claude in Cuba in 1930, used warm sea water as the working fluid. The pressure above the warm water is lowered sufficiently and the water is flash evaporated. This vapour is used to drive the turbine and cold, deep water is used to condense the water vapour exhausting from the turbine.

International OTEC Projects

A complete OTEC system was constructed, deployed and operated successfully at the sea off shore of Hawaii in the US I Mini-OTEC programme in 1979. In this first demonstration of OTEC power with an installed capacity of 50 kW gross, the net power was low due to fact that the turbine generator, the seawater and ammonia pumps operated at low efficiencies.

OTEC-1 experiment, sponsored by Department of Energy, USA and conducted by Argonne National Laboratory, was to simulate OTEC heat exchanger operation. It used shell and tube titanium heat exchangers. The project gave valuable information about the operation of heat exchanger, the deployment of cold water pipe and also about the bio-fouling control. The turbo generator was replaced by a throttle valve. It was operational only for four months in the year 1981, and hence, seasonal variations on OTEC system could not be studied.

The Nauru plant in the Pacific region with a capacity of 100 kW was a shore based plant with Freon-22 as the working fluid of the rankine cycle. It was operational for nearly ten months from October 1981. The heat exchangers were of shell and tube type with titanium as material. The evaporator tubes were coated with sprayed copper particles to improve the heat transfer co-efficient. Nauru test provided accurate experimental data on the performance of the power cycle and the construction and operation of a pilot plant.

In 1992 a land based open-cycle experimental plant with a capacity of 210 kW was designed, built and operated by Dr Luis A Vega and his team in USA. This was the first open cycle plant after Claude's pioneering work. It could produce a peak of 255 kW gross and 103 kW net. This plant provided much valuable information such as the corrosive nature of seawater, violent outgassing of cold seawater, unstable synchronous generator output due to the large inertia of the turbine etc. The equipment, which caused frequent trouble to the system was the vacuum pump.

OTEC Programme in India

The Indian OTEC programme started in 1980 with the proposal of General Electrical Co. of USA to install a 20 MW plant off the Tamil Nadu coast. In 1982, an OTEC cell was formed in the Indian Institute of Technology, Madras. A preliminary design was also done in 1984 for 1 MW closed Rankine Cycle floating plant with ammonia as working fluid. After a bathymetric survey, a land based, 1 MW capacity OTEC plant was proposed for one of the islands of Lakshadweep group.

In 1993, National Institute of Ocean Technology (NIOT) was formed by the Department of Ocean Development (DOD), Government of India to pursue the research activities on ocean energy as part of their various mission-based activities. Under this mission a major thrust was given for the technology development for OTEC.

An MOU was signed in 1997 between NIOT and Saga University, Japan for a joint development of OTEC plants. In 1998, Department of Ocean Development, Govt. of India approved a Technology Demonstration OTEC plant with a capacity of 1 MW (gross). This plant operating on closed loop Rankine cycle uses ammonia as the working fluid. This will be a barge mounted plant, positioned off Tamil Nadu coast which is free from cyclone over the past 100 years. NIOT conducted detailed surveys at the proposed OTEC site near Tuticorin, South India. Based on the temperature and bathymetric profiles, the optimization of the thermodynamic cycle of the closed loop systems was done with the assistance of Saga University in 1998 .

The nominal design of the power plant is based on a temperature difference of 22°C, with surface water of 29°C and cold water from a depth of 1000 m at 7°C. The operating environmental conditions for the sea water systems are: wind speed 23 m/s, current speed 1 m/s; significant wave height 4.25 m, wave period 7.3 s.

This pilot plant uses titanium plate heat exchangers for the evaporator and the condenser. The evaporator has an additional coating on ammonia side to increase the overall heat transfer coefficient. The evaporator is from M/s. Alfa Laval, Japan and the condenser from M/s. Sondex, Denmark. The turbine is specially designed by M/s. Turbotech, Bangalore with the help of NREC, USA. The manufacturing is in progress at present. The conceptual design of the sea water system is done by M/s. Makai Ocean Engineering, Hawaii, USA. The assembly of pipe and deployment will be carried out from the port of Tuticorin. The plant is accommodated on a barge that is single point moored. The OTEC plant will, be located in the region bounded between 8°22'N-8°28'N latitude and 78°28'E-78°36'E longitude. The cold water pipe made of HOPE forms part of the mooring. The design of the sea water system is such that under storm conditions the barge can be disconnected from the cold water pipe and moved to a safer location. When the weather returns to normal conditions the barge can be brought back and reconnected to the cold water pipe.

This technology demonstration of this floating OTEC plant of 1 MW capacity is expected to be integrated and commissioned during the last quarter of the year 2000 for performance evaluation. Successful demonstration of this technology will lead the way for the establishment of higher capacity OTEC plants of capacity of the order of 100 MW for future commercial application.

WAVE ENERGY

A small portion of the energy from sun is converted as wind energy and a part of it is transferred to the sea surface resulting in the generation of waves. This energy is carried to the coast lines where it is dissipated as the waves break. If this energy is tapped and used economically, it can provide a sizeable portion of the energy needed, since India has a very long coast lines. The wave energy potential varies from place to place depending upon its geographic location. Even at a given place the energy availability varies during the day and from season to season.

The wave energy is highly fluctuating and random in nature. The wave energy potential is a function of the, significant wave height and the zero crossing period of the wave. The average wave height in the areas near the equator is much less compared to the areas in northern latitude. A wave energy potential of about 60 to 80 kW/m has been reported in the north Atlantic and North Sea areas. Along the coasts of India, the average wave power potential is estimated to be between 5 kW/m to 15 kW/m.

This ocean wave energy conversion technology utilises the kintic energy of ocean waves to produce power. Means of energy extraction and conversion include mechanical cams, gears and levers; hydraulic pumps; pneumatic turbines; oscillating water columns (OWC), etc. Of these the OWC system is very promising. The OWC consists of a chamber in the sea exposed to wave action through an entrance at the bottom or on the side. The air inside the chamber gets pressurized or expanded due to wave action, causing air movement through a turbine which is coupled to a generator.

International Wave Energy Projects

The Japanese government had a very active wave energy research and development programme for many years. The most well known project, supported by the International Energy Agency, was the KAIMEI with a 800-t barge-like platform containing about ten oscillating water columns. The oscillating water column (OWC) system with the air turbine was subjected to sea trial in the Sea of Japan in October 1979. The average output of the system was not as high as predicted. One of the major reasons for this was that the moored barge was heaving up and down with the waves resulting in less power absorption.

The United Kingdom wave energy programme initiated in 1974 was very ambitious and resulted in a wide variety of conversion techniques. The programme slowed considerably in the last decade and is now once again being promoted. Shell Renewables of UK has initiated a renewable energy demonstration programme funded at about $500 million for five years.

Norway has conducted an extensive wave power programme. These efforts included the installation of a 500 kW prototype wave power system, called the multi resonant oscillating water column, on the West Coast of Norway. Operational in 1985, the plant was swept off its foundation and destroyed during a severe storm in 1989. In 1986, the Norwegian firm NORWAVE A.S installed a new system called TAPCHAN, a tapered channel wave power plant in Bergen, Norway, that produced 350 kW of power. As a wave passes through the tapered channel, its wave height is gradually increased as the channel narrows. The wave then spills over into a reservoir where it is stored and subsequently passes through a low-head Kaplan water turbine to generate electricity.

Wave Energy Programme in India

Wave energy potential along the Indian coasts is not as high as in the northern latitude countries. Therefore, a wave energy system purely to generate electricity from the waves may not be commercially viable in the near future. However, there are many other utilities that may arise by regulating the waves. A multi-purpose wave regulator system has been proposed by the Wave Energy Group at Indian Institute of Technology (Madras), Chennai to absorb the energy of the waves by providing a long wave barrier and to convert the energy into electricity; to develop a calm pool of water between the barrier and shore that could be used as a natural harbour or space for aquaculture or space for coastal transport with lighter crafts. This wave absorber system also provides shore protection against erosion by the waves.

A technology demonstration wave energy pilot plant was commissioned at Vizhingam, Kerala in 1991. The conversion of wave power to pneumatic power is through the owe. To achieve this a concrete caisson of 10 m width with an owe chamber has been installed at 10 m water depth and 600 m away from the shore at the Vizhinjam harbour. The caisson is connected to the top of the breakwater of the harbour by a bridge. The power module of 150 kW rating with a wells turbine, an air turbine, and an induction generator mounted on the same axis, and installed vertically on this owe caisson. This system has been commissioned in October 1991. This plant has demonstrated the technology of the conversion of wave power into electricity and delivered it to the local grid. This plant was used to check the performance of each of the sub-systems. Based on these studies, an improved version of the turbine and generator power module was configured. This new power module of 55 kW capacity with a twin rotor Wells turbine and the generator was horizontally mounted and commissioned in March 1996. The rotors were mounted one on either side of the generator and had tapered chord blades. The electric power generated by the unit was connected to the Kerala Electricity power grid. The performance of the system was evaluated in detail. This unit produced a peak power of 27 kW and an average 7.5 kW. Since the wave energy is random with high peak to average ratio as in non-conventional energy resources, the Wells turbine could not absorb the wide range of the wave energy spectrum. In the higher energy range the turbines stalled due to flow separation, and in the lower energy range the generator connected to the power grid became a motor. To improve the efficiency of energy conversion, an impulse turbine with self pitching linked guide vane was designed, manufactured and commissioned in May, 1997. Experiments conducted showed the best average power of 13.5 kW and peak power of 70 kW. Based on further studies to improve the reliability in marine environment a fixed guide vane impulse turbine was designed for optimum energy absorption. This unit was manufactured and successfully evaluated in the wave energy facility. Thus, the technical feasibility of wave energy generation was demonstrated. Further efforts are directed towards cost optimisation of the plant in general and owe system in particular.

TIDAL ENERGY

Tidal power is derived from the energy induced in the ocean by gravitational forces of the Sun, the Moon and the Earth. The ebb and flow of the powerful ocean tides are greatly influenced by the tidal swing, volume of water involved and inshore geological features. Tidal energy is generated by collecting rising tidal water behind a barrier and then releasing it at ebb tide through turbine to generate electricity. Relatively conventional hydro-electric turbines are used. The tidal power varies in time and space and is intermittent in nature. Due to well defined nature of the tidal phenomenon, the tidal power can be predicted with great accuracy. Tidal energy extraction depends on the natural configuration of inshore geological features.

International Tidal Energy Projects

In November, 1966, the first large scale modem tidal electric plant 'La Rance' went into operation in the Rance Estuary in France. Within a year, the plant was fully commissioned with 24 turbines of 10 MW each and is operating successfully since then. The length of the tidal barrage is about 750 m with the maximum tidal range of 13.5 m. The average availability of the machines has been 94% and most of the 6% downtime is planned maintenance. Cathodic protection system has, solved the blade corrosion.

In 1969, a pilot tidal power plant commenced operation at the mouth of Kislaya Gulf on the coast of Barents Sea in Russia. Although the installed capacity is only 400 kW, it has proved the feasibility of floating method construction for tidal power station.

In 1980, a 3 MW tidal power plant has been commissioned in China. A demonstration tidal power plant having a single 'STRAFLO' unit of 20 MW with runner diameter of 7.6 m has been commissioned in Canada in 1984. This tidal power plant has been constructed in the existing barrage across the Annapolis Royal, Nova Scotia.

A tidal range of 3 m to 4 m is considered viable for installing a tidal power plant. There are large number of sites around the world having tidal range of more than 10 m. Several feasibility studies have been done which includes 'Garolim' tidal power piant in Korea and one at Gulf of Kutch in India.

Tidal Energy Programme in India

India also has a few potential sites for tidal power developments. The most attractive locations are the Gulf of Cambay and Gulf of Kutch on the west coast where the maximum tidal range is of the order of 11 m and 8 m and the average tidal range 6.77 m and 5.2 m, respectively. The delta of the Ganga in the Sunderbans in West Bengal has also some good locations for small scale tidal power plant with the maximum tidal range of about 5 m and average tidal range of about 3.0 m. The estimated tidal power potential in India are about 7000 MW in the Gulf of Cambay, about 1200 MW in the Gulf of Kutch and less than 50 MW in Sunderbans. The Central Electricity Authority of Govt. of India and the Gujarat State Govt. jointly took up a detailed project study in collaboration with Electricite de France, the pioneer who built the 'La Rance' plant for 800 MW rated tidal power plant in Gulf of Kutch.

NIOT and IIT, Chennai recently prepared a feasibility report on the construction of a mini-tidal plant at Durgaduani Creek in Sunderbans. Based on the measured tidal ranges, a tidal power plant was designed with 3 MW rating. The period of tidal cycle is approximately 12.5 h. During each cycle the power generation will vary from 3.5 to 5.5 hrs. Thus, the power availability will be intermittent varying from 6 h to 12 h per day. A diesel generator will have to be connected parallel to the tidal power plant to provide continuous power to meet emergency needs.

CONCLUSION

To sum up, the OTEC power can be cost effective only if the unit cost of power produced is comparable with that from the fossil-fuelled power plants. OTEC system can also have other benefits like enhanced mariculture due to cold nutrient rich waters being brought up to surface. Dr Luis A Vega has done extensive work on OTEC economics. For small plants of 1 MW range the unit power generation cost is considerable compared to conventional energy sources It is apparent from the study of Dr Vega that OTEC is economical and power generation cost is competitive for higher capacity plants. It is estimated that OTEC plants of 100 MW range could be competitive to other conventional thermal or hydroelectric power plants. In spite of R&D for several years no country has yet established any operational wave energy plant. Though the technical feasibility has been demonstrated the techno-economic feasibility is yet to be established. However, wave energy plants could find applications as a source of power for remote areas and also for offshore navigational buoys.

Though the tidal power development has gone through long stages of development over the years, there afe relatively few tidal energy power stations operating in the world today. The excellent performance of 'La Rance' tidal power plant since its commissioning in 1966, the successful construction of Kislaya Guba pilot tidal plant in Russia, and Eastern Scheidt Storm Surge Barrier in the Netherlands using Floated-in-Caisson construction technique, and the recent advance made in the design and optimisation techniques, design of turbo generators for low head plants as used in Annapolis tidal power plant in Canada make the tidal power an attractive source of energy. Among all ocean energy technologies tidal power is relatively well developed and is in operation commercially.

As we see the engineers of today have great challenges and opportunities ahead in the ocean technology developments to make contributions towards the improvements of the quality of life on our planet.

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Science and Technology in East and West

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Today technology is becoming the centre of national attention, as a tool for development, as a creator of economic wealth, as support for national security and in various other roles. It is however also feared: as a tool for social oppression, as a source of environmental degradation, as the coinage of global power and compellance and as the protected possession of certain countries across the world.

The striking thing about much of the technology that we commonly encounter, especially in our cities, is that its products - so widely used all around us - seem to have come almost exclusively from the West. Whether it is automobiles, telephones, television, aircraft, or even the projector that I might use during a presentation like this, the source of the technology does not seem to be here. A major question that we have to ask ourselves is how the West has come to have such a Roddani Narasimha dominating position in science and technology in the world. This question does not concern only India, but the East in general. The famous scientist and historian, Joseph Needham, after carrying out a monumental study of science and technology in ancient Chinese civilization, raised the question about why science and technology arose in Europe around sixteenth and seventeenth centuries and not in the other great civilizations of the world, such as those of India, China or West Asia. This question is in a way central to our understanding of the present and the future of our own country. For, one other major fact of history is that till about the middle of the eighteenth century Asian countries dominated the global economy. A detailed study by Andre Gunder Frank estimates that 80% of the world's GNP around 1750 came from China, India and West Asia. Over the last 250 years however the situation has changed so much that, around the middle of the twentieth century, these civilizations were amongst the poorest and weakest in the world.

Needham's question becomes intriguing not only because of the relative economic strength of Asia till the middle of the eighteenth century but also because the science and technology of Asian countries was ahead of those in Europe till some time in the sixteenth century. Indeed, a case can be made for saying that the growth of Europe around the middle of the second millennium was, at least in part, fuelled by the science and technology of the East. The major inventions that made an impression on Europe in the fifteenth and sixteenth centuries were gun powder, compass and the printing press — all of which came from China. Similarly the mathematical ideas that came from India, with the extraordinary facility that they provided for handling numbers, and even symbols as in algebra, could well have been responsible for the growth of a mathematical picture of the physical world around us that characterize Europe of those times. The synthesis that occurred in West Asia, combining early Greek ideas with those of civilizations further to the East, alongwith the creative contributions from within the region, led in Europe to the scientific and industrial revolutions that came to occur there some centuries later.

These are the issues that concern science and technology in East and West, and we need to understand this history if we have to chart a course for ourselves in this country.

* * *

But before we discuss this question, we should understand better the relation between science and technology. The public in general thinks of science and technology together, often in the same breath: it is Tweedledum and Tweedledee to them. This perception has become widespread especially in the last fifty years or so. After all, did not nuclear energy – spectacularly demonstrated by the bombs that were dropped in Japan in 1945 — stem directly from Einstein's famous equation $E = mc^2$? Has not the whole computer industry — the silicon chip, for example — been rendered possible only because of our understanding of the properties of materials such as silicon through the revolutionary ideas of quantum mechanics — how otherwise would we have seen the esoteric possibilities that lay hidden in such a common material as sand (which is mostly silicon)?

Such spectacular examples have persuaded the public to think of 'S&T' as almost one subject — one force, to be exploited or feared depending on one's feeling of mastery or diffidence before the overwhelming pace at which knowledge of the physical world has revealed here-to-fore unimagined possibilities.

These developments have led to a related view, which emerged at the end of the Second World War as a result of the role that many 'pure' scientists played in the development of powerful military tools for offence or defence (nuclear weapons, radar, cryptography etc.). Scholars who had till then remained in their laboratories or libraries, writing of their discoveries at appropriate intervals largely for an audience of peers (an 'invisible college', it has been called), emerged during the War to lead the design and fabrication of operational systems for the armed forces of their nations. The successes associated with those war-time projects led to the view that technology is basically applied science. This view was most forcefully expressed in a famous report prepared for the U.S. President in 1945 by the American science administrator Vannevar Bush, who wrote: 'Basic research provides scientific capital. It creates the fund from which practical applications of knowledge must be drawn. New products and new processes ... are founded on new principles and new conceptions, which in turn are painstakingly developed by research in the purest realms of science'.

This view implies a linear relationship that goes from science to technology, and has influenced much thinking on all related issues for several decades after the War. It is implied that the relation is asymmetric, uni-directional.

However, as the history of technology is explored in greater detail, it becomes increasingly clear that such a 'linear' view is not valid. First of all, the understanding that has come out of science, even in recent times, has often been unable to help predict the course that technology will take. We may recall here that Lord Rutherford, the father of modern nuclear science, said as late as the 1930s that 'he who talks about atomic energy on a large scale is talking moonshine'; Niels Bohr was similarly pessimistic — in 1939. There is the well-known instance of a Committee of the US National Academy of Sciences that reported to President Roosevelt, also in the 1930s, looking ahead on what science and technology promised in the years to come. In retrospect it is striking that the Committee — consisting of very distinguished scientists — could not foresee any of the major developments that took place in the following decades: nuclear energy, penicillin, transistors, computers etc. were all missed. More recently, there were very few who foresaw even as recently as ten years ago the way that the use of the Internet would spread across the globe. In 1949 the President of IBM did not foresee that more than 10-15 computers of the kind that IBM were making at that time would ever be sold in the world. Again, nobody foresaw the extraordinary way in which the use of lasers would spread, all the way from making nuclear weapons to crushing kidney stones to reading price-labels in a supermarket or accession numbers in a library; and lawyers at Bell Laboratories were even unwilling to apply for patents on the device.

This situation is nothing new: the story has been the same for quite a long time. In 1896 the great British scientist Lord Kelvin said that he did not have 'the smallest molecule of faith in aerial navigation other than ballooning', as the Wright Brothers, two bicycle mechanics in Dayton, Ohio, proceeded to prove him wrong seven years later. Kelvin at that time was a leading figure in world science, and an authority on the motion of fluids (among other things); he was also a very 'practical' scientist, for he helped lay the first trans-Atlantic telegraph cable and made much money from his patents and consulting fees.

It is therefore clear that the course that technological developments take is something that is extremely hard to predict. The difficulty is not that the people who try to make these predictions do not know the state of science at that time; as the list above indicates some of them have not only been the most distinguished scientists of their age but quite often those who were pioneers in the area in which predictions were being made. The point rather is that the most rewarding applications of any new idea (or even an old one, for that matter) are very hard to foresee, because we do not understand either the compulsions of technology or the dynamics of human choice. Many industries depend on market surveys to tell them what products are likely to sell. While of course such surveys may be helpful when a product line is relatively mature, it is also well-known that when truly novel products are being created such surveys are virtually useless, because people do not know what uses a new product can be put to before they have handled it for some time. Cost-to-benefit ratios, so dear to economic analysts, are difficult to estimate when a product is so novel that its benefits cannot be assessed with confidence — for the simple reason that they are not known. The fact is that the new product quite often makes the market, and not the other way round: successful technologies create a cascade of unforeseen applications, invention becomes the mother of necessity. The pioneers in technology are often people who have a gut feeling for what the public needs - and know it well before the public does. Several instances in the consumer electronics and computer industries can be quoted to prove this, including the now ubiquitous personal computer. When the first such machines were made by young, fun-loving university drop-outs, very few foresaw the giant industry that would rapidly emerge and affect every walk of life.

Of course the reverse side of the coin is that several products that quite often may seem to be obvious needs turn out to be duds in the market place (e.g. the picture-phone of the 1960s). Or a prediction that seems eminently reasonable from a scientific view-point turns out to be technologically not feasible — at least in the short run. One example is controlled thermonuclear fusion, which at one time was expected to become such a cheap source of energy that there would be no need even to meter it. A second and more recent example is warm superconductivity, where the problems of fabricating devices from the ceramics that possess extraordinarily attractive properties as conductors have turned out to be technologically formidable. The Greek myth of Daedalus and Icarus is therefore still being played out. But failure is a part of the inventive process: it has been pointed out that one of the great things about Silicon Valley is that no stigma attaches there to failure — on the other hand, the technologist who conceived of a new product - even one that did not make it in the market place — is often considered a valuable person to have in any new venture, because he has demonstrated that he has a powerful imagination. A field of technology in which there are no failures at all is most likely stagnant, or mature if not senile. So mistakes can be made both ways: 'unlikely' products may succeed, 'sensible' products may fail.

We must also understand that there are many products even now that operate without a level of understanding that would be satisfactory to a scientist. The most common example — and a very shocking one, indeed — is ordinary plumbing. To this day it is not possible to predict, based only on the first principles of mechanics (for example Newton's laws), how much water can be pushed through a given pipe for a prescribed pressure drop across it. The reason is that the flow in the pipe is often in a state of turbulence, and turbulence remains (as the famous physicist Richard Feynman remarked) the last unsolved puzzle of classical physics. Of course engineers have successfully pushed water through pipes for thousands of years. They have been able to do this because the required knowledge is there, but it has been acquired through a great deal of experience, testing and simulation, and some very clever analysis, rather than by irrefutable arguments involving logical deduction from fundamental science; such 'engineering' knowledge may be unreliable outside the domain of experience. To underline our ignorance about the subject, there was in 1996 a well-known investigation by a famous mathematician which concluded that under certain conditions (outside the range of present experience) prediction of pressure loss by current accepted engineering practice could be upto 65% in error! (No convincing confirmation or refutation of this prediction has yet been possible.)

As a second example, consider steam engines. When they were first developed in the late 18th and early 19th centuries, thermodynamics did not exist as a subject: it developed subsequently, in an effort to understand the engines that had already come to be used widely. It is for this reason that such fundamental ideas as the Second Law of Thermodynamics have for long been enunciated in terms of what idealized engines can do. Indeed, it would be entirely justified, from a historical point of view, to call thermodynamics "Applied Heat Engines" - that is, heat engines applied to understand nature — in a neat reversal of the 'linear' relationship from science to technology that has been the ruling paradigm during the last half-century.

All of this, of course, is what makes for the romance of technology development. But behind this romance is the truth that the difference between science and technology is fundamental. Science, as its practitioners see it today, has to do with 'understanding' nature, and predicting it, using the minimum number of independent principles possible: 'intellectual economy' is a major goal. 'More is in vain when less will serve', said Isaac Newton in the Principia (1687). Technology on the other hand has to do with making new products, or 'artifacts', often never imagined before. In doing this scientific knowledge can of course be of the greatest value, but if the understanding is not available the engineer is willing to use whatever information he has or can generate on the processes that he has to manage. He uses theory if a serviceable one is on offer, otherwise he will resort to empirical correlations, handbooks, test data, experience, simulation, and even folklore that he will have heard from his colleagues or read about in the literature. His philosophy was accurately summed up by the famous British electrical engineer Oliver Heaviside, who pointed out that we do not wait to understand the process of digestion before we start to eat. It therefore seems clear that the nature of knowledge in science is different from that in technology; and indeed some engineers have now gone so far as to say that technology is autonomous, with its own methods for "validating" the knowledge that it uses. Some of this knowledge is explicit and is indeed based on science - and may be said to constitute 'engineering' and 'engineering science'; but some is also tacit and may never be part of the public knowledge system of the world. If we use 'understanding' as a code word for what science offers us, we could say that at any given time we know more than what we understand, but that we get to know even more whenever we gain in understanding.

We must however realize that progress in technology can and does depend vitally on progress in science; and increasingly so with time. But correspondingly progress in science depends on technological advances as well — a point that we will not argue here but is obvious from the vast efforts in engineering and instrumentation that go into experimental work in the 'pure' sciences (such as giant telescopes and super-conducting super-colliders), or in making computers that can perform trillions of mathematical operations per second. So a linear relationship of the kind that is suggested by thinking of technology as 'applied science' is certainly misleading.

I now want to discuss a point of view that emerges from considering the role of science and technology development in countries that did not take part in the scientific and industrial revolutions that swept Europe in the 18th and 19th centuries. While much of the recent debate on the relation between science and technology has been influenced by events in the industrialized world during the last fifty years, it is possible that an examination of earlier history elsewhere in the world can shed some light on the question. While there are various social and cultural factors as well as accidents of history that may have determined the course of the industrial revolution that took place in Europe, I would like to present one perspective that comes from looking at a rather curious episode in the development of rocket technology in India and Europe between 1750 and 1850.

* * *

The history of the development of rockets offers some fascinating insights into the complex interactions between science, technology, and society, and the shifting balance of technological prowess in the world with time and the forces that may effect the shift. It is widely agreed that the first recorded use of rockets comes from China in the 11th century CE. The invention travelled rapidly (presumably through the Mongols) to Europe, where it was first mentioned in 1258 CE and was experimented with and used upto the 15th century: in England Roger Bacon (1214-1294) had worked on both advanced gunpowder and rockets. However, towards the beginning of the 16th century the cannon (invented around l300 CE, after the rocket) had improved so greatly in accuracy, range and fire-power that the military rocket fell into disuse.

The re-emergence of the rocket as a significant military weapon during the 18th century in Mysore is a fascinating little episode in the history of technology in India; and we now briefly narrate how this happened, and the interesting sequel of its development in 19th century Britain and Europe. The interest in the events of the late 18th century arises from two facts: the balance of industrial power began to shift from Asia to Europe in that period, and interesting accounts have been left behind by European observers.

* * *

The rockets used by the Mysoreans consisted of a metal cylinder (,casing') containing the combustion powder ('propellant'), tied to a long bamboo pole or sword which provided the required stability to the missile. It bears a strong resemblance to the much smaller 'rocket' that is a part of the fireworks that are so commonly seen during Deepavali to this day. Two specimens preserved in the Royal Artillery Museum, Woolwich Arsenal in England have these dimensions:

- Casing 58 mm outer diameter × 254 mm long, tied with strips of hide to a straight 1.02 m long sword blade.
- Casing 37 mm outer diameter × 198 mm long, tied with strips of hide to a bamboo pole 1.9 m long.

These rockets had a higher thrust and range than anything in use at that time in Europe, as confirmed by later experiments in England. The range is often quoted as about 1000 yards, There are however other accounts that speak of rockets that generally weighed 3.5 kg, tied to 3 m bamboo poles, and with a range of upto 2:4 km: this was by European standards outstanding performance for the time (Baker 1978).

The superior performance of these rockets cannot be attributed to the propellant, which was standard material like gun-powder. There was nothing unusual about the aerodynamics of these rockets, or about their shape and stability: it turns out that their chief advantage lay in the material employed for the casing. The casing was a metal cylinder made of hammered soft iron; although it was crude, it represented a considerable advance over earlier technology, as European rockets of the time had combustion chambers made of some kind of paste board; e.g. Geissler in Germany used wood, covered with sailcloth soaked in hot glue. The use of iron (which at that time was of much better quality in India than in Europe, as we shall discuss further below) increased bursting pressures, which permitted the propellant (gunpowder) to be packed to greater densities; this is what gave the rockets their 'outstanding' performance.

There was at that time a regular Rocket Corps in the Mysore Army. Beginning with about 1200 men in Hyder's times, this eventually reached a strength of about 5000 in Tipu's army, with several units of rather more than a hundred men each. There are accounts that mention the skill of the Mysorean operators in giving the rockets an elevation that depended on the varying dimensions of the cylinder and distance to the target of attack. Furthermore, the rockets could be launched rapidly using a wheeled cart with three or more rocket ramps.

The vigorous use of such rockets in the Anglo-Mysore wars may have had something to do with Tipu's character, for he was an innovator in many ways, and would today have been called a 'technology buff'. He was curious about European inventions such as barometers and thermometers, and made vigorous efforts to promote the manufacture of novel devices in various cities of his state in areas often known as Taramandai-pet (which may be aptly translated as Galaxy Bazar), one of which still survives to this day in the older part of Bangalore and houses many small workshops and power looms. (These were the 'technology parks' of his day.) These efforts were encouraged in later years by the favourable impression his weapons made, especially the rockets, on such notables as the Sultan of Constantinople, to whom they had been sent as presents.

The first striking account we have of the use of these rockets is in the Battle of Pollilur, which was fought on 10 September 1780 during the Second Anglo-Mysore War near a small village about 180 km east of Bangalore. Hyder and Tipu achieved a famous victory in this battle, and it is widely held that a strong contributory cause was that one of the British ammunition tumbrils was set on fire by the Mysore rockets, a scene that is celebrated in a famous mural that can still be seen at the summer palace in Tipu's capital Srirangapatna. Writing about this war, a British historian of this century remarked that, as a consequence of this defeat, 'The fortunes of the English in India had fallen to their lowest water-mark'.

One incident in the rocket attacks that were part of the battles of the time involved Col. Wellesley, to become famous later as Lord Wellington and the hero of Waterloo, and took place in the 4th Anglo-Mysore War of 1799. Before the siege could be pressed closer to Tipu's capital, a large mango grove (near a place called Sultanpet), which gave shelter to Tipu's rocketmen, had to be cleaned out. Wellesley was chosen for this task. Advancing towards the grove after dark, he was set upon with rockets and musket-fire and lost his way. His men gave way, were dispersed, and retreated in disorder. Several were killed, and twelve grenadiers were taken prisoner. This 'Sultanpet incident', as Wellington's biographers call it, clearly had a profound and traumatic effect on Wellesley; even late in his life, well after Waterloo, Wellington used to come back to the incident with his own 'explanations' for what had happened, presumably to counter what some of his detractors hinted was a black mark on an otherwise illustrious career.

The effect that these rockets had on British troops is well described by a young English officer, who said in his journal:

> 'The rockets and musketry from 20,000 of the enemy were incessant. No hail could be thicker. Every illumination of blue lights was accompanied by a shower of rockets, some of which entered the head of the column, passing through to the rear, causing death, wounds, and dreadful lacerations from the long bamboos of twenty or thirty feet, which are invariably attached to them'.

In spite of all this, however, the battle was over on 4 May 1799 when Tipu was killed in action.

Two facts stand out clearly from these accounts. First, the British were caught off guard by the Indians' use of rockets, which at the least caused great fear and confusion. Second, in spite of this, the rockets could not tilt the balance decisively in favour of Tipu and his armies in the later battles. There is however no doubt that the British were extraordinarily impressed, as their effort at developing their own rockets in the decades following Tipu's defeat and death shows: we shall discuss this briefly now.

* * *

A vigorous programme of what we would now call 'research and development' on rockets took place in Britain at the beginning of the 19th century, triggered in particular by accounts of the Anglo-Mysore Wars. The programme began when several Indian rocket cases were collected and returned to Britain for analysis. Further development was chiefly the work of Col. (later Sir) William Congreve, who was told that the British had suffered more from the rockets than from shells or any other weapon used by the Indians in these wars.

In 1801-2, Congreve bought (out of his own pocket) and tested the biggest sky-rockets then available in London. Their range was found to be about 500-600 yards, less than half that of the Mysore rockets. He then started developing his own, using the facilities of the Royal Laboratory at Woolwich Arsenal. Congreve first tested various combinations for propellant, and eventually developed a rocket motor with a stout iron case of 100 mm diameter and a conical nose. The rocket weighed about 14.5 kg, and was attached to a 4.6 m long stick 38 mm in diameter. This rocket, already bigger than what the Mysoreans had used, cost him about £1. In 1804 he published a book titled A Concise Account on the Origin and Progress of the Rocket System. He reported that 13109 rockets had been manufactured by August 1806.

It is of special interest to note that Congreve reasoned on the basis of Newton's third law of merion, and recognized that one of the chief advantages of the rocket would be the absence of the recoil force ('to ground', so to speak) that made it so difficult to use cannon on ships. He therefore argued that rockets were particularly suited for sea-borne assault, although he apparently came to feel later that this was not the best method of using them. At any rate, the argument persuaded the British Navy to tryout rockets in an attack on the French channel port of Boulogne, where Napoleon had been assembling his forces with the intention of taking the war 1:0 British soil. The first attack was unsuccessful, but the secoad, mounted on 8 October 1806, turned out to he devastating, In about half an hour above 2,000 rockets were discharged, and in less than ten minutes after the first discharge the town was reported to be on fire. Napoleon was forced to abandon all plans for a cross-channel expedition on Britain. This success was followed in 1807 by an effective barrage of some 25,000 rockets 09 Copenhagen, and later in various other wars in Europe. The Congreve rockets were also used in several engagements during the Anglo-American 'War of 1812', sometimes with little and on other occasions with great effect: they were still rather unreliable and inaccurate, but had greater range than cannon and could even be fired from row-boats (because of the lack of recoil mentioned above). Indeed the rockets were responsible for the fall of Washington. It was a spectacular but unsuccessful attack on Fort McHenry that led to the reference to 'the rockets' red glare' in the US national anthem.

The main advantages of these rockets were that their range exceeded that of other movable artillery of that time (which is spectacularly true again in the second half of the 20th century, with missiles having inter-continental ranges), and the absence of recoil which, apart from permitting operation from boats, also eliminated the heavy 'barrel' required to direct other projectiles. For Congreve had demonstrated that a rocket barrage could be discharged even from collapsible wooden frames (but this would have been no surprise to Indian rocketmen, although they would have been unable to connect it with Newton's laws), and thought of the rockets as 'the soul of artillery without the body'.

Virtually all the European powers of the time as well as the US quickly followed the footsteps of Congreve and the British.

Congreve's achievements were remarkable for their comprehensiveness. Beginning with the application of the laws of mechanics to understand rocket behaviour, he experimented with a number of black-powder formulas and set down specifications for their composition, standardized construction details, used improved production techniques (the stabilizing stick could be quickly inserted into hoops on the side of the casing and crimped), offered designs permitting either explosive (ball charge) or incendiary warheads (the former could be independently timed by trimming the fuse length before launching), studied the tactics of their use (recommending that they be fired in volleys of at least 20 and preferably 50 rockets once every 30 seconds, to compensate for their dispersion), and designed simple collapsible wooden frames to serve as launchers (dispensing with the heavy wheeled carriages that were so necessary for transporting cannon and made them unusable in difficult terrain). In 1827, Congreve published his third book on the subject; he had by then succeeded to his father's position at Woolwich and to the baronetcy, and been elected to the Royal Society and Parliament.

At least twenty books on the subject of rockets appeared around the time in Europe.

Although they continued to be used for some more time, the use of rockets had however considerably declined by midcentury, as artillery gained in accuracy and became more effective once again.

* * *

Two points can be quickly made. First, even in the late 18th century there were still certain products, of which the rocket was one, where Indian technology was superior to Western and was so recognized by both sides. As the superiority of the Indian rocket was chiefly attributable to the better quality of the iron/steel that was used for the casing, it is worthwhile to look at metallurgical technology briefly.

It has been pointed out that ‘iron made in India [at that time] was of a high quality ... even though Indian furnaces were operated inefficiently as compared with those of Europe. Samples of Indian iron were sent to Sheffield, because it was "excellently adapted for the purpose of fine cutlery", and it was difficult to obtain such good iron in England, except through imports from Sweden’. In fact, in the 1790s the British started importing Indian iron to reduce their dependence on Sweden. In a decade or two thereafter, however, forced by both politics and technology, iron production in India started to decline, and almost vanished in the 1850s. (It picked up again only another few decades later, but this time using British technology.)

Secondly, following the nasty encounters with Indian rockets, the British effort to understand and master the technology already had the beginnings of the sophistication that we have come to associate with research and development in this age: scientific principles were applied, appropriate designs were made, suitable products developed, tested and systematically evaluated, and all of this was carefully documented. This whole process was something which was alien to Indians of the 18th century. The period we are looking at was of course rather special in British history. It saw the emergence and preliminary consolidation of British geo-political power (although the American colonies were lost in 1776). Equally, the period also saw what historians agree was the first wave of the Industrial Revolution, often dated as lasting from 1750 to 1815. The transformation that took place in Britain during these years can be easily illustrated in terms of various parameters, such as for example pig iron production, which spurted steeply in Britain beginning some time around 1770. The period also saw many interesting developments in science and technology in Britain. Although Newton's famous Principia had been published about 70 years earlier, it was only during the 1760s that its direct relevance to the solution of practical problems began to be appreciated. For example, the pioneering studies of John Smeaton on wind- and watermills date from this period: his diagrams of water wheels appeared virtually unaltered in British engineering texts almost right down to the 1950s. In 1776 James Watt's steam engines were in operation at many places. Smeaton formed a Society of Engineers in 1771; engineering emerged as a profession, and engineering science as a pursuit, culminating in the foundation of the Institution of Civil Engineers in 1818.

Simultaneously there was a marked decline in the technological capabilities of India, accompanying the rise of British power. In the decades following the Battle of Plassey (1757) India's famed textile industry faced total ruin, as the British imposed stiff duties against Indian imports and started flooding India with textiles from Manchester of steadily improving quality. Indeed, recent historical research confirms that the period we are considering was a turning point in global economic history; as Andre Gunder Frank has pointed out, before about 1800 the major industrial powers were in Asia (chiefly China and India), but in the 19th and 20th centuries there was a shift to Europe and America.

To summarize, therefore, there were products of Indian technology that in the second half of the 18th century were still superior to those available anywhere else in the world, but India was untouched by the vast transformation that Britain and the rest of Europe were experiencing.

From the examples still available, it is evident that the Indian rockets used in those times were very well-made; but they were not standardized, being rather the creation of artisans who had a long tradition of working with well-understood materials and techniques. Although the rockets improved slowly over time, and much thought was obviously given to the best methods of using them in warfare, it is equally clear that rocket manufacture never went beyond being a craft. It remained within families, the skills being often handed over from father to son; one family that had been involved in making rockets had survived in the area till the 1960s, when a fire in their establishment put an end to a long tradition. Returning to metallurgy in India, we note that its history is long and distinguished, and has been well studied for some time. Historians suggest that iron has been used in India since about 1300 BCE, and artifacts of the metal appeared around the same time in at least seven areas within the country, including what later came to be called Mysore. The use of iron may have been responsible for an early green revolution that led to the Indian prosperity of the first millennium BCE. There is a legend that, during his raid of India (4th century BCE), Alexander was given a gift of a ball of iron or steel, of some 15 kg in weight (about 15 ern diameter). Developments in technology continued over a long period, leading to such remarkable achievements as the rustless iron pillar (of early 5th century CE) that is now found in the Qutb Minar complex in Delhi, and the use of Indian iron for the celebrated Damascus swords.

It is remarkable, however, that so little ancient literature exists on these subjects in India. I cannot find any early Indian work that discusses rockets, for example, in any technical detail; certainly there are no pictures or drawings at all, a situation that is in stark contrast to the situation in China or Europe. It is even more remarkable that the literature is so scarce even in metallurgy, where there was a tradition extending over more than three millennia and Indian technology was outstanding. What written treatments are available describe metal- processing for medical and pharmaceutical purposes, or for alchemy. Some of these were written with great authority, based on direct experience and observation; for example the author of a 13th century text said: 'I describe for the benefit of the world what I have done or observed with my own eyes, not something recorded only from hearsay or from a teacher's instruction'. The most significant text perhaps is an early 14th century compilation known as Rasa-ratna-samuccaya (Handbook of Gem-Mineral Chemistry). None of these, however, was illustrated. A point of interest to us here is that the knowledge in these books was closely guarded and was meant to be handed down only to selected pupils and family members. For example, the Samuccaya says, 'This chemical knowledge is powerful when secret, impotent when public; so guard it with determination, as you would the privacy of your mother'.

In general, great secrecy has surrounded the transmission of knowledge in India over long periods of time. Many examples of this can be quoted, from the earliest philosophical texts to Indian classical music almost right down to the present day. Thus, the most sacred teaching was meant for those 'sitting nearby', which is the concept underlying the word Upanishads — for the well-known ancient Indian works of philosophy.(Interestingly, some of the earliest of these works contain evidence that even the secret teaching was available to those without a right to it by birth, if the guru was convinced about their ability and motivation. The great rigidity of the system was perhaps a later development.)

Al-Biruni, a Muslim scholar-traveller in India who wrote extensively around 1030 CE about the country and the belief and knowledge systems of its inhabitants, mentioned that, among several reasons why it was difficult to 'penetrate to the essential nature of any Indian subject', one was that Indians 'are by nature niggardly in communicating that which they know, and they take the greatest possible care to withhold it from men of another caste among their own people, still much more, of course, from any foreigner.'

When European adventurers introduced various new technologies to India, some were accepted, some not; among those that found no takers was the printing press, indicating no strong pressure from any quarter to spread any kind of knowledge, sacred or secular.

It is of course not in India only that what is today called 'intellectual property' was guarded jealously: a certain kind of practical information has always been held with great secrecy everywhere in the world. Nevertheless, it is difficult not to feel that India went further than most in this respect. The Indian social system seems to have encouraged such secrecy; the inter-dependence among the castes, which was a strong feature of the system that contributed to its remarkable stability, must have been encouraged in part by an 'allocation' of different knowledge subsystems to different castes. In particular, there developed over a period of time a dichotomy between the 'thinkers', who communicated in Sanskrit within a pan-Indian community of scholars, and the 'doers', whose skills were orally handed down in families and local caste groups that married among themselves. There was of course some interaction between these groups; thus the magnificent sacred sculptures (made out of metallic alloys such as bronze) that are among the most striking creations of Indian art combined sophisticated concepts in aesthetics with the remarkable skill of the artisans who ran the foundries and finished the sculptures. Nevertheless, it appears certain that at a time when the craftsmen were making the best rockets in the world, there were no scholars in India who could provide direct intellectual or scientific support: it is doubtful if anybody knew about Newton's laws (for example), or was willing to analyse rocket performance using the mathematics that had been so imaginatively developed in the country for astronomical applications.

The net result of these characteristics of Indian society was precisely to promote its division into largely non-intersecting and even non-interacting groups of people, each with its own skills and monopoly of knowledge. There was a corresponding slowness in innovation, as these knowledge domains remained unchallenged except by foreign sources.

* * *

There is one other major factor which distinguishes the science and technology enterprise in India from that in the West. This factor is chiefly philosophical and can be traced to the views so forcefully expressed by Francis Bacon in England around the middle of the sixteenth century. Bacon appears to have caught some essential spirit of the time in his country and in Europe, for his ideas spread very rapidly and had a profound influence on the scientific revolution that took place in Europe. In particular the Royal Society, when it was founded in the middle of the seventeenth century, was completely dominated by Baconian philosophy, but so were the French a little later. And Bacon's views inform, to this day, the spirit of science in the West. To understand Western attitudes on science, therefore, it is necessary to understand Bacon's views.

According to Bacon truth had to be extracted from nature, if necessary by force; he said nature had to be 'put on the rack' - i.e. tortured - to achieve man's aims. He went on to say that nature and her creations - and these creations were both animate and inanimate - had to be 'enslaved'. He talked at great length about "the effecting of all things possible". In other words Bacon upheld the philosophy that nature was a force to be mastered, that man was capable of doing it, and that there was an efficient way to go about it. Now I believe these thoughts will sound revolting to Indians even in the twenty first century, whereas Bacon's ideas continue to influence Western thought virtually down to this day. Thus while we now admire Western science and have worked very hard to learn how to use its methods and tools, we have not really accepted its inspiration; indeed we have rarely bothered to find out what that inspiration is. Indians tend to think of science as a very generalized quest for knowledge, without the attendant drive for mastery that was at the heart of Baconian thinking.

A major question IS therefore why India and many other countries of the world have felt uneasy with the Baconian philosophy. Perhaps, in a tropical country such as ours, we tend to see nature as bountiful and generous, India is a subcontinental oasis surrounded by desert, mountain, jungle or sea - Indians have seen no reason to wage war with nature. On the other hand people living at higher latitudes may have a different view of nature; indeed to them it is a force that is hostile, 'red in tooth and claw'. Low temperatures, short springs, few crops, low productivity made the inhabitants of these inhospitable latitudes see nature as a force to be mastered. If you ask Indian scientists and engineers today about their motivations, they are likely to cite 'national development' as the major goal. This is a view that has been promoted by the Indian political and scientific leadership, beginning with Jawaharlal Nehru. One could say that Indians are doing science with post-Baconian tools, but with a pre-Baconian motivation or philosophy. Is that the reason that most technological advances seem to take place in the West rather than here? Is that the reason why even those in India who pursue science rarely look at what the implications are for a Baconian mastering of nature? Is that why most Indian engineers are often content with available technology and rarely try to formulate or devise totally new products? These philosophical issues appear to me to be central to understanding the relative positions of science and technology in West and East.

* * *

What are the implications of this account for the relation between science and technology? A discussion of this issue is clouded by different perceptions of what constitutes 'science' in different cultures. In the West, as already pointed out, science has in recent times stood for 'understanding nature' and predicting its behaviour in terms of the fewest possible principles or hypotheses, of the kind that (according to Karl Popper) must be 'falsifiable'. In many other cultures, and to some extent even in the West, science often also stands for any systematized but objective or consensible knowledge. The chief characteristic of both kinds of science is that a large number of the people who study that branch of knowledge, pursuing a course of vigorous but creative skepticism, eventually find that they can agree on its contents.

India has had a long and strong tradition of science, especially in the second sense of the word. The most striking examples are in medicine, mathematics and astronomy. In the latter subject, the work of Aryabhatta (5th century CE) often combines physical and mathematical procedure in a rather modern way, and created science in the first sense of the word. Grammar and linguistics, especially in Sanskrit, were also treated very 'scientifically,' largely in the second sense of the word but with a profound respect for the demands of intellectual economy. There was also a keen appreciation that scientific and philosophical truths may emerge from direct physical observation.

Technology has also had a long tradition, as we have already seen. However the two traditions resided in different communities, to a far greater extent than in the West; interactions between them were not non-existent, but appear to have been very weak. It is true that many of the pioneers of the European industrial revolution were also artisans or 'mechanics', but even they had greater contact with 'learning'. For example, James Watt was an instrument mechanic, but at the University of Glasgow; Robert Stephenson did not go to school, but learnt to read at age 18 so that he could gain access to whatever was available in books. And then there were people like Congreve and Smeaton, who combined in themselves what in India were separate traditions - not to mention Archimedes who made weapons of war for Syracuse, Newton who invented new types of telescope, and Einstein who took out patents for refrigerators: such examples are hard to find in India. It appears as if what science there was in India rarely worked for technological purposes.

Returning therefore to the relations between Science and technology that we began with, we are led to conclude that while there is no justification for thinking of technology as (mere) applied science, it can be and has been disastrous to separate the two. In particular, the history of one episode analysed here shows that science (in both senses of the word) is the greatest ally that technology can have; and one is tempted to speculate that it is the rapidly increasing strength of such an alliance in the West, after the 17th century, that may have been a major factor in the explosive growth of both science and technology there; and correspondingly that the lack of such an alliance led to the stagnation of both in India (and perhaps in other eastern societies), although their traditions in science and technology of certain kinds were each very strong. The structure of society, which itself develops in response partially to technological developments but also to a variety of other forces, appears to have reinforced this separation between 'science' and 'technology'. In some of these societies, these communities are getting together in the latter half of the 20th century, for almost the first time in their history: it does not take extraordinary perception as a social observer to see this happening in front of one's eyes.

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The central theme of this talk was accurately expressed by the Vira-saiva poet Jedara Dasimayyya (10th c. CE), who said in A K Ramanujan's wonderful translation

Fire can burn
but cannot move.
Wind can move
but cannot burn.
Till fire joins wind
it cannot take a step.
Do men know
it's like that
with knowing and doing?

Europe learnt 'to know and to do' some five hundred years ago. We still need to discover — or rediscover again — that lesson here in India.

Destination Disaster Free India

Shri R K Bhandari

Director, Centre for Disaster Mitigation and Management
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It is a matter of great pleasure and indeed an honour for me to be invited to deliver the 23rd Sir Rajendranath Mookerjee Lecture. What redoubles my joy is the fact that by this lecture, the Institution of Engineers (India) is reliving the memory of its Inaugural President. a great son of the Indian soil. and an outstanding engineer. Of the many notable contributions of Dr Mookerjee, the one best known is the second Howrah Bridge. While paying my own tribute to Dr Mookerjee, I have chosen to speak on a subject that would require building of a majestic bridge between the Disaster Torn India and Disaster Free India. It is a daunting challenge, which we can shoulder only by following the footprints left by people of his stature, on the sands of time.

DISASTER TORN INDIA

India is highly hazard prone. It is a hard ground reality, a fact of life, an unavoidable inheritance and a disturbing thought. That India is disaster torn is, however, our own making and a national shame. Hazards will continue to loom large as they have been for centuries of our existence, but there is absolutely no reason why they should be allowed to turn in to formidable disasters, catastrophes, and calamities. Earthquakes, landslides, floods, cyclones, drought, traffic accidents etc are all seen to take there random turn, and toll, causing turmoil and tension only because we are vulnerable, totally unprepared and hopelessly disorganized. We are indeed so regularly overwhelmed with the sheer weight and frequency of disasters that global issues like climate change, receding of glaciers, sea level rise, ozone depletion, EINino and La Nino effects etc., do not bother us much, and will not bother us more, until they hit us on our heads provoked by population explosion, unchecked urbanization and haphazard development.

The fate of millions of people in India is written and rewritten, and often underscored, not in the texts of the developmental plans and reports but by the onslaught of frequent cataclysmic events. Disasters often lead, and the Plans follow. Survivors are condemned to their fates, as if worse than the dead. Besides huge losses of lives and property, the very wheels of progress and development get jammed. Sometimes, even if the initial impact of a disaster is not quite severe, its eventual consequences could still be lethal. For example rainstorm-tlood contamination — epidemics; or cyclone — flood contamination — epidemics can end up in to a mass graveyard scenario, throwing even the best of the post disaster management machinery haywire. This did happen during the Orissa super cyclone of Dctober-Novernber 1999, and again during the Bhuj Earthquake of 26th January 2001, when we passed through traumatic times and very painfully learned how to arrange mass funerals or bury the dead by dozens!'

Since the hazardous events are quite frequent, degree of preparedness is low and the urbanization is really out of control, the losses are usually staggering. The routine development plans frozen in time and spaces are naturally irrelevant in a dynamic situation such as the one we face, because the change is complex and quick. What we need is, therefore, the strategic thinking to be able to unfold scenarios before they really occur so that we can update our road map, revise our gameplan, and sharpen our strategic sense. Sharing of resources, pooling of expertise and leveraging of capacities come naturally with strategic thinking.

DISASTER FREE INDIA — THE DREAM DESTINATION

Disaster Free India ought to be our dream destination, Bhandari (1998). The High Powered Committee on Disaster Reduction Plans (which has submitted its report to the Government of India on 30th September 2001) has done immense honour to me by accepting my dream of Disaster Free India as its grand Vision to insulate our country from disasters. It is doubtless a do or die situation for all of us and, therefore, it is high time that we tighten our belts, and raise the concern for environment as also the peoples participation in disaster mitigation to such a commanding height that disasters are averted, and losses are, in the process, ren dered minimal and rare. There is a universal agreement on the urgency to shift the focus from post disaster relief. rehabilitation and reconstruction to predisaster planning and prevention. Despite so, what is, however, rarely appreciated is the obligation that goes well beyond the mere thought of prevention, deep in to the ethos of culture of prevention. (A parallel to this can be found in the much higher value billed to the culture of science vis a vis science itself). Enough has been spoken and written about disaster prevention. The time has come to do something about it. If the Agenda 21 is any guide, the Disaster Free India is sure to emerge out when the streams of the cultures of strategic thinking, prevention, preparedness, and quick response will all meet at a point and thoroughly intermingle to produce a single powerful stream, that should wipe out disasters from the Indian soil.

With the weapon of modern science & technology, we can perhaps master the science and art of disaster mitigation and management but that alone would not lead to victory over disasters. We can develop the capacity of instant decision-making under uncertain premises in crisis times and arm ourselves with quick response capacities, but that too would be of limited gain. Our fate will continue to hang in balance between disaster management and disastrous management unless the culture of prevention gets in to our very blood, and become our religion. Once that happens, the strategic thinking and swift decision-making will serve as tonics. Disaster mitigation and management actions will then provide to us the healing touch, and eventually a soft landing as Disaster Free India.

THE GATEWAY TO DREAM DESTINATION

The distance to the dream destination will make a one thousand mile long journey, which for India has just begun, in a sense, with the Orissa supercyclone and the Bhuj Earthquake. First time we realized that what use it is to preach sermons when the ship is sinking. Most of us are unnecessarily laboring to unravel the secrets of disaster mitigation, already unfolded many times over at different flora, for instance at the Earth Summit of 1992.1t has already given us a mega blue print of action - the Agenda 21- in which lies the vision, the direction and the hope for the future. What we now need is our own road map and a compass. Massive mobilization of the people. a strong political will and grand ambition to succeed will make our task simpler. One cannot expect meaningful socio-economic development of India unless it's people feel reasonably safe and secure from the repetitive threats of disasters. The following 11 Point Agenda is proposed for adoption. for us to be able to save the ship from sinking.

FIRST and the foremost, we must recall and identify ourselves fully with the message of UNESCO that reminds us that we have not inherited this world from our forefathers. but borrowed it from our children. It is therefore our obligation to posterity that we cry halt to the reckless assault on Nature. and conduct ourselves in harmony with it. If each of us could look after our individual safety. India would look after itself. We could begin to achieve that by taking simple. small vows of nonviolence against Nature. With the realization of even small goals on the right road. we may soon come to perceive the difference each of us makes on our environment. We should simultaneously work for our collective security by reducing vulnerability again through small vows, in a step-by-step manner. Everysuch step will shorten distance to the dream destination.

SECOND,we must mount pressure on the Government to invest intensively on disaster education and on spreading public awareness about disasters and register peoples pro-active participation, especially in vulnerability and risk reduction programmes. Disaster education and training will necessarily have to be fine tuned to the felt national, regional and local needs. Indeed our best hope lies in creating knowledge societies capable of blending traditional wisdom with the best in modern science. Grass-roots level initiatives and movements for environmental protection and sustainable development must be supported to the hilt.

THIRD, the national strategy for disaster mitigation and management should be unambiguously articulated with well defined chain of commands, and very clear stipulation of roles and responsibilities at all levels of hierarchy. The time has come to insist on accountability and re ward performance, while discarding the inefficient. An area of activity falling in no man's land, as also those of unwanted overlap, should be reallocated to the organized territory. The recommendation of a separate ministry of Disaster Mitigation and Management made by the High Powered Committee on Disaster Mitigation Plans, if approved, will streamline the whole system.

FOURTH,our individual as well as collective attention must turn to shift the focus from post disaster quick-fix approach to prevention engineering and science. This would require a well-knit set of imaginative and smart disaster mitigation and management plans right from the national, state and district levels to the level of a community and a family. The Central Government and State Governments should jointly draw the interwoven Plans and commit to their conscientious implementation in a time bound fashion. And national capacity building and constant upgradation of the capacity should become a normal part of our lives. The science, the art, and the administering of early warning should be encouraged.

FIFTH, Disaster Management as a subject is not listed in the seventh schedule of our constitution. The prevailing position is that States are expected to manage disasters for which financial assistance is usually forthcoming from the Central Government for meeting expenditure on identified natural calamities, which assume a national dimension. A Calamity Relief Fund constituted by every State in to which annual assistance is credited, generally limits our vision to relief. The need for renaming the Fund to Calamity Prevention & Relief Fund is indicated.

Calamity Relief Fund Projections for the period 2000-2005 (Table 1) and the release of monies for Calamity Relief from national funds (Table 2) speak volumes about the great scope of saving funds through the acts of prevention, and by plugging losses.

Table 1 : Calamity relief fund during 2000-2005 (NCDM 2001)

(Rs. In Lakhs)

States	2000-01	2001-02	2002-03	2003-04	2004-05	Total 2000-05
Andra Pradesh	19806	20796	21836	22928	24074	109440
Arunachal Pradesh	1202	1262	1325	1392	1461	6643
Assam	10149	10657	11189	11749	12336	56081
Bihar	12366	12984	13633	14315	15030	68328
Goa	124	130	137	144	151	685
Gujarat	16140	16947	17794	18684	19618	89184
Harayana	8130	8537	8964	9412	9883	44926
Himachal Pradesh	4349	4566	4794	5034	5286	24029
Jammu & Kashmir	3490	3665	3848	4040	4242	19285
Karnataka	7457	7830	8221	8632	9064	41204
Kerala	6724	7061	7414	7784	8173	37156
Madhya Pradesh	9010	9461	9934	10430	10952	49786
Maharashtra	15720	16506	17332	18198	19108	86864
Manipur	287	301	316	332	349	1586
Meghalaya	394	414	434	456	479	2177
Mizoram	297	312	328	344	361	1642
Nagaland	196	206	216	227	238	1083
Orissa	10947	11494	12069	12672	13306	60488
Punjab	12272	12885	13530	14206	14917	67810
Rajasthan	20700	21735	22822	23963	25161	114381
Sikkim	691	725	762	800	840	3817
Tamil Nadu	10264	10777	11316	11882	12476	56714
Tripura	520	546	573	602	632	2873
Uttar Pradesh	17864	18757	19695	20680	21714	98711
West Bengal	10110	10616	11147	11704	12289	55866
Total	199210	209170	219629	230610	242141	1100759

Table 2 Releases from National Fund for Calamity Relief (NCDM 2001)

States	Allocations for the Years 1995-96 to 1999-2000 (Rs in Crore)					Total
	1995-96	1996-97	1997-98	1998-99	1999-00	
Andhra Pradesh	—	163.00	42.00	26.50	75.36	306.86
Arunachal Pradesh	—	13.00	—	13.47	—	26.47
Assam	—	21.00	—	59.90	—	80.90
Bihar	—	28.00	10.00	11.45	38.18	87.63
Gujarat	—	—	86.90	55.35	54.58	196.83
Harayana	39.41	—	—	13.27	—	52.68
Himachal Pradesh	12.49	10.56	24.80	—	—	47.85
Jammu & Kashmir	18.17	—	—	—	73.42	91.59
Karnataka	—	—	22.00	49.98	17.09	89.07
Kerala	—	—	12.91	—	—	12.91
Madhya Pradesh	—	—	67.76	35.00	38.86	141.62
Meghalaya	—	10.00	—	—	—	10.00
Mizoram	4.71	—	—	—	6.00	10.71
Orissa	25.75	55.00	4.00	—	828.15	912.90
Punjab	16.16	—	—	—	—	16.16
Rajasthan	—	21.00	—	21.98	102.93	145.91
Sikkim	—	5.52	7.00	7.67	—	20.19
Tamil Nadu	—	25.00	—	—	—	25.00
Tripura	—	—	—	5.05	5.34	10.39
Uttar Pradesh	—	—	—	131.15	16.68	147.83
West Bengal	—	21.00	—	66.33	29.52	116.85
Manipur	—	—	—	—	4.93	4.93
Total	116.69	373.08	277.37	497.10	1291.04	2555.28

The recommendation of the High Powered Committee to earmark 10 per cent of the Plan funds at the National, State and District levels to specifically address prevention, reduction, preparedness and mitigation of disasters, if implemented, will go a long way to further shorten the distance to disaster free India.

SIXTH, The emergency response to disasters in India should rise well above it's present tardy and neglect status to the level of unquestionable professionalism and finesse. Natural. man-made and biological disasters, or any combination of these, get bracketed and painted in the same hue by the affected people, when it comes to the hard question of life and death. It, therefore, follows that our emergency response apparatus ought to be sensitive to the varied, complex and some times unprecedented demands that may be raised on it. from time to time, in eluding the most recent anthrax menace. Roles of Military, Para Military, Civil Defence, Home Guards, Voluntary Organizations, Private Sector and International Agencies should not only be fully understood and specified, but also fully practiced upon, by all parties. In the words of Iohn Steinbeck, "by not acting, there is a crime here, which goes beyond denunciation. There is a sorrow here that weeping cannot symbolize. There is a failure here that topples all our success". And in the words of JRD Tata, 'the art of management makes all the difference between heaven and hell. In heaven, the policemen are English, the cooks are French, the artists are Italians, and the administrators are Swiss. In hell, the policemen are French, the Cooks are English, the artists are Swiss, and the administrators Italian'. Indeed there is the need to deploy the talent appropriately and trained people should not be frequently transferred. It is not enough to be accountable for what we do. We should also be made accountable for what we do not do.

SEVENTH, It is time for seeking swift change over from the Victorian ways of life. Science and Technology has attained such a towering height that its apt use can undo knottiest of our problems. The rich scientific talent and impressive S &T infrastructure in the country has the potential to propel us in to the league of disaster resistant countries. We must seek appropriate and timely technological interventions and strive hard to constantly innovate and keep discarding the inefficient as we move forward in our mission. Many of our States are technology starved and most of them lack killer instinct. Identification of technology needs should thus top our agenda. The magical advances in space technology, communication technology and information technology should be brought to bear upon the game plan for combating disasters. Their relevance stands well established for the entire cycle of disaster mitigation and management. While doing so, it must be remembered that all that litters is not gold and the wisdom lies in being vigilant about the pressures of mindless technological switch overs. As Winston Churchill said, It would be a tragedy if the sunrise of a technology were to be the sunset of mankind.

EIGHTH, the unfinished task of mapping of India should be brought to fruition as a mission mode programme. Small-scale maps have done us immense good at the macro level planning. For instance, the Vulnerability Atlas delivered by the Building Materials Technology Promotion Council has been successful in projecting a broad-brush picture of disasters affecting different parts of our country. The next logical step is to produce large-scale hazard maps (1: 10 000) for all major hazards. Which must eventually telescope in to multi-hazard maps of the vulnerable areas. Without reliable large scale hazard maps, the damage scenarios will continue to elude us and assessments of risks will always carry question marks, compounding uncertainty. The mapping procedures should be not adhoc but scientific and transparent, especially while do ing hazard zonation. Hazard Zonation exercise should logically extend to micro zonation and multi hazard mapping.

NINETH, since the mitigation and management initiatives will be toothless without the availability of the right information, to the right people, at the right location, in the right time, the High Powered Committee's recommendation of establishing an all compassing Disaster Knowledge Network for India deserves to be pursued. The network of networks so created must display adequate concern for all players, major or minor, should serve as a huge black board in cyberspace for interactive dialogue, and should be intimately coupled with the great learning exercise, Bhandari (1998,1999).

TENTH, Techno-financial regimes should be sharpened. Construction of new buildings and facilities should be strictly regulated. Retrofitting of building-foundation- soil systems in areas of high hazard should be expressly undertaken. Sound damage assessment methodologies and rehabilitation technologies should be introduced. Rationalized measures for insurance should be developed using knowledge-based expert systems and considering various parameters such as, locality, building/structural system. building configuration, materials and methods of construction, age of buildings and their maintenance. The insurance regime so developed shall be widely publicized to benefit individuals and communities.

ELEVENTH, The process of achieving Disaster Free India can be hastened by forging meaningful international partnerships. It could be for a multitude of reasons and may vary in form and texture on a case-to-case basis. Partnership with expatriate Indian nationals will be of great advantage.

THE DRIVING FORCE AND MOTIVATION FOR CHANGE

There is both the need and urgency to change over from the very painful and expensive culture of post disaster relief. rehabilitation and reconstruction to the culture of strategic thinking. predisaster planning. Preparedness and mitigation. The high frequency of natural. manmade and biological disasters and their deadly blows; the ever growing public suffering; the awareness and stimulus provided by the IDNDR, and the national commitments to minimize losses due to disasters have all combined to provide the necessary driving force for change.

New awakening and vigor to keep pace with the best in the world will also motivate the change. We in India are especially encouraged by our trust of our leaders in Science & Technology, and in our capacity to innovate. The Indians have brought laurels to India by working abroad. Surely they are capable of evolving solutions elegant enough to annul the destructive power of hazardous events back home. The Prime Minister's declaration of higher funding for Research and Development, and his flagging of Disaster Mitigation as an area of priority are big stimulus.

India is not alone in its fight against disasters. Most developing countries do sail in the same boat. This is because 80 percent population lives in the developing countries virtually without any serious game plan or any noticeable effort or investment in disaster mitigation and management. It is, therefore, no surprise that they are literally sucked on to the suicidal course of mindless urbanization; well in to the so-called forbidden territory, and they ultimately become mute witnesses to reckless and brutal assault on Nature. Disasters come naturally as the consequence. The trend is highly upsetting, as also totally unacceptable, and must be reversed before it is too late.

There is a genuine realization that the problem of natural disasters is grave because their frequency has recorded more than a five-fold increase in the last two decades. The economic losses on account of them have shot up by over 3.5 times. and the rise in total insured losses is about six times. The year 1998 was regarded as the warmest year in the 1200 years history. But perhaps the worst is still to come. The temperatures of the oceans are rising. The typhoon breeding areas have increased by over 16% during the last 20 years. If our business continues as usual. and the green house effect compounds, the global rise of temperature may lead to alarming sea level changes and consequent submergence of small island States. As the trends go, the tropical storms will probably extend toward Poles. more water vapour will mean heavier rainfall, more severe floods and greater number of thunderstorms, and tornadoes. The coastal regions will see far more storm surges, particularly in areas where the rise in sea level and a higher frequency of storms coincide. And there could also be frequent and serious droughts, if the frequency of El Ninos were to increase. Finding timely solutions to all these problems constitute the greatest challenge for us all.

CHANGE MANAGEMENT

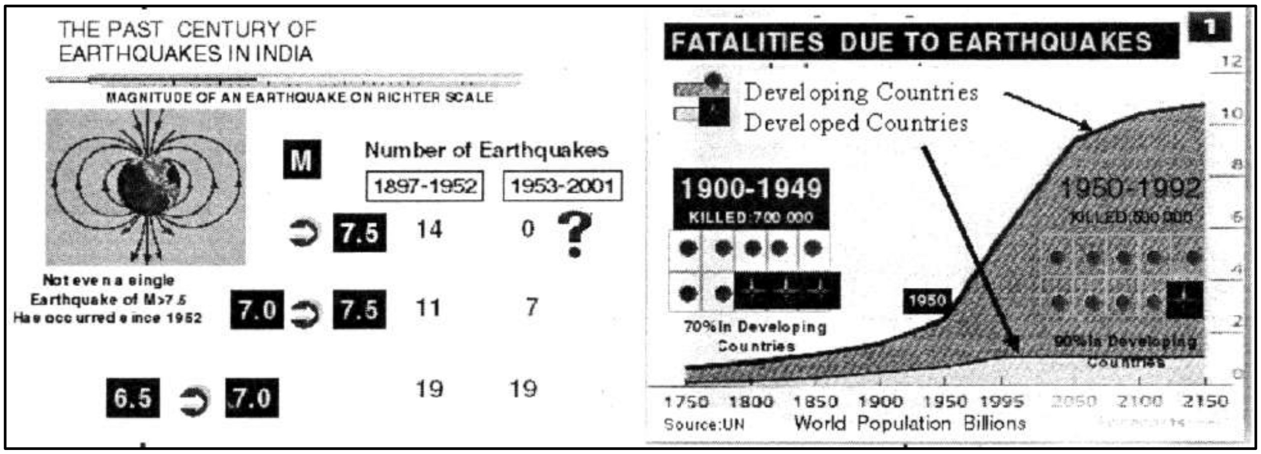
Size up the Problem

The effective change managementis possible through sound understanding of our problems. Name any disaster and there will be spectacular examples to cite from India. We must size them, classify them, and study them before setting to find solutions. Since India suffers from multiple hazards of a great variety, only a few major hazards are considered here to illustrate the point. There are States like West Bengal, which suffer from droughts, floods, cyclones as well as earthquakes and landslides. There are others like Rajasthanthat suffer from droughts, floods, desertification and heat waves. In every case, the first and foremost, we must know our problems. Magnitude and scale of the problems associated with some of the major disasters are discussed below.

- Earthquakes

With the revision of the India's macro-seismic zonation map, its every square inch is vulnerable to seismic activity. Evenbefore the revision of the map, about half of India's total area of 3.3 million sq. km fell in the five identified seismic zones. That area was higher than the seismic areas of Japan and California (USA) put together. The most earthquake prone areas belong to the Himalayan belt in the northern region from Kashmir to Assam. In the east, the earthquake prone areas are Nagaland, Manipur, Mizoram and the Kutch region, all in Zone V. The peninsular shield of India was until recently considered calm and more or less earthquake free (non-seismic), but the devastating earthquake, which rocked Latur in 1993, has exploded the myth. Seismic activity is also noticed along Narmada. Son and Godavari rivers and sometimes over the Eastern and the Western Ghats. Various faults and lineaments that are known to be active and related with earthquake activity are central thrust and boundary fault along the Himalayas and Narmada - Son Lineament in the Peninsular India. Most of the Himalayan earthquakes tend to be shallow earthquakes. Severe grounds shaking fault rupture. tsunamis. landslides. differential ground movements. liquefaction etc, thus follow causing staggering losses to human settlements. Infrastructure and environment.

Of the numerous earthquakes, those of the Rann of Kuchh (1918), Shillong (1987), Kangra (1905), Bihar - Nepal (1934, 1988) and Assam (1950) did cause extensive damage to the life and property. The death and destruction brought about by the Uttarkashi. Latur. Chamoli and Jabalpur earthquakes are a common knowledge. Some of the damaging earthquakes are listed in Table 3. Earthquakes of Magnitude 6+ on the Richter scale have frequented India every 2 years. Table 4. Lower orders of seismic activ,ity are so frequent that it has become a routine part of our lives. For instance. there have been at least 10 earthquake events in the Magnitude range 4.0 to 5.6 (on Richter Scale) just in a single year. Table 5. There has been not even a single earthquake of magnitude 7.5 and above in last half a century when there were as many as 14 in the first half of the twentieth century. Fig 1. Also. fatalities in the developing countries during the period have increased from 70% to 90 %. Fig 2.



- Floods

In India, of the total 62 major rivers, eighteen are flood prone and drain an area of 150 Mha. Floods are mainly due to heavy rainfall in association with tropical lows, depressions and cyclones. On an average 60% of the total damages due to floods in a year are in the States of Assam, Bihar, Uttar Pradesh and West Bengal. Crops in the States of Assam, Bihar, and West Bengal cover about 40% of the total area affected. In terms of the monetary value of crop loss, this is 90% of the total damage in these States. In Uttar Pradesh, crop loss is about 55% of the total damages incurred. The maximum damage recorded due to floods in In dia was about Rs. 654 crore in 1980, while that in 1965, it was only of Rs. 11 crore. The problem has aggravated considerably in the recent years. Some of the devastating floods during the period 1980-1996 are listed in Table 6.

In spite of many disastrous consequences. the floodwaters do bring about some positive effect. The alluvial soil brought by the floodwaters is a great boon to agriculture. For example, in the Sabarmati basin areas, moderate floods are beneficial as they provide the necessary moisture for raising the crops and help in suppressing the salt present in the soil. The same is also true for the rivers like the Palar, the Cheyyar, the Kunleru and the Swarnamukhi in the southern India.

- Landslides

Landslides of a great variety threaten large parts of India. The regions affected by landslides can be classified according to the severity of the landslide events; Table 7. Some of the recent landslides in India are listed in Table 8. Exceptionally heavy rainfall coupled w,ith poor drainage due to urbanization has been the cause of many major landslides, Table 9. The worst of the landslide problems come from the Himalayas and the North Eastern States of India. Then there are landslides in the Western Ghats in the south. along the steep slopes overlooking the Konkan coast. Landslides are also very common in the Nilgiris. characterized by a lateritic cap which is very sensitive to mass movements.

In the Nilgiris, in 1978 alone, unprecedented rains in the region triggered about one hundred landslides. which caused severe damage to communication lines, tea gardens and other cultivated crops. One of the valleys in the Nilgiris is called "Avalanches Valley". In this area, the majority of landslides occur in a loose cover of debris consisting of boulders. Devastating debris avalanches usually come down from a height of 199 m to 150 m. The major landslides in the Nilgiri hills are the Runnymede landslide, the Glenmore slide, the Conoor slide and the

Karadipallam slide. In recent times. casualties and damages due to landslides have increased in the Nilgiri hills. During October-November 1978, 90 people died and property worth Rs. 15 crore was damaged.

Table 3 : Some Damaging Indian Earthquakes

Earthquake and Location	Date and Time	Magnitude MM Intensity	Focal Depth (Kms)	Lives Lost and Injured	Houses Damaged
Rann of Kutch, 23.6 N,68.6 E	June 16 1819 6.45 PM	8.0	-	1543(d)	7000(t)
Bihar-Nepal	August 26 1833 5.30 PM	7.0-7.5 IX	-	414(d) in Nepal +many in India	2000(t)
Sopor, J & K 34.61 N,24.6 E	May 30 1885	7.0	-	3200(d)	
Great Assam 26 N,91 E	June 12 1897 5.15 am	8.7 0.5 g	-	1542(d)	
Great Kangra 32.25 N, 76.25 E	April 4 1905 6.20 am	8.6 X	-	20000(d)	
Great Bihar 26.6 N, 86.8 E	January 15 1934 2.00 PM	8.4	-	10,700(d)	
Great Assam 28.5 N, 97.0 E	August 15 1950 14:09:30 (GMT)	8.5	15	1530(d)	200(t)
Hindukush	June 6 1966	0.055 g	-	-	-
Anantnag	February 20 1967 8.49 PM (IST)	5.3~5.7	24	-	786(t) 25000(p)
Koyana 17.37 N, 73.75 E	December 11 1967 22:51:19 (GMT)	6.5 VIII + 0.67g	8	177(d)	40000(p)
Broach 21.7 N, 72.9 E	March 23 1970	6.0	-	20(d) 250(i)	2500(p)
Kinnaur ,H.P 32.38 N,78.49 E	January 19 1975	6.7 IX	-	60(d)	2000(p)
Indo-Nepal	May 21 1979	6.0 VI	-	-	-
Western Nepal-India	July 29 1980	6.2~6.5 VIII	-	-	-
Great Nicobar	January 20 1982	6.3	28	-	-
Cachchar 24.64 N, 92.89 E	December 30 1984	5.6	-	-	-
Dharamshala 32.1 N, 76.3 E	April 26 1986 13.0:5: 17 (IST)	5.7 VIII	10	-	-
Assam 25.14 N, 95.12 E	August 6 1988 6.36 hrs (IST)	7.2	96	-	-
Bihar-Nepal 26.775 N, 86 E	August 21 1988 4.54 hrs (IST)	6.6 VIII+	71	931(d) 3767(i) and many in Nepal	150000(t&p)
Uttarkashi 30.75 N, 78.86 E	October 20 1991 2.53 hrs (IST)	6.6 IX	12	768(d) 5000(i)	80000+(t&p)
The Latur (Killari) 18.07 N, 76.62 E	September30 1993 3.56 hrs (IST)	6.4 VIII + 0.2 g	12	7601(d) 15,846(I)	28700(t) 170000(p)
Jabalpur 23.08 N, 80.06 E	May 22 1977	6.0	35	40(d) 500(I)	8267(t) 40,000(p)
Chamoli 30.4 N, 79.42 E	March 29 1999 00.35 (IST)	6.8 VIII 0.36 g	21	103(d) 400(I)	4500(t) 25000(p)
Aksai Chin 35.34 N,78.133 E	November 19 1996 10.44.46.06(IST)	6.9	33	-	-
Bhuj 23.45 N, 70.34 E	January 26, 2001 08:46:54.8 (IST)	6.8 IX+	23.0	19000(d) 166812(I)	308700(t) 719700(p)

d - death, i - injured, t - total damage/collapse, p - partial damage
For an effective Disaster Mitigation plan hazard assessment (hazard monitoring, hazard zonation), vulnerability assessment, risk assessment, prevention (structural and non-structural measures), preparedness activities have to be strengthened.

Table 4 : Earthquakes of Magnitude 6+ on Richter Scale during 1991-2001 (Ten years)

Date	Location	Magnitude
October 20, 1991	Uttarkashi, U.P	6.6
September 30, 1993	Latur, Maharashtra	6.3
May 22, 1997	Jabalpur, M.P.	6.0
March 29, 1999	Chamoli, U.P	6.8
January 26, 2001	Bhuj, Gujarat	6.9

Table 5 : Seismic Activities in India during 2000-2001 (One Year)

Date	Location	Magnitude (Rs.)
September 05, 2000	Koyana, Maharashtra	5.0
September 12, 2001	Bhavnager Distt, Gujarat	3.8
October 09, 2000	Andaman Sea	5.4
October 17, 2000	Jabalpur, M.P	5.2
November 05, 2000	Andaman Islands region	5.0
December 12, 2000	Idukki Distt, Kerala	5.0
December 24, 2000	Rann of Kutch	4.0
January 07, 2001	Idukki Distt, Kerala	4.8
January 29, 2001	Karnataka	4.3
September 25, 2001	Tamil Nadu	5.6

Cloudbursts and flash-floods accompanied by heavy rainfall is the main cause of landslides in some parts of India. In the Sikkim Himalaya for example. the annual rainfall ranges between 3500 mm and 5000 mm of which 80% is concentrated in the four monsoon months. Rainfall is often punctuated by cloudbursts. which do last from a duration of a few minutes to as much as a couple of hours. and leave behind a trail of devastation. Cloud bursts of intensities exceeding 1000 mm in 24 hours trigger mass movements practically under any circumstances, Table 10. In the Himalaya during major landslides, high-speed mudflows and avalanches occur with a speed ranging between 3 m to 50 m per second. Accumulation of boulders and landslide debris often block the narrow river passages. This builds up reservoirs of trapped water, which ulti mately force the debris out, but in the process, triggers more landslides in the surrounding hill regions. The famous Alaknanda tragedy provides a striking example of breach of landslide dam in Patal Ganga, which triggered a flood wave down river Alaknanda to cause unprecedented deluge, Bhandari (2001).

Vast areas of the Himalayan Mountains including western Sikkim, Kumaon, Garhwal and Himachal Pradesh, are getting robbed of the protective vegetation cover. The deforested slopes not only have increased soil erosion but also landslides. Statistics concerning the number of landslides occurring each year are not available at a single place. However, scientific observation in north Sikkim and Garhwal regions in the Himalaya clearly reveal that there are an average of two landslides per sq. km per year and annual soil loss is about 2500 tonne per sq. km.

Based on the general experience with landslides, a rough estimate of loss in economy is of the order of Rs. 200 crore to Rs. 300 crore per annum, at the current price for the country as a whole. In Sikkim, a large number of people are killed every year and the number of injured is also quite high. Devastating landslide in 1880 in Nainital. which travelled one km in 30 seconds. killed 150 people and demolished a number of tourist huts in the town. In Sikkim alone, restoration works because of the major landslides were estimated to cost Rs. 14 crore in 1968 and Rs. 8 crore in 1973, respectively. The indirect monetary loss to people due to snapping of communication links was also quite high. In the Darjeeling Himalaya, the flood of 1968 created a number of devastating landslides killling thousands of people. The landslides occurred over a three-day period with precipitation ranging from 500 mm to 1000 mm. The 60 km mountain road link to Darjeeling was cut off at 92 placed and the tourist industry suffered greatly. The great Malpa tragedy of August 1998 provides a great example of how a notorious landslide could be, Bhandari (2000).

Table 6 : Details of Devastating Floods that occurred during 1980-1996(NCDM 2001)

Duration	Area Affected	Synoptic Systems
17-23 July 1980	East Uttar Pradesh	Low Pressure area
7-27 August 1980	Central & SouthwestUP	Land depression
4-10 September 1980	Southeast Uttar Pradesh	Land depression
18-24 September 1980	South Orissa	Deep Depression
18-24 September 1980	Andra Pradesh	Deep Depression
18-24 September 1980	Central Uttar Pradesh	Deep Depression
9-15 July 1981	Gujarat	Low Pressure area
16-22 July 1981	Rajasthan	Low Pressure area
9-29 July 1981	Uttar Pradesh	Low Pressure area
6-12 August 1981	East Uttar Pradesh	Cyclonic storm
3-9 September 1981	East Uttar Pradesh	Land depression
19-25 August 1982	East Madhya Pradesh	Well marked low pressure area
28-31 August 1982	North Orissa	Depression
30 Aug-3 Sep. 1982	Uttar Pradesh	Depression
20-23 June 1983	Gujarat	Land depression
11-17 August 1983	West Maharashtra	Trough off Maharashtra coast
18-31 August 1983	Northeast Uttar Pradesh	Low Pressure area
15-19 September 1983	Marathwada & west Maharashtra	Low Pressure area
8-14 September 1983	Southeast Uttar Pradesh	Land depression
21-27 June 1984	West Bengal	Well marked low pressure area
28 June- 11 July 1984	Uttar Pradesh	Low pressure area
23 Aug. 5 Sep. 1985	Bihar	Low Pressure area
12-25 September 1985	East Uttar Pradesh	Land pressure area
11-18 September 1985	Bihar	Well marked low pressure area
17-23 July 1986	Bihar	Land Depression
7-20 August 1986	North Andra Pradesh	Deep Depression
23-29 July 1987	Bihar	Low Pressure area
30 July –20 Aug. 1987	North Bengal	Cyclonic circulation
3-16 September 1987	Bihar plateau	Well marked low pressure area
15-19 July 1988	North Gujarat	Cyclonic Storm
25 Aug.- 7 Sept. 1988	North Gujarat	Cyclonic Storm
21-28 September 1988	Punjab	Low pressure area
19-26 July 1989	Coastal Andra Pradesh	Depression
13-26 July 1989	Western Maharashtra	Depression
1-6 July 1990	Northwest Rajasthan	Low pressure area
16-29 August 1990	Vidarbha	Depression
23-29 August 1990	Gujarat	Depression
25-31 July 1991	Vidarbha	Deep depression
5-13 September 1991	North Bengal	Cyclonic circulation
16-22 July 1992	Gujarat	Cyclonic Circulation
10-16 September 1992	Jammu & Kashmir	Cyclonic Circulation
10-16 September 1992	East Uttar Pradesh	Well marked low pressure area
1-14 July 1993	Gujarat	Cyclonic circulation
8-14 July 1993	Punjab	Cyclonic circulation
15-20 July 1993	Bihar plateau	Well marked low pressure area
15-21 July 1993	North Bengal	Well marked low pressure area
9-15 September 1993	Uttar Pradesh	Well marked low pressure area
14-27 July 1994	Gujarat	Low pressure area
1-7 September 1994	Orissa	Low pressure area
1-7 September 1994	Vidarbha	Well marked low pressure area
17-23 August 1995	Bihar	Low pressure area
5-15 September 1995	Harayana	Low pressure area
20-26 June 1996	Rajasthan	Low pressure area
25 July-7 Aug. 1996	Bihar	Low pressure area

Table 7 : Macro-Zonation of Landslides (Rao, 1997)

Hill Range	Landslide Incidence Potential	Proximate Causes
Himalayas	Very high to high	Predominantly natural increasing due to human Intervention
North Eastern Hill Ranges	High	Predominantly Natural
Western Ghats and Nilgiris	High to moderate	Human intervention dominant Natural causes Secondary
Eastern Ghats	Low	Predominantly due to Human intervention
Vindhyas	Low	Predominantly due to Human Intervention

Table 8 : Some Recent Disastrous Landslides in India (Gupta, 1997)

Location	Date / Year	Damages
Kullu, Himachal Pradesh	Sept, 1995	About 22 persons killed and several Injured
Malori, Jammu	June, 1995	six persons lost their lives National Highway-IA badly damaged
Aizwal, Mizoram	May, 1995	25 People Killed, Road severely Damaged
Kashmir	Jan, 1994	National Highway-IA severely damaged, closed for several days
Nilgiri Hills	Nov 1993	about 40 people were killed, property worth several lakhs damaged
Kohima, Nagaland	Aug 1993	many people injured and over 200 housed destroyed in landslides on NH-39. Kohima was cut-off from rest of the country.
Kalingpong, West Bengal	Aug 1993	40 People killed, heavy loss of property
Itanagar, Arunachal Pradesh	July 1993	25 people buried alive, road Disrupted
Aizwal, Mizoram	June 1993	four persons buried in the debris
Nilgiri Hills	Nov, 1992	Road network damaged and property worth Rs 5 million was destroyed
Assam	July 1991	300 people killed, damaged roads and buildings worth million of rupees.
Nilgiris	Oct 1990	36 people killed and several injured. Several buildings, roads damaged and communications disrupted
Himachal Pradesh	March, 1989	At Nathpa, about 500m of road was damaged. Slide is still active. Road is frequently blocked due to sliding
Nashri, Jammu & Kashmir	Jan, 1982	the slide is repeated every year since 1953. Road and communica tion lines are disrupted.
Himachal Pradesh	Dec 1982	at solding Nallah, 3 bridges collapsed in the last decade. About 1.5km of NH-22 vanished.

Table 9 : Exceptionally Heavy Rainfall and Devastating Landslides, Bhandari (1987)

Place / Area	Date	Consequence of Heavy Rainfall
Darjeeling and Jalpaiguri	3-5 Oct, 1968	Widespread landslides and other mass movement caused death and devastation all over
Uttar Pradesh	July, 1970	Alaknanda River caused considerable loss of life among pilgrims. Many bridges, houses and an entire village were washed away.
Uttar Pradesh	Sep. 1970	Landslides & house collapses killed 223 people.
Jammu & Kashmir	Feb. 1971	Widespread landslides caused disruption of traffic & communication systems.
Jammu & Kashmir	Aug. 1972	Widespread landslides caused damage to life and property.
Jammu & Kashmir	March, 1973	Landslides cut off Kashmir valley from the rest of the country.
Shimla (H.P.)	July, 1973	Landslides cut off Shimla from the rest of the country.
North Bengal	July, 1975	Teesta, Jaldhaka and Diana rivers were in spate. Widespread landslides and floods rendered 45,000 people homeless.
Jammu and Kashmir	Sept. 1975	Landslides killed 2 labourers and disrupted transportation system for 3 days.
Darjeeling	June 1976	Teesta in floods triggering many landslides, 3 people were buried alive due to caving in of a hillock.
Jammu and Kashmir	July, 1977	Srinagar-Leh road was blocked due to landslides.
Mandi	Aug., 1977	Road washed due to heavy rainfall and flash/floods in the Beas River.

Table 10 : Record of Cloud Bursts in the Teesta Valley, Bhandari(1987)

Year	Date	Recorded rainfall (mm)	Hrs	Rate Mm/hr.	Mm/day	Event coefficient*(%)	Reference
1902	Sep, 26-27	320	24	129	310	6.2	Chandra (1975)
1915	Jun, 11-13	690	24	28.8	690	13.8	Chandra (1975)
1950	June, 12	546	24	22.8	546	20.9	Chaturvedi and Mullick (1981)
1968	Oct, 3-5	1580 (Padamchen)	36	43.9	1044	20.9	Chandra (1973)
	Oct, 5-6	465	24	19.4	565	9.3	Chaturvedi and Mullick (1981)
1969	Aug. 5	3000 (Labha-Phaperkheti)	72	41.7	1001	20.0	Chandra (1973)
		2970 (Alagarah-Gorubathan)	96	30.9	742	14.9	Chandra (1973)
1972	May, 17	168	1	168	4032	80.6	Chaturvedi and Mullick (1981)
1977	Jun, 10	320	12	19.2	460	9.2	Chaturvedi and Mullick (1981)
1978	May, 20	225	3	75	1800	36	Chaturvedi and Mullick (1981)

*Event Coefficient (Ce) = (Precipitation record of the event/mean annual precipitation) Mean annual precipitation = 5000 mm.

- Avalanches

Snow avalanche are matters of very serious concern to us. Especially in the high altitude regions of the Himalaya.Some examples of avalanche disasters are given in Table 11.

- Cyclones

The east and west coasts of India are annually attacked by cyclones taking a heavy toll of life and property. These cyclones are usually associated with very strong wind, rain and eccasisnallv high tidal waves. The pre-monsoon cyclonic storms, between April and May, as well as the post-monsoon cyclonic storms, between October and December, are common. Cyclonic storms also occur in the months of August and September. i.e. during the monsoon period, but their frequency is rather low. The east coast cyclones usually originate in the Bay of Bengal. Andaman Sea and in South China Sea, and move towards the coasts between Tamil Nadu and Orissa or West Bengal. The cyclones hitting the west coast usually originate near Sri Lanka and Lakshadweep and move north or northeast and usually hit Kerala or Saurashtra Coast. The east coast cyclones, after crossing the land. cause heavy rain on their way and emerges as depressions or lows in the Arabian Sea, or fade out in Himalayan Highlands as upper air circulations. The areas most susceptible to cyclone attacks on the east coast are Tamil Nadu, Andhra Pradesh, Orissa and west Bengal. On the other hand, Kerala and Southern Gujarat are the only affected States on the west coast. Some of the severe cyclones are listed in Table 12. The frequency of tropical cyclones with particular focus on those of the Bay of Bengal and the Arabian Sea is reported in Table13.A distinction befween tropical storms and cyclonic winds emerge, based on the range of mean sea level pressure, Table 14.

- Storm Surges

Cyclones are usually accompanied by windstorms and rain, and storm surges. For instance, the cyclone which hit the coast of Orissa on 29th Oct 1999 unleashed high winds and rain, and triggered storm surge as high as 9m, killing more than 10,000 people, flooding large areas, destroying crops, disrupting rail and communication links, and affecting about 13 million people. It at once revived the memory of the 1970 cyclone of Bangladesh, which had brought about deluge and devastation following abnormal rise of sea level due to storm surges. The worst coastal flooding occurs usually when the peak storm surges coincide ride over high tides.

Table 11 : Some Avalanche Disasters (NCDM, 2001)

Location	Year	Damages
Himachal Pradesh	Sept, 1995	Due to avalanche, Huge chunk of debris came down which later changed into flood.
Himachal Pradesh	March 1991	Tinku avalanche takes place every year 4-5 times from Jan-March, road was blocked for 40 days in 1991.
Jammu & Kashmir	March, 1988	70 People killed, communication lines disrupted
Ladakh, J & K	Dec, 1984	27 soldiers were killed under avalanches generated by artillery fire
Jammu & Kashmir	Dec, 1982	Over 100 people killed. Communication lines disrupted
Lahaul & Spiti, H.P.	March, 1979	About 237 people killed. Communication Lines disrupted.
Himachal Pradesh	March, 1978	30 People killed, Road and Property Damaged
Lahaul & Spiti, H.P.	Jan, 1975	Earthquake shocks triggered avalanche of great dimension over extensive areas damaging roads, houses etc.

Table 12 : Some severe Cyclones in India (NCDM 2001)

Location	Date / Area	Damages
Bengal	Oct, 1847	75,000 people and 6000 cattle killed. Damage to property and communication system.
Bengal	Oct, 1874	80,000 people killed heavy loss to property and communication disrupted.
Andra Coast	Nov, 1946	750 people and 30,000 cattle lost life. Damage to property and roads also reported.
Tamil Nadu	Dec, 1972	80 people and 150 cattle killed and communication disrupted.
Bengal	Sept, 1976	10 people and 40,000 cattle lost life. Damage to property including communication.
Andra Coast	Nov, 1977	8547 people and 40,000 cattle lost life. Communication disrupted heavy loss to property.
Tamil Nadu	May, 1979	700 people and 3,00,000 cattle lost life. Communication disrupted.
Orissa	Sept, 1985	84 people and 2600 cattle lost life. Land of 4.0 hac damaged.
Andra Coast	Nov, 1987	50 People and 25,800 cattle lost life, 8400 houses, roads and other communication disrupted.
Orissa	June, 1989	61 people and 27,000 cattle lost life, 1,45,000 houses, communication disrupted.
Andra Coast	May, 1990	928 human lives lost, 14,000 houses damaged.
Tamil Nadu	Nov, 1991	185 people and 540 cattle dead, Property including roads worth 300 Crores damaged.
Bengal	April, 1993	Over 100 casualties, communication system including road disrupted and damaged.
Bengal	Nov, 1994	More than a thousand houses damaged in 26 villages, damage to lake and fisheries, disrupted all communication.
Andra Pradesh	Oct, 1996	1057 casualties, 6,47,000 houses damaged road network completely damaged.
Gujarat	June, 1998	1261 casualties, 2.57 Lakh houses damaged.
Orissa	Oct, 1999	10,086 Casualties, 21.6 Lakh houses damaged.

Some of the examples of storm surges of the 1990s are listed below:

- October 1994, Chennai: 304 people killed; one lakh huts and 60000 hectare of crops damaged.
- November 1995, Gopalpur, Orissa, 96 people killed; 2.84-lakh hectare of crops damaged.
- June1996, Visakhapatnam: 1979 people killed; 13.378 hectare of crops damaged.
- June 1996, between Kodiar and Diu: 47 people killed; 30.000 houses destroyed.
- November 1996, Kakinada: 978 people killed; 1.375 missing, 6.4 lakh houses and 1.74 lakh hectare crops damaged.
- June 1998, Kandla 550 people killed; caused great destruction.

Countries bordering Bay of Bengal and the Arabian Seasuffer frequently from storm surges. Some of the contributing factors especially in the Bay of Bengal are (a) shallow coastal waters (b) densely populated low lying areas and islands (c) innumerable inlets in the rather complex coast line dominated by Ganga-Brahmputra-Meghna, the world's largest river systems. For dealing with cyclones, inter alia, special attention is necessary on issues such as :

- Reliable monitoring of storm surges in the Bay of Bengal and forecasting of storm surges.

○ Estimation of the height and time of peak water level at the coast and the extent of area vulnerable to inundation.
○ Public awareness andtraining of vulnerable peoplefor matured response to warning in the event of red alert.

The subject is important because more than half a million people have reportedly been killed by storm surges in the marginal seas of the Indian Ocean in this century alone.

Table 13 : Frequency of Tropical Cyclone by Areas and Months (UNDRO 1991)

Northern Hemisphere

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Western North Pacific	0.5	0.2	0.5	0.7	1.1	1.7	3.9	5.1	4.5	3.8	2.7	1.1
Eastern North Pacific	–	–	–	–	0.3	1.3	2.1	2.0	2.4	1.4	0.2	–
Bay of Bengal & Arabian sea	–	–	–	0.3	0.7	0.6	0.5	0.4	0.4	1.0	1.1	0.4
North Atlantic Ocean	–	–	–	–	–	0.5	0.5	1.8	2.7	1.7	0.4	–
Western North Pacific	2.0	2.0	1.9	0.7	0.1	0.1	–	–	–	–	0.1	0.7
Eastern North Pacific	0.5	0.5	1.8	2.7	1.7	0.4	–	–	–	–	–	–

Table 14 : Classification of depressions and cyclones (UNDRO 1991)

Classification	Range of Maximum wind speed (mph)	Range of mb (mb)
Depression	28-31	3.0 – 3.4
Deep depression	32-38	3.5 – 5.9
Cyclonic Storm	39-54	6.0 – 8.9
Severe Cyclonic Storm	55-73	9.0 – 15.9
Severe Cyclonic Storm of hurricane intensity	>74	>16

❑ Drought

Drought is usually a disaster in slow motion. It is the consequence of rainfall deficiency and of low air humidity. Droughts do occur in several parts of India because of the abnormalities in atmosphere circulation. The late start of monsoon. prolonged break, and early withdrawal of monsoon are known to result in drought. The areas of recurring concern are Gujilrat, east Rajasthan, parts of Punjab, Haryana, west Madhya Pradesh, Central Maharashtra, interior of Karnataka, north-west part of Bihar, and part of Tamil Nadu. The recent drought in Gujarat is enough to stir our imagination.

- Mining & Forest Fires

The problem of fires in mines is as old as the history of mining itself. In India, The first fire was reported in the Raniganj Coalfields in 1865. The scenarios of fire in Indian mines are highly disturbing and complex. Some fires even communicate to the surface through cracks developed in the subsided strata. Recent occurrence of New Kenda mine disaster at Raniganj Coalfield took toll of 55 miners. In 1994, a study conducted by CMRI, Dhanbad revealed that there are about 196 fires existing in different coalfields of India. In Jharia Coalfield, 70 "active fires" are reported covering an area of 9 sq. km. The mine fires in the coalmines have been found to originate due to spontaneous heating of coal in underground mines due to improper ventilation; leakage in air through cracks developed up to the surface due to subsidence; spontaneous heating of loose exposed coal in benches in opencast mines; spontaneous heating of coal in the stacks; spontaneous heating of carbonaceous shales in overburden benches and dumps; negligent acts, e.g., dumping of hot ashes, making of coke at quarry edges or along outcrops of coal seams and over subsided areas, etc;breakdown of insulation of electrical cables; fires in conveyor belts and explosions; explosions and crossing of fire from neighboring mines.

We need to categorize coals in the Indian coalfields with respect to their susceptibility to spontaneous heating; develop methodologies for increasing/extending incubation period of coal seams; engineer techniques of quick sealing of fire areas; introduce suitable coatings for minimizing contact of exposed coals to air; Indegenisation of continuous monitoring systems for mine atmosphere with provisions to give ample warning in case of abnormalities; designs leak proof quick erecting stopping. Development of methodologies for fighting different types of mine fires both in opencast and underground mines also deserves attention. The strategies for disaster prevention in respect of the mine fires should address (a) Preventing spread of the existing fires and their mitigation, (b) Integrating preventive measures in mine planning and design, (c) Provision of periodical technical audit of the mines to check deviations ftom the planned activities, (d) Creating a fire mitigation fund for meeting the expenditure on the mitigation of the existing fires (e) Permitting the mines to sell the reclaimed land at prevailing rates to recover the costs of reclamation and development of the land. Coalfields and the actions being taken for their mitigation and (f) Strengthening the Mine Fire wings of the coal companies.

India, the forest fires are so common that their news come and go in a flash, year after year. For instance, in 1995, although the forest fires of UP hills destroyed more than 735,000 hectare of the forest wealth, it was briefly reported in the Press and forgotten thereafter. The so-called slash and burn method is still considered to be by far the cheapest means of clearing a forest to promote re-growth of diverse types of vegetation of different ages. For the poor farmers, ash residue is, in fact, more or less a free fertilizer.

Learn From Past Experience

Learning is an endless process. In the context of disasters, the real lessons are learned only when every disaster is looked upon also as a great learning opportunity. No laboratory in the world, howsoever well organized and modern, can ever duplicate, not to speak of excelling the potential of live laboratories created by every full-scale disaster. Ordinarily, we learn from textbooks and classroom teachings, or by trial and error, or occasionally by accident or experiment. Learning through training programmes has been another popular way. At the end of such training programmes, everyone becomes a certified expert but his knowledge is usually of pedagogic value seldom updated! The real progress by learning however comes when an inquisitive mind begins to-leek for hard facts in Nature's laboratory with a spirit of scientific inquiry. The narratives of the eye witnesses of disasters or those who had to pass through the traumatic times because of disasters do teach us a lot be sides providing very useful clues to reconstruct the whole story. More enlightened among us learn as much from their own mistakes and experience. as they do from the mistakes and experiences of others. Garbachov once said that a thorn of experience is worth a forest of instructions!

Disasters, almost in every case, do offer a new, live laboratory to test our ideas on the whole range of issues. and innovate. Every disaster provides poiicy makers the heaven sent opportunity to put their policies on the anvil. Professionals charged with the responsibility to counter disasters. likewise. get a good opportunity to introspect and see by hindsight where their preparedness plans and strategies have failed them and why? Scientists do get their food for thought as also fresh ideas and the rare ammunition to re-write their research proposals towards fulfilment of their insatiable quest for improved, cost effective solutions. Since dead tell no tale. those who survive (while cursing their own misfortunes), learn first hand. The learning process strengthens the weak, and arms the strong.

Tragedies nevertheless leave behind priceless lessons. which must be learned in order to deal more effectively with the future recurrences. It is now possible to capture or create the travails of such tales as they occur with all their important features captured and backed by life-like sound and visual effects, thanks to multimedia and the tools of modern information technology. It is in deed a paradox that the more we learn, the more remains there to be learned. When exposed to the after math of a disaster, indeed the sky becomes the limit to which the learning process could go on and on, and there is always enough to learn. For everyone at all levels of hierarchy, at all times. In the ultimate analysis, the best way to learn is by closely observing Nature and the way it works and by being always vigilant of the consequences of disobeying Nature. It has rightly been said that Nature to be commanded must be obeyed first!

A very large number of institutions in India, including the Disaster Management Institutions are contributing significantly to the overall learn ing process. However, we need innovation in our ideas, which can best be achieved by transforming existing institutions in to smart organizations, creating centres of excellence and nurturing them, protecting intellectual property and rewarding innovation both in the formal and informal sectors.

Tap the Best in Science & Technology

The fundamentals of natural disasters are not yet fully understood. For instance, how the forces acting within the crust of the earth and the movement of the planets combine to create earthquakes? Why the earthquake belts and the belts of volcanoes coincide, as they seem to do? Why the extinct volcanoes are slowly but surely becoming active? How an earthquake triggers a landslide or tsunamis? How does a volcano induce a tsunami? Why the track of a cyclone plays dice with Planet Earth? And there are a host of other such questions, which the science will have to answer for satisfactory engineering and technology interventions to develop. Some of these aspects are covered in a paper by the author, (Bhandari, 1999).

Fundamental research is essential for probing deep into some of the gray areas, which have profound bearing on our understanding of natural disasters. Research on, for instance, global warming; prediction of monsoon; EI Nifios, Sea level changes; and forecasting of earthquakes, landslides, typhoons, volcanoes, floods etc. all constitute very important areas to work on. There is also an urgent need to develop appropriate instrumentation and measurement methodology as also the scales against which magnitudes and intensities of the hazardous events like earthquakes and cyclones could be measured. Mind boggling advances in Science & Technology provides the hope.

Let us remember that never before in the history of human race has the science and technology been so powerful, penetrating and visible as it is today. Furby, a $30 toy that talks to humans contains more processing power than the lunar module that landed on the Moon some 30 years ago. As James Heath says, Science has made it possible to compress computational power of 100 workstations on the size of a grain of sand. It certainly has the potential to cap or crack any problem, no matter how grave, provided technology is honestly used as an engine of growth.

Remember that it is the abject poverty and not the choice that drives people to live in risk prone areas, and a tighter coupling between scientific progress and social progress alone could reverse the trends of environmental degradation. What is good for science is good for humanity, and therefore, all we need to do is to address the basic question of what, and whom it is for? We need right kind of technologies. Technological Interventions derive their mussels from the high level of technology market in the world today. For instance, there was a time when we relied on rather crude methods of surveying and mapping which were not only time consuming but often unreliable. Today, we have powerful ground penetrating radars, which X-ray ground with same case as the doctors X-ray a human body. The GPS provides a powerful tool to monitor behaviour of locations all over the globe. There are also very reliable early warning systems based on actual measurements using powerful sensors. The under water vehicles available today, effortlessly probe into the mysteries of deep seas, to depths as high as 6000 m. Space borne synthetic radar has changed the rules of relief support and damage assessment exercises. There are observatories on altitudes as high as 5000 m There are underground measurements being done to depths as lows as 4450 m.

The other big hope comes from the great impulse of some of the landmark events for Global Environmental Action, such as the UN Declaration of 1990's as the International Decade for Natural Disaster Reduction; the 1992 Earth Summit, and the 1994 Cairo Conference on Population. The golden concept of sustainable communities and eco-citizens coupled with trans-boundary and trans-generation strategic thinking are the outcome of the intensive dialogue across the globe.

Accelerate The Pace of Mapping

Without maps we reach nowhere. With small-scale maps we reach as far as we have. And with large-scale maps we will reach where we ought to be. Mundane methods of mapping will not take us very far. It would be best to look around and find out how others have tackled this issue. The first time ever a new world map in three dimensions is in the making. It is now possible to have digital maps of exceptional precision. For an area of 30 m × 30 m, a precision of up to 6 m of possible deviation is all that can occur. This provides a staggering contrast with a deviation of 100 m of height for 1000 sq km. Shuttle Radar Tomography Mission (SRTM) is yet another break through in remote sensing. According to DLR Cologne. hydrologists can exactly determine areas of flooding. geologists can figure out smallest changes in earthquake zones, ecologists can receive reliable information on the extent and condition of vegetation, and climatologic are able to improve their forecast models.

Similarly Air borne altimetric Light Detection and Ranging, popularly known, as LIDAR has already become a versatile player in topographic data gathering for geo-information projects. There have been mind-boggling improvements in Cameras and photographic techniques. Small format aerial photography by 35 mm automotive camera is light enough to be lifted by a kite as it clicks every few seconds in a hand free operation. Remotely piloted unmanned vehicles have also proved to be assets in aerial photography. It can be operated at altitudes of less than 150 m even in residential areas where a full size aircraft is restricted to a mi nimum altitude of 300 m. The first very high-resolution digital multispectral air borne stereo is acknowledged for its high photogrammetric accuracy (15-20 cm), very high spatial resolution (10 cm from 2500 m flight altitude, small dimensions. low mass. low power consumption and a robust design. It turned out to be superior to film based camera systems, as it provided easy access to digital data and high radiometric resolution. All this became possible because of Russian 96 Space Mission to Mars.

Space technology in India is well developed. We could however continue to be front rankers by taking note of the state of the art. For instance we are inspired by TNO built star mappers who keep satellites in place in relation to the earth. The novelty comes from the principle of redundancy. Each component of it, except for the lens, has its own back up part. If a certain part fails to operate. the other will take its place so that the satellite can simply continue operating. Similarly we are inspired by the Chinese prototype of 6000 m under water vehicle. which is a break through in deep-sea investigations. Italy-Nepal Observatory. The highest in the world too is a break through in overland investigations.

It is important to think to scale especially when it comes to hazard and risk evaluation. The suggested scales are given in Table 15.

Respect Building Codes and Byelaws

National Building Code of India awaits revision for the last 16 years. It should be expedited. Apart from following the prevalent codes in letter and spirit, it is also important to stipulate clearly the criteria adopted for assigning earthquake intensity values and classify structural damages accordingly. A recent example from Bhuj earthquake is cited in Tables 16 and 17.

Engineer Rapid Rescue & Relief

The strategy for quick response would embrace this consideration fully. Apart from standard operating standards, there has to be apt response to contingency plans. The training needs of first responders, rescue and relief teams, doctors, Para military forces, disaster managers, NGOs and others can never be over-emphasized

The communication systems need toning up .The creation of no fail corridors to secure vital installations is also important. The national, the states and the districts disaster response plan should cover this aspect adequately. One must go we" beyond this to ensure how the traffic will be regulated, Table17.

Preparations for relief and rescue must necessarily be made in peacetime. What is really essential is an integrated approach of which relief and rescue should emerge as the last weapon.

Invest Imaginatively in post disaster remediation

The best way to decide on priorities is to think global and act local. The priorities wi depend on a combination of factors such as the gravity of the problem, risks associated with the problem and stakes involved, financial requirements vis-a vis available budget, items of competing priorities and the political will at any given point of time. Expending huge sums of money in achieving a partial remedy to a seemingly intractable problem may not always be wise. When the problem at hand is huge and complex, and risks are likely to persist even after technological intervention, it is better to invest more on public awareness, early warning, and construction of safe heavens. On the other hand if a problem is in its infancy, a stitch in time through immediate technological intervention could pay rich dividends, Table 19.

Very often retrofitting or strengthening of buildings is taken as the ultimate answer. There are a number of situations where such initiative will fail to take out the centre of gravity of the problem. For instance, during the Alaknanda Tragedy, when a the flood waves surged downstream upon bursting of the landslide dam, it did not make any distinction between buildings retrofitted and the buildings not retrofitted. Similarly when the massive rock avalanche at Malpa hurtled down the slope to bury nearly 250 people, it also took the toll of good as well as bad buildings.

Table 16 : Criteria Adopted for Assigning Intensity Values (Sinvhal et al., 2001)

Building Type	Grade of Damage at Different MMI Intensities				
	VI	VII	VIII	IX	X
Traditional rural houses in random rubble stone masonry	Moderate	Heavy	Destruction	Collapse	Collapse
Load bearing masonry wall buildings with reinforced concrete beams and slabs of					
* Three story	Slight	Moderate	Heavy	Destruction	Collapse
* Two story	Slight	Moderate	Moderate	Heavy	Destruction
* Single story	–	Slight	Slight	Moderate	Heavy
Temples	–	Heavy	Collapse	Collapse	
Municipal Overhead Tanks	–	–	Slight	Slight	Moderate
Roads and Road Bridges	–	–	Slight	Slight	Moderate
Industrial buildings on firm ground	–	–	Slight	Moderate	Heavy
4- to 6-storied reinforced concrete buildings not having suitable architectural configuration for earthquake resistance	Heavy	Destruction	Collapse	Collapse	Collapse

Table 17 : Classifications of Structural Damages (Sinvhal et al., 2001)

Intensity	Classification of Structural Damage as per IS: 1893-1984		
	Type of structure	Grade of Damage	Quantity
X	C	4	Many
		5	Few
	B	5	Many
	A	5	Most
IX	C	3	Many
		4	Few
	B	4	Many
		5	Few
	A	5	Many
VIII	C	4	Many
		3	Few
	B	3	Most
	A	4	Most
VII	C	1	Many
	B	2	Many
	A	3	Most
		4	Few
VI	B	1	Many
	A	1	Many
		2	Few

INTENSITY 'X'
Places visited : Bhachau[1] Samakhiali[2], Rapur[3], Manfara[4], Kado[5], Amardi[7], Dudhai[9], Kharoi[10], Trambau[11], Vondh[12], Adesar[13], Bhimasar[14] (Rapar).

Notable Structural Damage : In Manfara, Trambau, Bhachau And Samakhiali, Rapur even well built RC structures were totally devastated. In all RC Buildings even those under construction, all columns and joints buckled and failed. A large number of 66 KVA GSEB substations collapsed.

Notable Ground Damage : Extensive liquefaction resulted in mudflows in Chang Nadi for several kilometers between Manfara-Chobari villages. Water fountains were reported in Bhachau, Samakhiali, Amardi, Dudhai villages. Fissures in roads within and roads leading to this region.

INTENSITY 'IX'
Places visited : Anjar0[15], Ratnal[16], Santalpur[17], Surajbadi Bridge[18]

Notable Structural Damage : Anjar, a 450-year-old town, was destroyed in the Anjar earthquake of 1956. New housed were later raised on old foundations. Additional stories were added on top of these. Such construction in the congested old Anjar was destroyed. Isolated 4 storied modern buildings could be seen with moderate damage.

Notable Ground Damage : The soil below surajbadi bridge is marshy. Fissures and water fountains were observed here. Many few pools of water were observed between Bhachau and Bhuj, north of the road and elongated along it. These were about 3 meters long and 2 meters wide. These and other water bodies were also seen in satellite images.

INTENSITY 'VIII'
Places visited : Kukma[19], Bhuj[20], Madhapar[21], Sukhpur[22], Kotada, Lodai[23], Ghadsisa, Gandhidham[24], Kandla[25], Radhanpur.

Notable Structural Damage : In Bhuj, dense clusters of two and three storey houses and shops existed on both sides of narrow streets, like in Vaniawadi locality. These collapsed on to the street and blocked all rescue and relief efforts.

Notable Ground Damage : Fissures in roads were as wide as 15-20 centimeters at several places, e.g. near Ghadsisa. Liquefaction and water fountains in Kaswali Nadi near Lodai.

INTENSITY 'VII'
Places visited : Nakhtarana[27], Naliya[28], Undot, Khawda[29], Mandvi[30], Jamnagar[31], Halvad[32], Marvi[33], and some pockets of Ahmedabad[34].

Notable Structural Damage : Poorly constructed GSEB houses in Nakhatrana were destroyed. Water fountains were witnessed at Undot at the time of the earthquake near Mandvi. Between Moti, Undot and Ghadsisa several culverts were broken and temples destroyed.

Notable Ground Damage : Nil

INTENSITY 'VI'
Places visited : Surendranagar[35], Viramgam[36], Rajkot[37], Gandhinagar, Ahmedabad[37], Surat[39], Vadodara[40], Broach[41], and the rest of Gujarat.

Notable Structural Damage : Nil

Notable Ground Damage : Nil

Table 18 : Examples of Traffic Control Following Disasters (PIARC 1996)

Cause of Damage	Type of Traffic Control					
	Complete closure to traffic	Control of vehicles and loads	Night-time restrictions	Speed restrictions	Alternating one-way traffic	Lanes closed
Collapse	*		*			
Crack, settlement, faulting (step difference), swelling	*	*		*		*
Rock fall, collapse of slope	*		*			
Dipping, moving of upper structure, falling of bridge	*	*			*	
Damage to support	*	*				
Crack, concrete peeling from pier or abutment body, damage to foundation		*				
Faulting (step difference) of bridge approach	*	*			*	*
Damage to underground pipes	*					*
Collapsed fence and stone masonry	*					*
Leaning and collapsed electric poles and trees	*	*				

* Indicates applicable traffic control

Establish Disaster Knowledge Network

Large tracts of our country are perennially threatened by disasters of a bewildering variety in diverse geoclimatic settings. It is, therefore, a matter of big challenge for us to evolve suitable decentralized mechanisms including a network of networks to meet the pressures of demand for prompt decision-making. A knowledge network is the most modern way that enable people and parties to communicate with one another, share ideas, information and resources on specific topics. Continuous inflow of new information and fresh ideas propel more ideas, and thus help develop clearer concepts. For rapid progress, the new data and findings should necessarily flow back into the learning loop and vice versa. It's important to remember that the critical part is not the network (its hardware or software) or the so-called finished product (such as for example a database or a network of databases) but the culture of interactive exercise that makes people (or the cluster of people) or communities share concerns and solve specific problems Important to them by collective wisdom. in a spirit of cooperative endeavour. And such an interactive dialogue should eventually become a way of life, with continuous value addition to the databases. and efficient networking.

Table 19 : Tuning Engineering Intervention to the Human Response in Disaster Threatened Areas

Human Response	Problem Statement	Examples	Engineering Intervention
Living or borrowed life (Most dangerous areas)	Area so unstable that Costs of remediation Usually Prohibitively high and unaffordable	Earthquake Zones IV Human Habitat on : Fragile slopes and landslides; cyclonic belt	Public Awareness Preparedness Contingency Plan
Living on Razor's edge(Dangerous area)	Area so unstable that Costs of remediation Usually very high	Living on dormant landslides in very high hazard zone or in areas earthquakes are feared	Early Warning Preparedness Contingency Plan
Living on tentor hooks (Unsafe area)	Engineering Intervention possible	Living on potential landslides with clear symptoms of impending; Failure Flood ravaged areas	Early Warning Retrofitting Contingency Plan
Living on engineered hopes (Stabilized area)	Engineering Intervention recommended	Unsafe buildings whose safety is suspect	Retroffing Remediation
Living on stable, dry ground	Carefree Living	Little probability of Hazard	Maintenance
Living on the top of world	Carefree Living	No Hazards	Upkeep

India really needs is a network of networks in which it is to be ensured that knowledge information is adequately filtered and authenticated, and knowledge is not lost in the haystack of information but gets intimately connected with the great learning exercise that normally goes with it. Indeed, as Francis Bacon has said, Knowledge is Power, and in apt use of this power lies our hope for the future. How efficiently can harness the great tide of knowledge that is currently sweeping the whole world?

The Knowledge Network will provide the answer

Knowledge Network is, by design, expected to foster, promote and sustain a dialogue not only between the haves and the have-nots but also between any combinations of groups, vertically and laterally. For example, continuous interaction is essential between the professionals and those at the grass-roots level. or between the policy makers and the professionals, or between the policy makers and the community based organizations, and so on. The National Disaster Knowledge Network is, therefore, expected to act as a 3-Dimensional organizational tool to collect. collate, organize, catalogue and disseminate (spread) information as a prelude to breeding a sound culture of durable multilateral communication and multi-directional interaction. The ultimate objective is to find timely and apt response to hazardsthat threaten safety.

The knowledge network of our dreams should not only be user friendly but it must show a deep concern for the real life problems and felt needs of all categories of users. It should respect our wealth of traditional knowledge on one hand and serve as a window of new knowledge on the other hand. It should tap the confluences of streams of useable information and knowledge, from all directions. And the flow of information will require, filtration, authentication, classification, constant updragation and perfect connectivity with the vast array of widely varying end users. It should act as a help line, and a platform for a's and A's in the cyber space, besides promoting Internet chats, which may eventually take the form of e-workshops and e-training programmes and eventually encourage wiring of training institutes.

Knowledge Network will deliver data and information on institutions, skills, core competencies, technologies and technical services. It should cover both the public and private sectors. Bridging of the knowledge and information gaps, which can otherwise hold back the development of our country, may perhaps be the next logical step.

Institutionalization of the knowledge network will be a mature way to register the collective wisdom of the various actors, including national and state governments, local authorities, affected communities, volun tary organizations, policy makers, bureaucrats, professionals, and the people at the grass roots level. This would however essentially be a network of networks and will be driven by our appetite for finding engineering solutions to real life problems. It may be expected to provide a dynamic, adaptive framework, and serve as a powerful tool for servicing the national missions flowing out of the national vision for the 2151 century. By effective national and international networking of knowledge on all spheres of disasters, and their mitigation and management. by tapping the enormous S&T potential within our country, by forging partnerships between the R&D institutions. Universities, the Industry, and other players, (a) Best practices could be spotlighted and publicized, (b) Policy Paperscould be written, (c) Action Planning Manuals could be developed, (d) Public Awareness could be achieved, (e) Training Modules could be prepared, (f) Land Useand Land Management Aids could be found, and (g) Vulnerability against disasters could be reduced. The initiative of establishing a disaster knowledge network is, therefore, central to the national disaster mitigation agenda. The culture of diuital transfer of information spread through wiring of libraries will give fillip to swapping and transfer of technologies between the interested parties. A vibrant knowledge network in a country like India will enable us to build on our traditional knowledge. Learning by Traditional Knowledge & respect for unsung Innovations at the Grass Roots Level are fundamental issues before us.

The questions of ownership of information and the whole range of economical social and legal issues connected with handling of information will also have to be frontally addressed. When that happens, the Government will be able to pilot the disaster management affairs much better. not only because of the easy access to right information at right time. but also because of the knowledge of public mood and responses. favourable or adverse.

Foster Promote & Sustain International Cooperation

The world has shrunk to the size of a global village on the Information super highway. We now have a rare opportunity to pool our experiences and accelerate the process of learning in the real time. pro bono hazpublico, Disaster Mitigation being a subject of profound global concern, hundreds of teams and taskforces are perennially busy addressing the multifaceted aspects of natural disasters in the different geo-climatic, cultural and socio-economic settings. In this age of seamless science, the continuous flow of new ideas from all directions, enable even a dwarf to see farther than a giant. provided one is willing to position oneself on the giant's shoulders. The phenomenal amount of information on the internet and that in the public domain, the countless institutions created in the wake of the International Decade for Natural Disaster Reduction, and the intense pressure of the string of live problems at hand provide us with an ideal setting to launch new initiatives by pooling of resources, building on the synergies, and leveraging of capacities.

Since developing countries including India are the worst hit by natural disasters and their problems are more or less of the same genre, building joint programmes and partnerships in science and technology with friendly countries seem quite useful and natural. Since most of the developing countries lack even the minimal of resources and wherewithal to fight natural disasters, they shall welcome the hand holding exercise as a very wise move of great potential and real mutual advantage. And indeed, wherever win-win partnerships have emerged, the cause of natural disaster reduction has flourished, without question. Onthe other hand, wherever developing countries have tried to stand in isolation either by accident or by the design, the progress has been tardy.

Most developing countries of the world are seldom out of the long and dark shadows of disasters of one kind or the other and are hardly able to find any time or resource to come to grip with the problems at hand, not to speak of preventing or averting calamities. When the problems transcend national boundaries or they are complex and big in scale, they tend to get out of individual's reach. International partnerships turn handy in pooling resources, leveraging capacities and sharing information and experiences. Global Initiatives are essential to put up a united fight against disasters .In fact they are most ideal in hot pursuit of regional and global issues like global climate change, rise of sea levels, advancing of sediment load in the deltaic regions, melting of glaciers, and so on. Then there could be examples of cross border spread of haz ards like travel of smog or epidemics across national borders. Disasters like tornadoes, earthquakes, oil fires etc., know no national boundaries and therefore call for united regional effort.

Joint research and development work, especially in advancing our fundamental knowledge about natural disasters, and in learning from one another's experience carry the potential seldom appreciated. Department of Science and Technology, Council of Scientific and Industrial Research, Indian Space Research Organization and many other organizations pursue international cooperation. The subject of Disaster Mitigation deserves high priority in such cooperation.

While selecting bilateral & multi lateral programmes our antenna should be powerful enough to capture front-line developments to maximize gains of international partnerships. Let us take a few examples of innovation.

CONCLUDING REMARKS

The dream of Disaster Free India is no doubt a tall order and a daunting task. To most people it would only mean mere wishful thinking and would rank synonymous with building castles in the air. In my judgment, it is where castles should really be. Then the only task before the one billion brains (sometimes even one is enough) and two billion hands would be to start building foundation to support the castle. Today we need champions; the leaders who could plant the seeds of Disaster Free India in Disaster ravaged Indian soil. According to Montesquieu whenever a new idea comes to birth, it is the leaders who produce institutions; later these very institutions produce leaders. That is what India wants today. There is the need to identify talent, as mediocrity knows no higher than itself and one thousand painters cannot paint Mona Lisa. President Kennedy dreamt of man landing on the moon. And it is now a part of the glorious history of human race. Normally we are condemned to repeat history by not learning from it. Now is time to repeat history in Kennedy style. Let me conclude by quoting James Elroy Flecker whose following words reverberate in to my ears as frequently as I dream of Disaster Free India.

We are the pilgrims, master,
We should go always a little further
It may be beyond that last
Blue Mountain barred with snow
Across that angry or that glimmering sea.
We travel not for trafficking alone,
By hotter winds our fiery hearts are fanned
For the lust of knowing what should not be known
We take the Golden Road to Samarkand.

ACKNOWLEDGMENTS

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REFERENCES

Arya, A.S. (1989), Damage Scenario of a Hypothetical 8.0 Magnitude Earthquake in Kangra Region of Himachal Pradesh, Proceedings of ISH Silver Jubilee Symposium, Roorkee, Feb.25-26.

Bhandari, R.K. (1987), Slope Instability in Fragile Himalaya & Strategy for Development. Journal of Indian Geotechnical Society. (IGS Annual Lecture)

Bhandari, R.K. and Chanchal Gupta (1985), Problems of Landslides in the Himalaya and Future Directions. Chapter in Environmental Regeneration in Himalaya.Concepts & Strategies. Edited by J.S.Singh

Bhandari, R.K (1999) Natural Disaster Reduction in Asia and the IDNDR Stimulus. Proceedings of the 11th Asian Regional Conference on Soil Mechanics and Geotechnical Engineering, Seoul, Korea.

BMTPC (1997), "Vulnerability Atlas of India", Ministry of Urban Affairs and Employment. Govt. of India, New Delhi. 1997.

Gupta, A.K.(1997) Effects of Natural Disasters on Roads in India.

PIARC G2 Group Seminar on Natural Disaster Reduction for Roads. CRRI. New Delhi

IS: 1893-1984. Criteria for Earthquake Resistant Design of Structures. 4th Revision. Bureau of Indian Standard. June 1986 (Fifth Revision is due in 2001).

NCDM (2001) Manual on Disaster Management in India. A Publication of NOM Division. Department of Agriculture and cooperation. Ministry of Agriculture, Government of India.

PIARC (1996) Natural Disaster Reduction for Roads. A Comprehensive Report of World Road Association Publication.

Rao, P.J.(1997) PIARC G2 Group Seminar on Natural Disaster Reduction for Roads, CRRI, NewDelhi

Sinvhal. et al. (2001) Iso-seismals for the Kutch Earthquake of 26th January 2001. International Conference on Seismic Hazard with particular reference to Bhuj Earthquake of January 2001, pp179

UNDRO (1991) Mitigating Disasters, Phenomena, Effects and Options. A Manual for Policy Makers and Planners.

Conceptual Design of Major Structures in the Developing Countries of Asia, Africa and the Pacific and Indian Oceans

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INTRODUCTION

A good conceptual design requires an inventive mind, an excellent grasp and understanding of the main parameters which have to be optimized in order to achieve the best results whilst conceiving a structure. The best results are obtained when the structure fulfills its function at the minimum initial cost, has low maintenance cost, has the required durability of around a 100 years (with normal maintenance), has good aesthetics and utilizes technology which maximizes the use of local resources.

The construction environment in the developing countries of Asia and Africa varies considerably from that of developed countries. On the one hand we have the South Asian sub-continent and China with cheap and abundant labour, technicians, engineers and enterprising contractors, who aspire to take up work involving new technology, but need to be trained to utilise the same. These contractors have a low capital base and therefore need to be provided with reasonably priced enabling equipment, specially designed to be in harmony with the construction environment. On the other hand we have the oil rich countries of West Asia where everything requires to be imported including labour, engineers, materials and equipment — the high cost of personnel results in the adoption of more mechanized techniques, local contractors are however often new in this business, and the principal task is to train their labour and technical personnel. In South Asia the ratio of cost of labour to materials is respectively, 25% : 75%, while in West Asia it is similar to Europe, ie, 60% : 40%. The South East Asian environment lies somewhere between that of South Asia and West Asia. Africa presents especially difficult problems arising from a less developed construction industry and local administration, except in South Africa and Zimbabwe.

As economic liberalization gathers momentum in countries like India and China, foreign and local investment has led to industrial growth. The consequent need for improved urban and interurban infrastructure has fuelled a phenomenal expansion in construction activity. China's cement production is already more than 400 million tonnes per annum and India's is expected to reach 170 million tonnes per annum over the current decade. As one third of the world's population alters its lifestyle, these two countries will provide for several decades, the, largest construction arena the world has known.

The level of construction activity in this region requires involvement from structural engineers the world over. How will they approach working in this environment? The question has both practical and moral dimensions.

Will they directly adopt methods currently prevalent in the West without reflecting that in this region the cost of labour to materials is the same as that which existed in Europe at the beginning of the last century ? This might suit some projects, but will be expensive being unsuited to the country. Or will they take the path of the pioneers of structural engineering in these countries, who, for three decades, have created the cable-stayed bridges,towers, hangars, nuclear containments, dams, ports and roads on which these countries function?

In these countries, the good engineer, while optimising the economics of his situation, tends to use thin sections and complex geometries requiring labour intensive procedures, often training the workforce himself. He adopts a holistic, innovative approach, using state-of-the-art knowledge of design and analytical tools which can be used across nations by competent engineers. However, construction technology has to suit the construction environment of each country. The engineer should therefore develop affordable construction technologies and equipment that best use local resources and thus become genuinely relevant to their environment — so much so that, they are subsequently adopted by other contractors resulting in a new construction tradition which enriches the local construction industry.

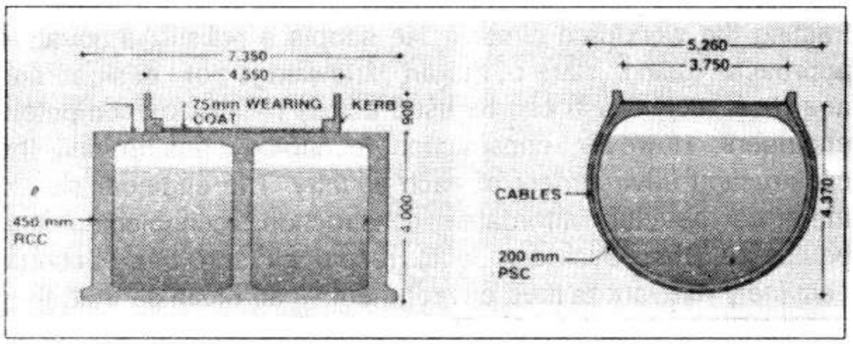
Given below are a selection of aqueducts, road bridges and nuclear reactor buildings which were designed for Asian and African countries in which the above principles are applied.

AQUEDUCTS

The Bhima Aqueduct

This aqueduct, 947 m long and carrying 42.5 cumecs of water and a single lane road, was originally conceived by the owners as a 1000 m long structure, composed of 40 m simply supported spans. The superstructure was to be a concrete double box, prestressed longitudinally and reinforced with passive steel for transverse flexure. It was to be cast in situ on 40 m high scaffolding.

The superstructure was modified to a truncated circle. Due to greater hydraulic efficiency the area required to pass the discharge was reduced by 25% reducing the weight of water to be carried by the same extent. The transverse effects in the deck were reduced mainly to membrane stresses and the aqueduct section could now be longitudinally and transversally prestressed to resist tensions in both directions. Due to these measures the aqueduct wall thickness was reduced from 450 mm to 200 mm and the area of the concrete section reduced from 6.37 sq m to 3.45 sq m, which led to reduction of 46% in self weight (Figure 1).



Simply Supported Box Prestressed in Longitudinal Direction
Cross Section of Superstructure at Center of Span
BHIMA AQUEDUCT – ORIGINAL PROPOSAL

Continuous Shell Prestressed in Longitudinal Direction and Transverse Direction
Cross Section of Superstructure at Center of Span
BHIMA AQUEDUCT – AS BUILT

Figure 1

The aqueduct superstructure rests on 40 m high cellular RCC piers founded on rock which replaced the massive masonry piers proposed by the owners (Figure 2).

The new superstructure is continuous in the longitudinal direction. Very significant construction economy was realized by adopting precast segmental technology for the construction of the superstructure, instead of a cast in situ box structure to be constructed on costly and high scaffolding.

However, the precasting plant had to be designed to be within the means of a medium size contractor and therefore, the handling and erection operations were engineered to suit the construction environment of a developing country like India.

All the handling equipment in the casting and stacking yard was hand operated. Figure 3 shows the casting yard. The segments were carried from here on trailers to the place where they were to be finally erected.

Figure 4 shows the lifting of segments by light and relatively cheap derricks — a launching girder would have been too fast and too costly for the situation.

Lifting of the steel bridge used for transporting derricks to the next span is shown in Figure 5.

The project yielded saving in the total cost of materials of more than 60%. The total weight of specially built up equipment for precasting and erection, designed and constructed locally, was 200 t and the total cost of 'this specially built equipment for precasting, transportation and erection was US $100 000 in 1985.

The 1000 m long superstructure was erected in less than 12 months. For the entire aqueduct the contractor's quotation was less by 35% than his quotation for the owner's design. The savings in material was 60% (Figure 6).

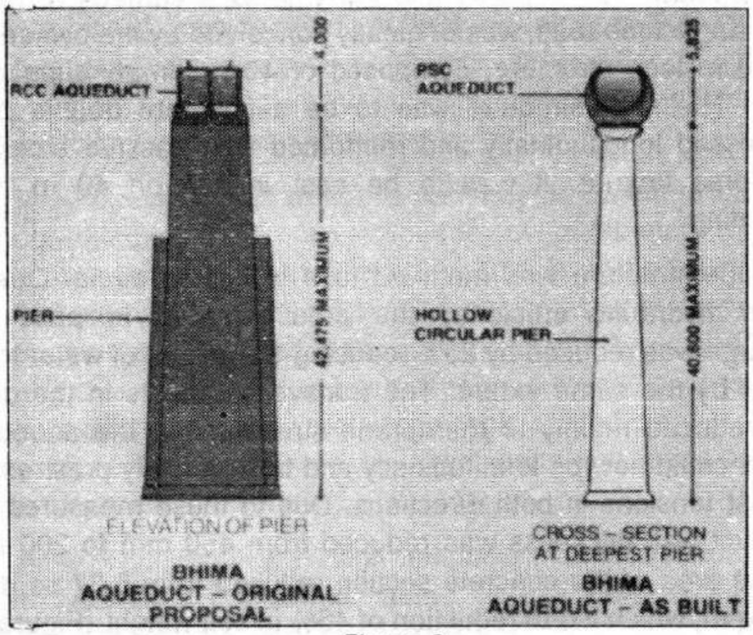


Figure 2

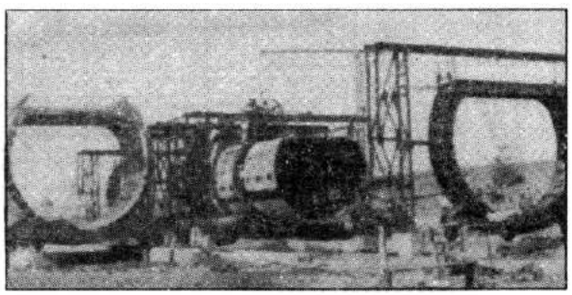


Figure 3

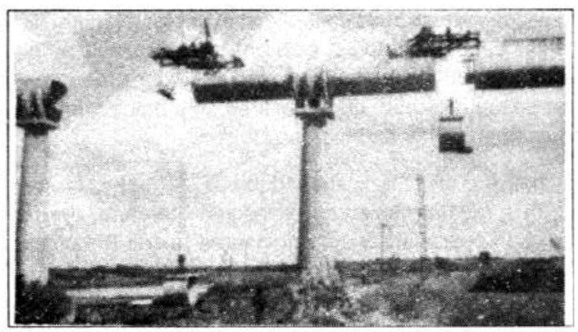


Figure 4

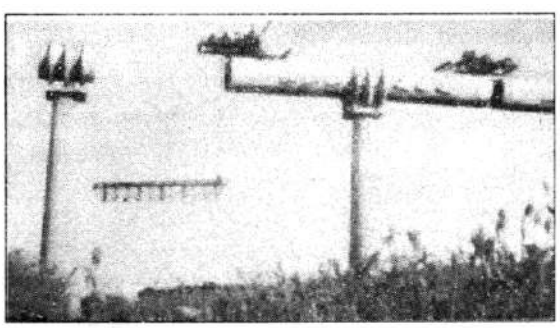


Figure 5

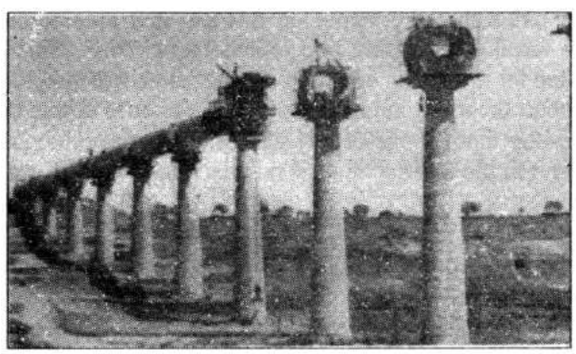


Figure 6

The construction work was carried out on a turnkey basis by AIPL a medium sized but enterprising construction company who were bidding far a bridgel aqueduct for the first time. Our role covered preliminary design, technical support for all stages of bidding and execution design of the structure, engineering all the enabling plant and construction assistance, including training of AIPL's staff.

The above aqueduct is well known but it best illustrates the holistic approach adopted, optimising inventively, between the structural, hydraulic and construction engineering disciplines, to create a structure which is superior in terms of economy, durability, speed and ease of construction and relevance of construction technology to the construction environment of India.

BRIDGES

India, with its major rivers, mountainous terrain, coastal waterways and marine crossings has always held a tremendous challenge for the bridge engineer.There have been numerous pioneering innovations and many major bridges have been built.

However, the durability of these bridges has become an important concern, especially since some relatively new bridges in coastal locations have shown signs of severe corrosion.

The issue of durability is not only a concern for India, but is currently a pressing concern across the world because many new bridges have shown unexpected distress and innumerable old bridges require retrofitting and replacement. The solutions that are suited for the Indian environment, however, are quite different from those for more industrialized countries and in this section, some of the innovations used for two major bridges constructed at the end of the last decade will be described.

The New Thane Creek Bridge

This Bridge (Figure 7) is already known, but is presented here because it brings out the holistic approach suitable for countries like India and China. This bridge was engineered with extreme care, because the existing Thane Creek Bridge connecting Mumbai to the mainland was being substantially derated within 15 years of construction due to excessive corrosion.

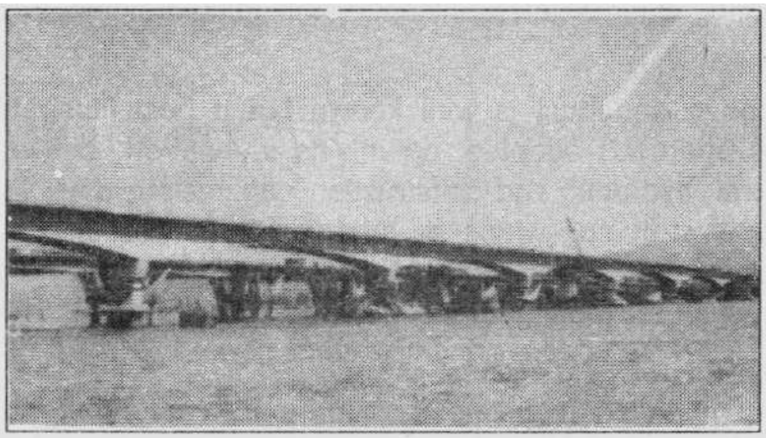


Figure 7

The new bridge is 1.84 km long and has two parallel decks of 3 lanes each with continuous spans of 107 m, ie, an aggregate length of 3.68 km.

The foundations which are sometimes as deep as 22.5 m below high tide level were of special concern and in order to ease construction and improve quality, they were buiit in situ in a dry environment.

An innovative cofferdam was engineered and fabricated locally to construct these open foundations. The cofferdam was towed to its final location on a pontoon. Then it was lifted off the pontoon by a catamaran barge (Figure 8) and lowered into the sea by six synchronous hand operated jacks. Sinking was carried out upto rock level by grabs excavating the marine clay within the cofferdam. The cofferdam is made up of a lower concrete section of height equal to the marine clay overburden (the thickness of the concrete shell is 300 mm with stiffening ribs every 2 m) surmounted by a reusable cellular steel portion of variable height (made up of 2 m wide segments each covering $^1/_4$ the perimeter). The concrete portion is precast on a pontoon close to shore, brought to its final location and the steel sections are attached to it and to each other during sinking using foam rubber gaskets to ensure water-tight joints.

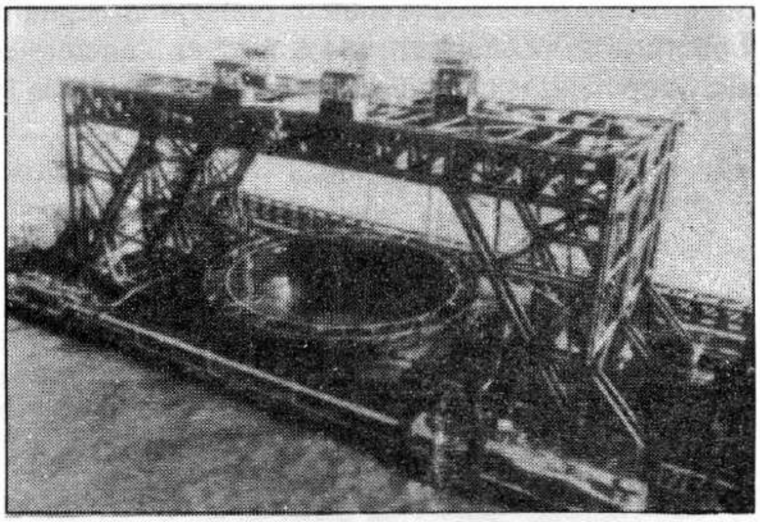


Figure 8

After sinking the cofferdam by grabs which excavate clay from within the cofferdam, water is pumped out to see whether the stiff clay is effectively sealing the gaps between rock and cofferdam, if this does not happen, divers clear the rock face near the periphery and place sand bags at a clear distance of about 60 cm from the inner face of the cofferdam. A concrete pump is used to pour concrete into the gap between the sand bags and the cofferdam, thereby creating a watertight seal between the rock face and the cofferdam.

Water is pumped out of the cofferdam and the foundation is constructed in a dry environment (Figure 9). In cases where the rock is extensively fissured and there is leakage through the rock at the bottom of the cofferdam, a 1.5 m deep concrete bottom plug, with weep holes is laid before de-watering.

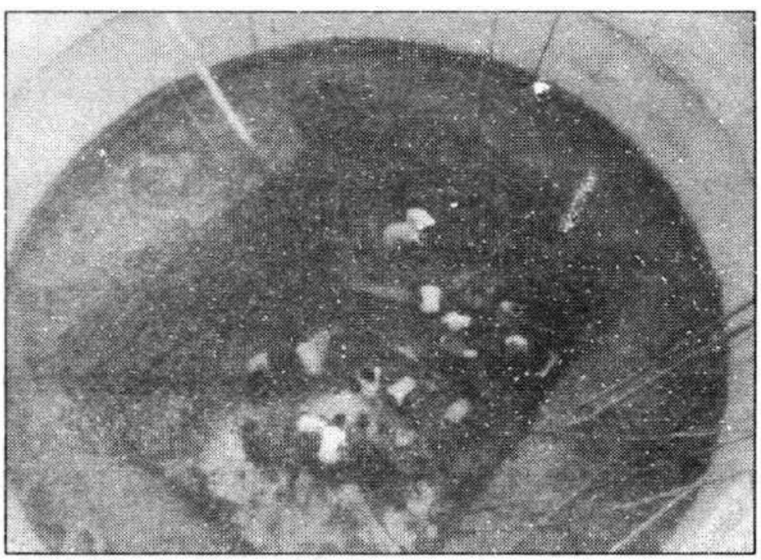


Figure 9

After constructing the pier the steel portion of the cofferdam is then detached for reuse elsewhere.

The webs are very thin and economical, 35 cm for 7 m height of box girder. This was possible, because there are no prestressing cables in the webs. The absence of prestressing cables in the webs also makes them easier to construct and therefore more durable.

Most of the prestressing cables are anchored just below the top slab or just above the bottom slab at their junctions with the webs. The resulting almost straight cable profiles and avoidance of grouping of cables simplifies threading and grouting. Furthermore, locating the cable anchorages below the waterproofed top slab and inside the box prevents ingress of moisture during service and thereby, reduces the risk of cable corrosion.

The details of concreting such thin sections were carefully studied at Thane Creek and full scale mock-ups were carried out for a typical segment over the pier plus one on either side of the same (Figure 10). The mock-ups were tested and demolished in order to examine dimension tolerances relating to concrete sizes, locations of reinforcement and concrete cover and also to verify proper compaction of concrete at all locations. Windows were also provided in the webs in order to insert needle vibrators during construction for achieving better compaction, the absence of cables and anchorages in the webs gives a simple and economic solution for achieving good quality of work. Rersonnel were also trained on the mock-ups.

Mock up of 2 voussoirs on either side of voussoir over pier (Figure 11).

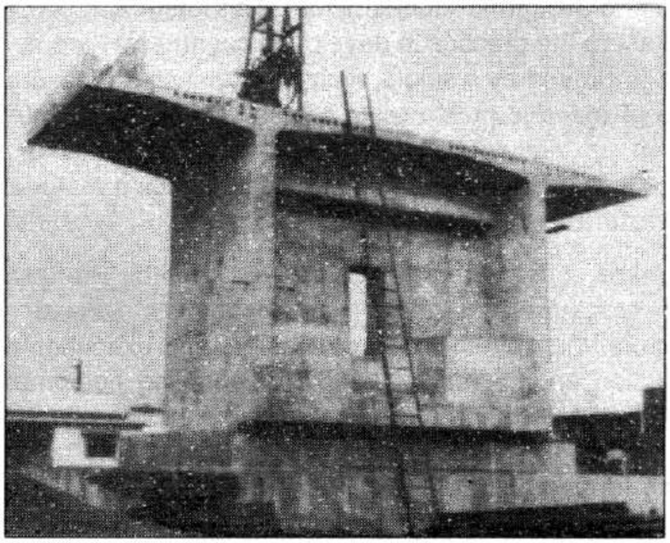


Figure 10

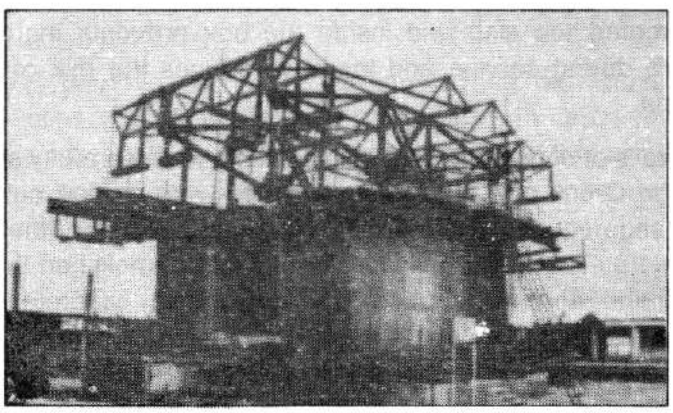


Figure 11

Simplifying the layout of the prestressing cables, appropriate positioning of the anchorages, improving the ease of construction and maintaining strict quality control all combine to give a very durable and economic superstructure. This integrated approach is in contrast to the practice in developed countries where durability is often improved by a single, typically expensive measure, such as, use of external prestressing cables. However, the integrated approach is equally effective and in this particular case, especially advantageous, as it resulted in reducing material costs and therefore, total costs.

The turnkey construction was carried out by Uttar Pradesh State Bridge Corporation Ltd - one of India's largest bridge contractors. Our role included preliminary and execution design, construction engineering of 1200 t of enabling equipment and construction assistance for the more complex operations.This is an example of the development of construction technology, detailing and structural design which led to economy, good aesthetics and durability in spite of an adverse marine environment.

Bridge at Bhagalpur

This Bridge across the River Ganges (Figure 12) has a length of 4.37 km - the second longest in India. The bridge has four types of structures (Figures 13, 14 and 15) corresponding to the 4 regimes of the river:

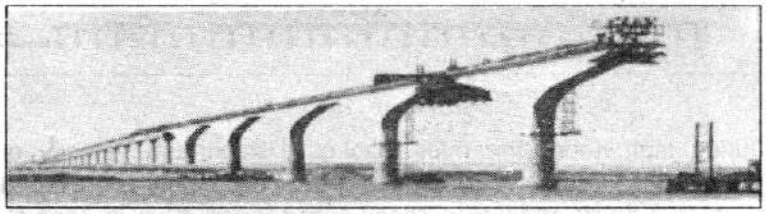


Figure 12

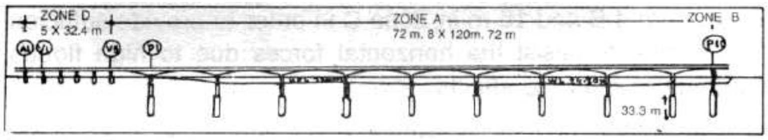


Figure 13

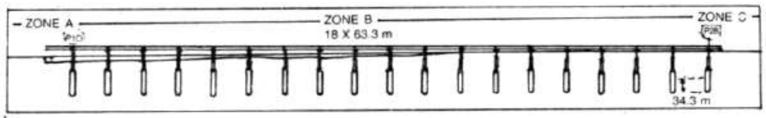


Figure 14

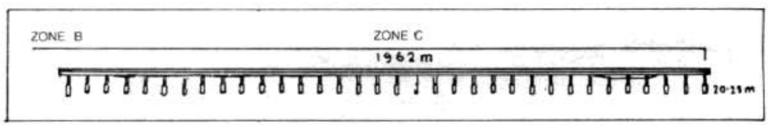


Figure 15

The approach viaduct Zone D, 162 m long, (Figure 13) has 5 simply supported box girder spans of 32.4 m, (at centre to centre (c/c) of piers), constructed on staging. The piers are founded on shallow cylindrical RCC well foundations sunk 18m deep below the highest riverbed in this Zone.

The next Zone A (Figure 13) across the deepest part of the river, consists of 120 m spans (at clc of piers), with a total length of 1104 m constructed over standing water, which at low water level has a maximum depth of 7 m. The superstructure is supported on hollow RCC piers constructed on 9 cylindrical RCC well foundations which were to be sunk from sand islands upto 7 m deep, by excavating soil from within the wells by grabs. The superstructure consists of prestressed concrete cantilevers of 48 m fixed to the pier and a 24 m reinforced concrete suspended span across the cantilever tips, to give effectively 8 spans of 120 m, (at c/c of piers) and approach spans of 72 m, (at c/c of piers), on either side.

Zone B (Figure 14) which is 1139.4 m long, is dry in the fair season and is covered with water only during floods. This Zone has well foundations which are sunk upto a depth up of 70 m. In this Zone the superstructure is made of simply supported prestressesd concrete box girders having a length of 63.3 m supported on hollow RCC piers.

Zone C (Figure 15) which has an aggregate length of 1961.8 m is constructed in a zone beyond the left bank (at the end of Zone B) to cross the backwaters which occur during high floods. It consists of wells sunk upto 60 m below the highest ground level in this area.

During high floods the river reaches a maximum velocity of 4.5 m/s and is therefore, expected to scour below High Flood Level to a depth of 47 m in Zones A and Band 40 m in Zone C. Therefore, the wells go down by an additional depth of 22 m in Zones A and Band 16 m in Zone C in order to provide sufficient grip length, to resist the horizontal forces due to high floods, earthquake and wind effects.

In Zone A, the depth of the superstructure at the pier is 9.6 m and at the cantilever tip it is 1.95 m, which are 1/11 and 1/62 of the span. These depth to span ratios result from an effort to reduce materials consumed.

The prestressed cantilever portion of the deck is constructed by the free cantilevering method with cast in situ segments.

The webs for a height of 9.6 m are only 37 cm in thickness. The longitudinal prestressing cables are placed in the top slab as in Thane Creek Bridge, so that,· the web is free of prestressing cables and can be concreted by form and pin vibration — with a succession of windows within the height of the web to facilitate pin vibration and observation of compaction of concrete during placement.

In Zone A the piers have a hollow circular section which flares into a hollow square section at its junction with the superstructure. The pier and the deck seem to flow into each other – a good looking consequence of a search for dematerialisation (Figure 16).

Lifting by prestressing cables of temporary steel decks used for casting the 24 m RCC central span (Figure 17).

The superstructure of Zone B is cast in situ on scaffolding supported on the dry riverbed. The piers have hollow conical sections which flare out at the top into a hammerhead in order to support the span on either side. The piers also flare out at the, bottom to rest concentrically on the walls of the well foundation (when there is no tilt and shift of the foundation).

The casting of the box girders on scaffolding resting on the dry river bed was cheaper than precasting and launching of entire spans (Figure 18).

The construction of the pier and foundations in Zone C, over backwaters which occur during high floods, was similar to that shown in Zone B (Figure 19).

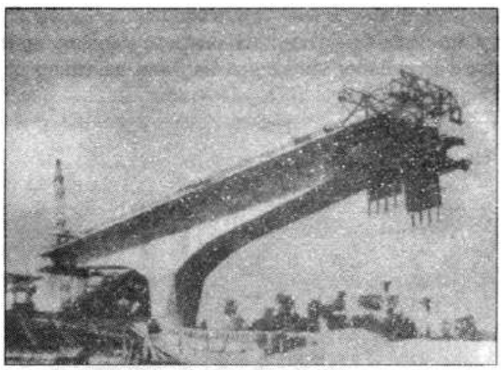


Figure 16

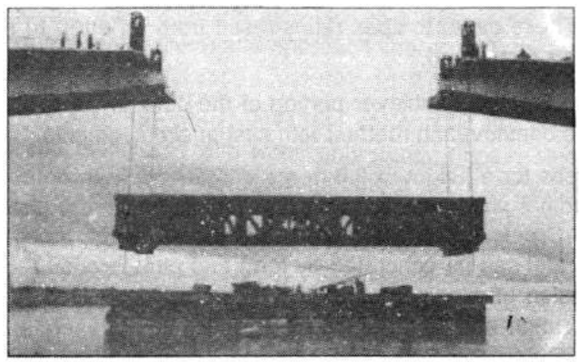


Figure 17

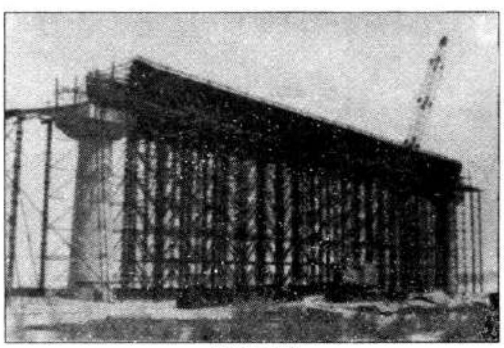


Figure 18

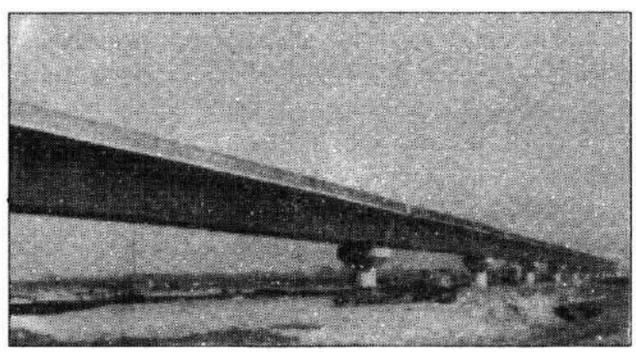


Figure 19

One would be exceptionally lucky if a bridge of this size, across a great Indian river is executed without any mishap. The alluvium in the Indo-Gangetic plain has a depth of 700 m, the scourable zone at the top is usually sandy and below that one can come across highly compressed sand, sandy silts, stiff sandy clays etc, which are difficult strata for well sinking. At this site, the maximum shift recorded at the top of a well was 186 cm.

Sometimes there can be unseasonal floods due to the early melting of Himalayan snows and the wells can also tilt and shift during such an event if they have not been sunk adequately.

During such an unexpected flood, wells that were not yet sunk adequately toppled over. Also a part of the bed which had been scoured did not get re-filled. The minimum depth of standing water became 22 m instead of the normal maximum depth of 7 m at Low Water Level. In the case of those wells which tilted excessively, smaller additional foundations were cast. The wells in this portion had to be cast by sinking hollow steel caissons. The space between the inner and outer walls of the caissons had a thickness equal to the lower part of the RCC well steining. It was constructed using catamaran barges and the sinking technique utilised for the cofferdams was the same as that for Thane Creek Bridge, except that concrete was poured into the hollow caisson wall to facilitate the lowering of the same, till it touched the river bed — verticality was maintained by equally stressed prestressing cables which were used for lowering the caisson. Thereafter, the construction was completed by the traditional sinking process utilised for all the other well foundations (Figure 20).

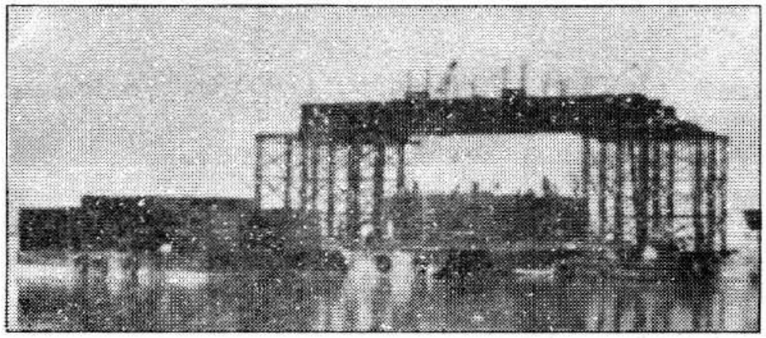


Figure 20

The only regret while working on this major bridge was that the Terms of Reference of the turnkey bid did not permit either segmental precast cantilever construction or a cable stayed solution, the pier locations were already fixed and therefore, the span arrangement could not be optimised. However, building a great bridge is always satisfying to all concerned - Uttar Pradesh State Bridge Corporation constructed the bridge, STUP carried out the design and construction engineering and provided construction assistance where required by this very capable contractor.

REACTOR BUILDINGS

RAPP

The first Indian built nuclear reactor buildings located in Rajasthan for RAPP I and II involved the third use of prestressed concrete for a Reactor Building and the first in India (Figure 21).

MAPP

In the next generation of external containments for a 235 MW nuclear reactor (1967), near Madras, MAPP I and II, India achieved a quantum jump in safety by pioneering the concept of a double containment (Figure 22).

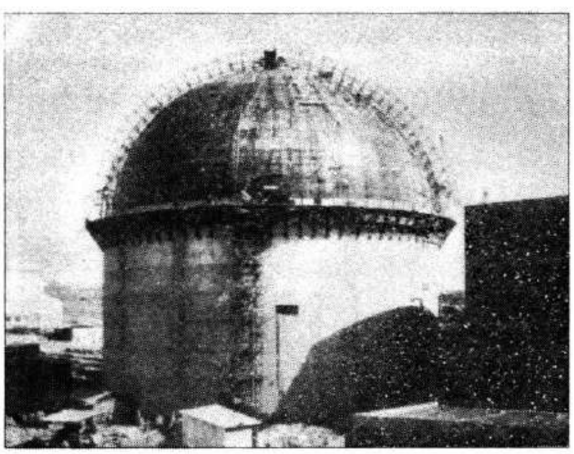


Figure 21

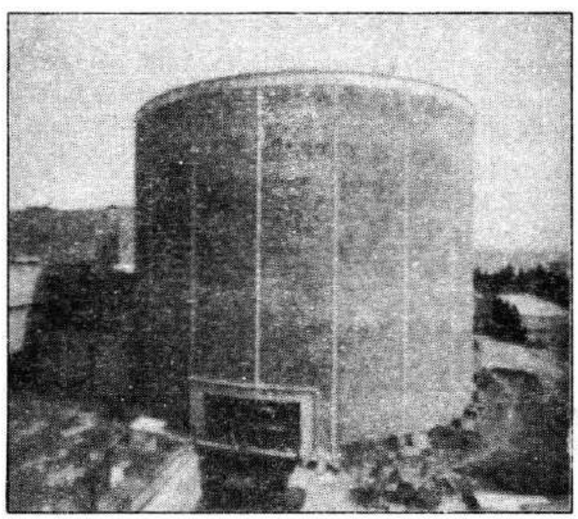


Figure 22

The inner prestressed concrete containment provides a leak tight environment which can withstand the internal pressures and temperatures during the Maximum Credible Accident. The outer wall provides a second barrter and additional radiation protection. The annular space between the containments is constantly maintained at below atmospheric pressure to aspirate any leakage from within the reactor which is cleaned and expelled through the chimney.

The entire outer containment is of reinforced masonry. This is because excellent granite is readily available in the area, a large amount came from the excavation for the reactor building itself. The outer containment is unique in that it is the only instance of a 35 m tall, 71 cm thick, free standing cylindrical shell made of reinforced masonry. This was possible because the local workmen are very skilled in stone work.

Apart from their greatly enhanced quality and reliability, the MAPP I and II Reactor buildings were 25% cheaper than the modified RAPP I and II.

The above is an example of improved performance and cost optimization obtained by utilising an advanced design approach combined with development of construction technology suitable to the local environment. This innovation has been adopted in all French and Indian reactor buildings constructed since 1967.

TAPP

The first reactor building for the completely Indian designed 500 MW PHWR nuclear reactor at Tarapur, TAPP III and IV, benefits from the previous developments relating to the sixteen 235 MW reactor buildings engineered by us since 1963. Stringent safety requirements have required scale model testing and proof loading as well as designing for 1000 year winds, extreme events involving dam f,ilures upstream and resulting floods and earthquakes of 10 000 years return period in regions of seismic activity. Due to the security environment, studies include nonlinear analysis of the outer containment for fighter aircraft or missile impact.

Today, with the increased need of power due to a growth in the industrial sector and improvement of the standard of living, combined with restrictions on import of oil, India has decided to expand its nuclear power program. At the same time, to meet the growing national and international concern for safety of the environment, the country is committed to making nuclear power even safer. As accidents are very rare events, use of traditional methods of reactor building design will be replaced by probabilistic techniques. Probabilistic risk analysis can be used to quantify overall safety and identify any existing weak links with up-to-date modern construction techniques. Systems reliability analysis can be used to identify critical variables and components which can then be subject to the strictest quality control and testing.

The construction technology being used, differs little to that which would be used in an European construction environment.

The availability of large cranes allowed operations, such as, introducing and removing the steam generators through ports in the roof and the corresponding reduction in height of the reactor building (large lateral construction opening is eliminated).

One of the boilers being lowered into position (Figure 23).

Some projects from various disciplines for which a similar approach was adopted will be presented below: such as, Airports (Figure 24), Architecture, Urban, Rural and Industrial Development (Figure 25), Highways (Figure 26) and Railways Infrastructure (Figure 27), Energy, Telecommunication and Space Infrastructure (Figure 28), Offshore, Harbour and Coastal Engineering (Figure 29), Water Resources and Agricultural Development (Figure 30), Environmental and Public Health Engineering (Figure 31), Major Structures, Construction Engineering and Project Management (Figure 32).

Figure 23

Figure 24

Figure 25

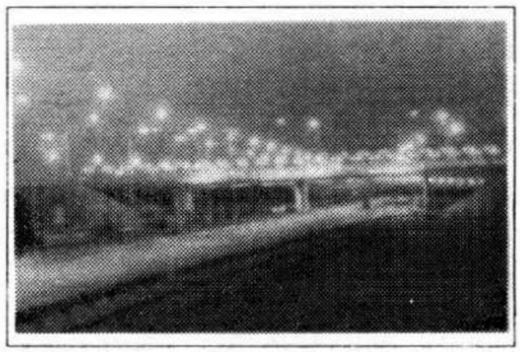


Figure 26

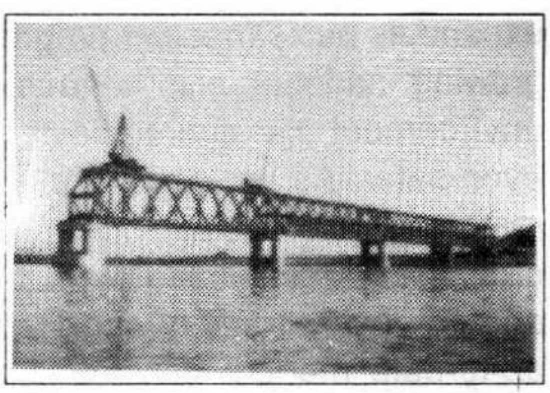


Figure 27

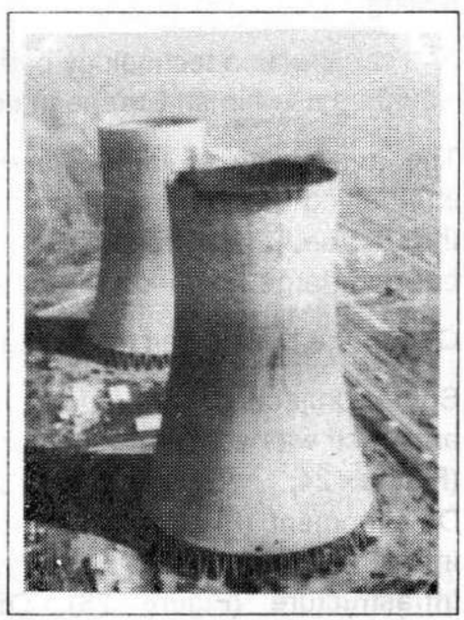


Figure 28

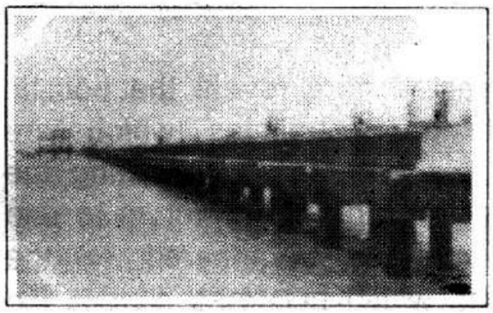


Figure 29

Figure 30

Figure 31

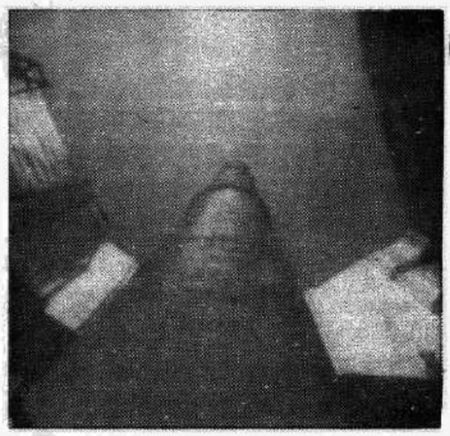


Figure 32

CONCLUSION

The sampling of structures presented here reveal the holistic approach State-of-the-art design techniques which are combined with innovative construction engineering suiting the local environment along with the training of contractors to use new construction technology specially engineered to the developing country's environment, which becomes a new and economic construction tradition, worthy of being reused by the construction industry of each country.

Nuclear Power for Energy & Environment Security

Dr Anil Kakodkar

Chairman, Atomic Energy Commission
and
Secretary to the Government of India, Department of Atomic Energy

Introduction

Let me begin by expressing my gratitude to the Institution of Engineers for this opportunity to pay tributes to the memory of Sir R.N. Mookerjee. I have chosen to speak on a topic that I think is important for development of India and where our domestic R&D efforts are well poised to meet the challenge.

India is the largest democracy with nearly one-sixth of world population and low per capita income. In recent years. it has witnessed an impressive growth rate in GDP. Development aspirations of its populace demand that this growth rate be sustained for a long enough time so as to enable them to have decent enough quality of life. This necessitates a matching growth in the availability of energy. Further, the development process, is also driving. as expected. a shift in energy use from non commercial energy sources to commercial sources, particularly electricity. This phenomenon is similar to what has been witnessed by the developed countries in the west. But the situation in India is more complex because of high density of population, continuing growth of population and demographic shift from rural to urban areas.

Let us look at the global picture first. The world's population crossed 6 billion mark in the year 1999. Most current estimates suggest that around 2 billion people will be added over the next 30 years with another billion in the following 20 years. The two factors namely. rise in living standards and the increase in the world's population are rapidly depleting the energy resources within the earth and producing vast amounts of waste products particularly when energy is produced using fossil fuels. That means the situation has come to pass where humankind can no longer afford to make unmindful use of resources.

Stabilization of population at as Iowa figure as possible is a crucial issue. When we visualize what the world may look like with 9 billion people, it becomes clear that the challenge of enhancing standard of living of the larger fraction of poor and underdeveloped societies would require out-of-box thinking. We cannot afford to harm Mother Earth including the environment anymore.

The concept of sustainability calls for exploitation of available resources to improve the quality of life of people without harming the interest of future generations, both from the point of availability of resources as well as degradation of environment beyond the inherent corrective capability of natural processes. While environmental burden has to be kept within the limits of self-correction and geographically well distributed, development aspirations of people have to be given a place of supreme importance in all decision making processes. After all "poverty is the biggest polluter" and is the source of several conflicts .

Nuclear Power — An inevitabel Option

Nuclear technology is an option, which can provide a million fold increase in energy per unit of mass extracted from the earth in an environmentally benign manner. Access to such large energy with minimum use of earth resources and negligible or minimum adverse impact on earth's environment is the challenge before the Technological community. I believe, we have reached a point where we need such quantum jump solutions in several areas without which maintenance of life sustainability itself would he under threat.

At the present stage of development, however, no single energy resource or technology constitutes a panacea to address all issues related to availability of fuel supplies, environmental impact particularly climate change, and health externalities. Therefore, it is necessary that all non-carbon emitting resources become an integral part of an energy mix — as diversified as possible — to-ensure energy security to the world during the present century. Available sources are low carbon fossil fuels, renewable and nuclear energy and all these should be subject of increased level of research, development, demonstration and deployment.

Forecasts by several agencies point towards a robust GOP growth in India over the next three to five decades. A group in OAE has studied available information on GOP growth forecasts, population growth trends with regard to energy-elasticity and electricity intensity of industries and has developed a scenario for growth of electricity. It forecasts that electricity generation will grow at 6.3% /yr in the coming two decades and will continue to grow till the middle of the century, though at somewhat decreased rates. Even after five decades, per capita electricity generation would reach only about 5300 kWh per year with a total generation of about 8000 billion kWh. It may be recalled that historical electricity growth rates during 1981- 2000 was 7.8%/yr.

From the perspective of fuel resource position, one has to examine cumulative resource expenditure. According to our study cumulative resource expenditure will be about 2400 EJ by 2052. The ratio of thermal equivalent of electrical energy to the primary commercial energy will rise from about 57% in the year 2002-03 to about 65% in the year 2052-53.

Power generation in India which was only 4.1 billion kWh in 1947- 48 increased to more than 600 billion kWh in 2002-03. Considering the past record, the future economy growth scenario and likely boost to captive power plant sector as a result of changes arising due to Electricity Act 2003. the target of generating about 8000 billion kWh per year by 2052 is achievable. The study brings out several important conclusions with regard to fuel resource position and the role nuclear energy has to play in India during the next five decades.

The essential conclusions are that considering our uranium resources and physics characteristics of metallic fuel based fast reactors, nuclear energy can contribute about 25% of electricity requirements by the middle of the century. Even after tapping full potential of hydro and other renewable energy resources, it would be necessary to meet a significant portion of the demand from fossil fuels. Considering our fossil resources and their projected usage, these will get exhausted by the middle of the century unless additional resources are found.

It is, therefore, necessary to ensure that nuclear generation through fast breeder reactors and thorium-fuelled reactors is poised to replace coal based generation after 2050.

In this context, let me talk about the status of the nuclear power programme as it exists today. At present, Pressurized Heavy Water Reactors (PHWR) form the mainstay of our nuclear programme and we have 12 such reactors in operation and six under construction, which include indigenously designed and developed 540 MWe units under construction at Tarapur. The designs of these reactors have progressively evolved taking into account the needs for indigeniz ation, our own operating experience. operating experience in PHWRs outside the country and progressive evolution of enhanced safety features. As India gains experience and masters various aspects of the nuclear technology, performance of operating plants has progressively improved to a level of world class excellence. The Nuclear Power Corporation of India Limited (NPCIL) has accumulated about 220 reactor-years of operational experience free of any serious incident involving release of radioactivity to the environment. Nuclear power technology in India has thus reached a state of maturity and the Department of Atomic Energy continues to take steps to further its development. These steps are aimed at further improving the safety and availability of operating stations. reducing the gestation period of plants under construction by usi ng innovative management techniques, cost optimization and development of new reactor systems.

In percentage terms, nuclear power contributes only about 3% of India's total electricity generation, but it signifies the fact that India has the technology base on which it can build further to provide long term energy security. India's modest reserves of uranium can support about 10 GWe of PHWRs and in around four years from now, NPCIL would have established an installed capacity of around 4.5 GWe with PHWRs. Another 2.32 GWe would come from light water reactors making a total of around 6.8 GWe as against the present capacity of 2.77 GWe.

Simultaneously, India is pursuing the fast reactor programme and in September 20 m, the Government of India approved construction of a 500 MWe Prototype Fast Breeder Reactor (PFBR) at Kalpakkarn. Hon'ble Prime Minister of India visited Kalpakkam on 23rd October, 2004 to participate in a function marking Golden Jubilee of the Department of Atomic Energy and said, "Our nuclear programme takes a major step forward today with launching of the commercial phase of the fast breeder programme. This is an occasion to celebrate and also to reflect on our past achievements and also to look to the future with hope, courage and confidence. The progress during past 50 years have made us proud".

Construction of the fast breeder programme will open up a vast source of energy for the development of the country. It also reflects the fact that Indian scientists and engineers have mastered the reprocessing technology to a stage where they feel confident about taking the bold step of launching the fast breeder programme on an industrial scale. It may be recalled that India has a 40 MWt Fast Breeder Test Reactor (FBTR) operating since 1985. FBTR is powered by a unique mixed carbide fuel, which has already undergone a burn up of 123,000 MWd/tonne.

Experience with reprocessing of carbide fuel from FBTR is also very encouraging. The experience of operating the FBTR has given us the confidence of thinking ahout a very large programme based on fast breeder reactor technology.

Our strategy for fast breeder reactors would involve setting up of mixed oxide based Fast Breeder reactors in the early phase to be followed by metallic fuelled Fast Reactors which would enable shorter doubling time. All these developments provide challenging assignments to the scientists and engineers working in the Department of Atomic Energy and other research institutions of the country. I can say with some degree of confidence that developments in nuclear energy technology in India are comparable to similar developments anywhere in the world. Rather in view of our fuel resource position, fast growing economy and the fact that we have a large necessity — availability gap in terms of energy. The research efforts needed to provide energy security in India have no parallel in the world. This is what is propelling us in DAE to nurture a strong and independent energy technology development programme.

Economics of Nuclear Power and Environmental Concerns

The comparative economics of nuclear power plants depends on local conditions, discount rates and availability of cheap fuels like coal and gas. Wherever fossil fuels are available at reasonable prices, the setting up of thermal power plants is an option to be considered in any technoeconomic analysis. Issues to be considered in case of thermal plants include location of coalmines vis-a-vis load centres, coal transportation, availability of railroads for transportation, sulphur and ash content of the fuel and associated environmental impact. Hydropower provides low cost electricity generation, but sites available for large projects are limited and social impact is very high due to submergence of large areas. Gas prices are subject to fluctuations due to market forces and form a sizable fraction of electricity cost produced from gas fired plants. Therefore, the cost of electricity generated from gas fired plants can vary a lot depending on the market conditions.

Generally only direct costs are used in comparative assessment of different electricity options. However, the opinion is building up in favour of internalizing all costs of generation in any comparative assessment of energy options and this would include, inter alia, the cost of impact on environment and health and cost of setting up of infrastructure for fuel transportation which is often subsidized. The largest environmental impacts associated with fossil fuels are carbon dioxide and other forms of air pollution which can cause chronic illness. (See fig 1 for comparative green house gas emissions). The risks associated with these impacts affect the entire planet. In addition. the volume of waste generated in case of energy generation from fossil fuels is quite large (See fig 2). Technically nuclear energy is far more benign and much of the cost is already internalized in financial plans. For example, nuclear power operators are required to provide funds for decommissioning of installations. External costs have been estimated by a study conducted under European Commission's Externe project results and reported in 1998 are summarized in the Table 1.

Figure-1: Greenhouse Gas Emissions from Electricity

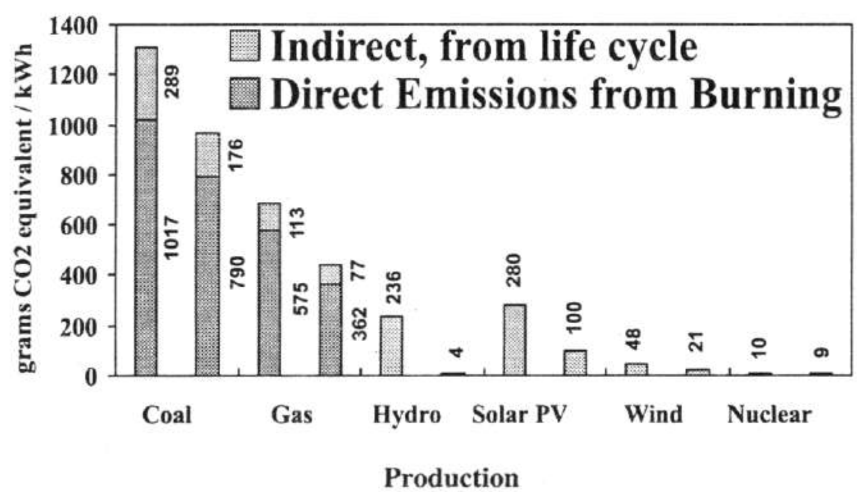


Figure-2:

Wastes in Fuel Preparation and Plant Operation

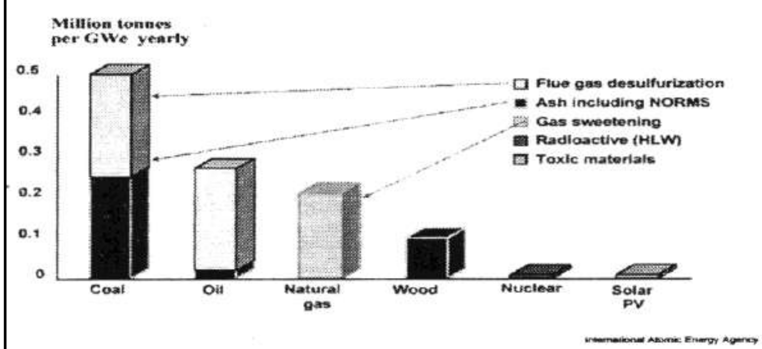


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Table 1 External Costs

	Costs (mEcu/kWh)	Equivalent lives lost (per GW-year)
Coal	18-150	213
Lignite	35-84	138
Oil	26-109	213
Gas	5-31	27
Wind	0.5-2.6	5
Hydro	0.8-7	2
Biomass	1.2-29	51
Nuclear	2.5-7.3	1

Adapted from European's Commission's Externe project - 1998

An internal study done by Nuclear Power Corporation of India Ltd. (NPCIL) indicates that nuclear power is competitive compared to coal fired thermal power, when the nuclear plant is about 1000 km from tile pit-head. There are several regions in the country where such haulage is involved. Being capital intensive in nature. the cost of nuclear electricity becomes more competitive with the age of the plant as- the capital cost depreciates. Interest during construction (IDC) adds to capital cost of a plant and it is necessary to reduce the gestation period NPCIL is working towards reducing the gestation period by adopting innovative project management practices including having large EPC packages and the plants under construction will be completed in about 5 years.

Climate Change and Associated International Conventions

To reduce the risk of global climate change, industrialized countries have made commitments to reduce GHG emissions under a protocol, negotiated in Kyoto. Japan in 1997 as an addition to the 1992 United Nations Framework Convention on Climate Change (UNFCCC). In the so-called Kyoto Protocol. industrialized countries have agreed to reduce their collective emissions during the period 2008-2012 by at least 5.2% below 1990 levels. So far no decision has been taken about carbon reduction commitments for the period beyond 2012, but statements have already been made, that countries like India and China should also make carbon reduction commitments. It is pertinent to note that per capita carbon emission in India is one tonne per year, it is 2.7 tonnes per year in China while for the industrialized countries, it is 11.4 tonnes per year. Therefore. while negotiating at international fora we have to take a careful stand with regard to accepting any carbon reduction commitments. At the same time, we have to adopt policies wherein we use advanced technologies so as to minimize carbon emissions. Nuclear energy produces virtually no GHG emissions and should be an important part of our strategy to reduce GHG emissions.

Nuclear Safety

Since the very inception. the Indian nuclear power programme has laid a strong emphasis on nuclear safety and radiation surveillance in the environment, The essence of our safety policy was spelt out by Dr Bhabha . when he said, "Radioactive materials and source of radiation should be handled in a manner which not only ensures that no harm can come to workers or anyone else. but in an exemplary manner so as to set a standard which other organisations in the country may be asked to emulate." This has really happened. In all industrial development programmes in India, environment monitoring has assumed importance and statutory regulations have been established. Systematic measurements of radiation levels in the environment and related investigations have been undertaken by the DAE long before such regulations were introduced.

Concern for safety pervades all aspects of the nuclear fuel cycle, in the design and engineering, in plant operation, and in regulation of the nuclear industry as a whole. In design and engineering, this includes adopting sound basic designs. adhering to appropriate codes and practices, using fully tested materials and components, providing adequate margins and failsafe arrangements. and facilitating maintenance and proper operation. Design of PHWRs in India has progressively evolved. An example is the manner in which reactor containment has evolved from the reactor near Kota (RAPS) to those at Kaiga. At RAPS we have a dousing tank. at Kalpakkam (MAPS) vapour suppression pool was introduced, at Narora partial double containment was introduced, and at Kakrapar full double containment was incorporated. At Kaiga, for the first time a high strength concrete has been used for the containment dome. In a similar manner. other systems such as secondary shut down system, emergency core cooling system have been evolved so as to ensure plant safety under all anticipated operating conditions.

We have designed an Advanced Heavy Water Reactor, which besides using thorium. also aims at enhancing safety to a level far higher than current safety requirements. which themselves are very stringent. Examples of safety features include pumpless primary cooling system, operator forgiving characteristics with a grace period of three days, passive containment isolation, elimination of impact in public domain etc.

The Atomic Energy Regulatory Board (AERB), an independent regulatory body in the country. is responsible for licensing and regulation of all activities related to atomic energy. To provide fillip to regulatory R&D, AERB has set up an independent Safety Research Institute (SRI) in 1998 at Kalpakkam. SRI conducts a substantial part of the research programme in an inter-institution manner. Areas of research covered by SRI include nuclear plant safety. radiological and environmental safety, fire and industrial safety.

Nuclear Waste Management

With total protection of the environment as the overriding consideration, management of the radioactive waste generated in the fuel cycle has received high priority in our nuclear programme right from its inception. Based on indigenous materials and capabilities, technology has been developed and is in routine use for the management of low and intermediate level wastes meeting the stringent regulatory requirements and standards. No waste in any physical form is released to the environment unless the same is well below internationally accepted safe levels. Treatment of reprocessing waste has received considerable attention because they contain nearly 99% of the activity generated in the nuclear fuel cycle. Based on years of development studies, a longterm action plan has been formulated for the management of these wastes.

In principle the Indian programme envisages two distinct modes of final disposition in respect of radioactive wastes:

- Near surface engineered extended storage for low and intermediate level wastes.
- Deep geological disposal for high level wastes and alpha bearing wastes.

A waste immobilisation plant for the treatment of High Level Waste (HLW) has been operational at Tarapur for quite some time and one more has been just commissioned at Trornbay. One more waste immobilisation plant is being set up at Kalpakkam. A solid storage and surveillance facility (SSSF) has also been set up for interim storage of vitrified HLW.

As regards ultimate disposal, considering the present small size of the Indian programme, considerable time is available before the need for a repository would be felt. However. studies on establishing a repository are being carried out in an ongoing manner. An experimental research station was set up in an unused portion of an underground mine located at Kolar near Bangalore. In-situ experiments for examining the thermal, mechanical, hydrological and chemical behaviour of the host rock under simulated conditions have been conducted.

High level waste disposal is often cited as show stopper for nuclear power. However. technological solutions for long-term storage of high level waste do exist now. Several countries have taken steps in this direction. Yucca mountain, Nevada, has been approved as the site for a national repository for nuclear fuel and high-level radioactive waste in the USA. Finland has also gone ahead with legislative approval for setting up a rock characterization facility at Olkiluto power station. Further R&D in waste transmutation should soon make high level waste storage a short term issue.

Conclusions

India has above 16% of the world's population and only about 6% of the world's coal reserves. oil and gas being less than I%. However. India has about 327c of the world's Thorium reserves. We have large hydro potential, but its exploitation is beset with issues like displacement of people and possible effects on ecology. Non-conventional sources, at present stage of technology development, are suited essentially for decentralised small capacity plants. Large-scale development of nuclear power is thus inevitable. India has developed comprehensive capabilities in all aspects of nuciear fuel cycle and as far as nuclear technology is concerned. India is a "developed country".

We believe that nuclear power is a clean source of energy. However, to make nuclear power economically more competitive, nuclear Industry has to continue to improve existing technologies, develop new technologies and adopt innovative project management practices to reduce capital cost and shorten construction period.

There are several other areas of development which are also being pursued with a long-term focus. Advanced Heavy Water Reactor for utilization of our abundant Thorium resources, High temperature reactor systems to enable use of nuclear energy for production of hydrogen in addition to electricity and desalination of sea water, accelerator-driven systems to enable growth of power capacity with Thorium systems and of course the fusion energy technologies are some of the important dimensions of this effort.

India in the Exciting Frontier of Space

Prof U R Rao

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Department of Space, Antariksh Bhavan, New BEL Road, Bangalore 560 094

I deem it a great honour to be invited to deliver the 28th Sir R N Mookerjee Memorial Lecture during the 21 st Indian Engineering Congress being held at Guwahati. Sir R N Mookerjee, the Inaugural President of IEI, was a great Scientist, Engineer, Businessman, Philonthropher and above all a humanist. Since in a few months we will be celebrating the Golden Jubilee of the Space Age, which has totally transformed our world, I have chosen 'India in the Exciting Frontier of Space' as my subject of talk today.

Introduction

It was just about 50 years ago with the launching of the first Sputnik in 1957, the humankind entered the exciting new space age, primarily to explore the mysteries of the vast Cosmos and understand the origin and evolution of our universe. The scientific discoveries made since then have revealed the nature of the interplanetary space and our own earth's environment controlled by the continuously flowing solar wind and the presence of exotic celestial Objects, such as, powerful radio quasars, x-ray stars, gamma-ray busters, pulsars and black holes some of which weigh millions of t/cc, thanks to the extensive exploration by low earth orbiting satellites, deep space probes, such as, Explorers, Pioneers, Surveyors, Voyagers and powerful space telescopes, such as, Hubble, Chandra, Einstein and Rossi. For the first time in the history of humankind, we have been able to see the exciting happenings in far off galaxies, including birth of stars, massive outbursts and explosions and closely stare and explore comets, asteroids and nearby planetary systems. In essence space has enabled us to reach almost the end of the universe and go back to the beginning of time when the universe evolved with a big bang.

Equally important is the vast reach and ability of space technology to instantaneously penetrate even the remotest corners of the earth, which has enabled us to establish global communication network, videobroadcasting, point-to-point and point-to-multipoint communication, fixed satellite services, tele-education and tele-medicine. Space has become an essential part of meteorological forecasting and disaster warning and management. Space technology provides vital inputs for the management of earth's natural resources, including agriculture, forestry, environment, soil and water, to achieve sustainable development. It is space technology combined with the convergence of computer and communication that has initiated the most powerful information and communication revolution.

Space has also become the fourth medium of war, much more powerful than land, air and sea. While rocket technology is at the root of ballistic missiles and anti-ballistic missiles, Anti-Satellite (ASAT) weapons of various types have been developed for efficient and accurate delivery of weapons of mass destruction in space, air and from the ground. In spite of the five treaties and five principles adopted by all nations under the United Nations Committee on Peaceful Uses of Outer Space (UNCOPUOS), aggressive space powers can turn space into an arena of serious confrontation to the greater detriment of the entire human species. In my talk, I do not propose to deal with this aspect of space, but confine myself to the tremendous challenges, excitement and satisfaction that the new frontier of space offers for the benefit of entire humankind in India's context.

Formulation of India's Space Vision

The Indian Space Program made a modest beginning with the establishment of an equatorial sounding Rocket Launching Station at Thumba, near Thiruvananthapuram in 1963, for conducting scientific experiments in aeronomy, upper atmosphere, meteorology and astronomy. Realising the vast potential of space technology for addressing many of the basic socio-economic problems of the nation, such as, abject poverty, large scale illiteracy, poor management of natural resources, unsustainable development and disaster proneness, India soon focussed its attention on developing a vibrant application oriented space programme, on a self-reliant basis. The guiding vision for India's space program was clearly enunciated by Dr Vikram Sarabhai, the father of the Indian Space Program, as 'there are some who question the relevance of space activities in a developing nation. To us there is no ambiguity of purpose. We do not have the fantasy of competing with the economically advanced nations in the exploration of the Moon or the planet or manned space flight. But we are convinced that if we are to play a meaningful role nationally and in the comity of nations, we must be second to none in the applications of advanced technologies to the real problems of the man and society'.

During the decade of the seventies, the Indian space efforts were primarily geared towards carrying out research and development in a variety of scientific and engineering disciplines of relevance to launch vehicle and satellite technology, as well as conducting selected large scale experiments in communication, education and remote sensing. During the decades of the eighties and nineties, the experimental initiatives undertaken earlier were progressively transformed into operational systems for providing nationwide services in communication, navigation, broadcasting, education, weather forecasting and management of natural resources. With its primary emphasis on large scale application of space technology on an end to end basis towards national development, the Indian Space Programme has distinguished itself as one of the most costeffective and development oriented Space Programmes in the world.

Development of Satellite Technology

The successful launch of ISRO's first technological satellite, Aryabhata in April 1975, weighing 360 kg, named after India's illustrious astronomer, within a short period of two and half years after the signing of the agreement with USSR Academy of Sciences, was a major significant milestone, which made India the seventh country in the world to design and orbit its own satellite in space. Concurrently, ISRO carried out the world's largest sociological experiment called the Satellite Instructional Television Experiment (SITE) in 1975-76, using NASA's ATS-6 satellite. In the SITE experiment, educational programmes were directly broadcast to specially designed 10ft chicken mesh antenna to 2400 selected remote villages in six states, for imparting education in health, hygiene, environment, better agricultural practices and family planning. The year long SITE experiment, which clearly demonstrated the capability of satellite lV medium for rapidly transforming our rural society, was followed by a hardware oriented experiment called STEP during 1978-79, conducted with the Franco-German satellite Symphony, thus paving the way for ISRO to embark on its own communication satellite programme.

Recognising the potential of space remote sensing for national development, particularly for a predominantly agriculture based country like India, ISRO initiated remote sensing efforts in the late 60's with aerial surveys using infrared and multi-spectral cameras. Beginning with the survey of coconut plantation in Kerala for the detection of wilt disease, ISRO carried out several aerial remote sensing surveys, such as, study of sugarcane plantation in Mandya (Karnataka), soil and land use studies in Ananthpur (Andhra Pradesh), agricultural inventory in Patiala, water pollution level in Godavari river and silting of some major reservoirs. The establishment of Landsat receiving station at NRSA, Hyderabad in 1979 was the next major step taken, which provided valuable experience to the Indian scientists in the processing, analysis, interpretation and use of satellite based remote sensing data for various identified applications.

Immediately following the successful launching of Aryabhata, ISRO launched two experimental remote sensing satellites Bhaskara-1 and Bhaskara-2 in 1979 and 1981, each carrying a two band optical camera and a Dicke Type, three frequency passive micro-wave radiometer. While the optical cameras mapped India's forestry, land use and water bodies at a resolution of 1 km., the radiometers examined the temperature, ocean dynamics and water vapour content over the sea, to provide end to end experience in remote sensing paving the way for ISRO to undertake the design of the state-of-the-art operational remote sensing satellites. Parallelly ISRO also developed a fully three axis stabilised geostationary satellite APPLE carrying 2C-band transponders, which was launched by Ariane in 1981. Through successful orbit raising of APPLE from transfer orbit to geostationary orbit, placing it on its final parking slot at 102°E longitude and operating it for over two years to carry out various communication experiments, ISRO convincingly demonstrated its capability to design and fabricate operational communication satellites.

After extensive studies ISRO decided to design unique multi-purpose and highly cost-effective INSAT satellite system combining communication, broadcasting and meteorology on a single geostationary platform, instead of following the normal practice of building separate satellites for each function. Even though the first generation INSAT-1 series of satellites had to be procured from Ford Aerospace Communication Corporation of US in 1980's to meet the immediate demand for TV broadcasting, ISRO confidently undertook the design, fabrication and launch of the second and subsequent generations of even more complex INSATs which have been in operation since 1990's. Unlike INSAT-1 series, which carried, 12C-band and 2S-band transponders and a very righ resolution radiometer (VHRR) with a resolution of about 2.5 km in the visible and 11 km in the IR, the indigeneously built second and third generation INSAT series of spacecrafts carried additional more powerful global coverage transponders, Kuband transponders for providing fixed satellite services, more sensitive VHRR instruments with a resolution of 2 km in the visible and 8 km in the IR, CCD Cameras with 1 km resolution, disaster warning systems and data collection platforms. To date over 15 INSATs have been launched of which nine of them are concurrently operating to cater to the widely varying and demanding communication, broadcasting and meteorological services, making India the proud owner of one of the largest communication satellite network in the world.

Following Bhaskara, ISRO decided to go on its own for building state-of-the-art first generation operational remote sensing satellites IRS-1A and 1B carrying multispectral imaging cameras with a resolution of 36 m which were successfully launched in 1988 and 1991.These were followed by the second generation IRS-1C and 1D satellites in 1995 and 1997, carrying multi-spectral cameras with an improved resolution of 23 m and a panchromatic camera having a resolution of 5.6 m, which was the world's best at that time. A technology satellite capable of imaging at 0.8 m in the panchromatic was also launched on PSLV in 2001. This has been followed by Resourcesat, an improved version of INSAT-1 D and Cartosat in 2005 carrying stereo imaging cameras with a 2.5 m resolution.

Development of Launcher Technology

Starting with the development of a series of Rohini Sounding Rockets capable of launching 10 kg - 150 kg payloads to an altitude of 60 km-550 km for carrying a variety of scientific experiments, ISRO embarked on the design and development of modest satellite launch vehicle SLV-3 capable of launching a 40 kg. Satellite into a low earth orbit. With the successful launch of SLV in 1981, which orbited a small Rohini Satellite weighing 35 kg, India became the sixth country in the world to have space launch capability.

Development of Augmented Satellite Launch Vehicle (ASLV), with two solid booster strap-ons attached to the first stage of SLV-3, to enhance its launch capability to 150 kg was undertaken immediately, which provided an unique low cost opportunity to develop and qualify complex control technologies including closed loop guidance required for accurate injection of satellite into a predetermined orbit. With the successful launch of ASLV in 1992 ISRO undertook the development of the operational Polar Satellite Launch Vehicle (PSLV) of 2.8 m dia, weighing over 300 t, which has now become the work horse for launching almost 4000 kg into a low earth orbit or about 2000 kg into 900 km Sun Synchronous Polar Orbit required for launching remote sensing satellites. Over 10 successful launches of PSLV since 1994 have fully demonstrated the very high reliability of the vehicle, which will also be used for launching Chandrayaan Moon Mission.

Parallelly the development of Geostationary Satellite Launch Vehicle (GSLV) utilising proven solid and liquid booster modules of PSLV for the first two stages with a cryogenic engine as the third stage was undertaken. With the successful launching of 4 GSLV's into geostationary transfer orbit ISRO has also achieved the capability to launch 2000 kg into GTO which will be enhanced to upwards 3000 kg very soon with the new 20 t cryogenic engine which is already undergoing its final validation tests.

Application of Space Technology

India has one of the largest domestic communication satellite system with over 175 communication transponders on nine geostationary satellites providing a variety of communication and meteorological services to the country. INSAT's have been very advantageously used for providing long distance communication on 10000 two way speech circuits, nationwide radio networking, business and computer communication and over 60000 VSAT terminals for providing fixed satellite, emergency communication as well as search and rescue services. Most dramatic impact of INSAT has been the rapid expansion of TV dissemination with 1400 transmitters and a large number of direct reception sets providing access to over 90% of India's population to national as well as regional services through 60 channels of telecasting. The rapidly expanding Direct to Home Television (DTH) service will no doubt require doubling of INSAT capacity in the near future to provide our citizens reliable access to high quality digital TV broadcasting services. Six developmental communication channels are being effectively used for broadcasting educational programs both to the universities and educational institutions and developmental programs for rural areas. Launching of EDUSAT in 2003, has greatly expanded the educational network and has become a valuable asset for students particularly faced with poor educational infrastructure and lack of qualified teachers. At present, under Edusat program, a total of 38 networks connecting 7600 class rooms in various states has already become operational.

Use of INSAT for providing specialized medical facility to even remote rural areas of the country, is fast emerging as an important application of satellite communication system. Telemedicine consists of customized medical software integrated with computer hardware connected to a commercial VSAT at each rural location linked in real time to R super speciality hospital through INSAT. Specialist doctor can access medical history, ECG, X-rays and other relevant records of a patient in the rural area to diagnise the problems of the patient and advice the patient and his paramedic at the rural end on the appropriate course of medical treatment. Already about 150 remote area hospitals in several states such as Karnataka, Kerala, Jammu and Kashmir and North eastern states have been linked to 34 super speciality hospitals, which has so far treated over 100 000 patients in just a period of one year.

The INSAT System has become the primary backbone of round the clock, regular, half-hourly meteorological imaging and continuous weather forecasting. The primary data from VHRR received by the Meteorological Department at Delhi, is processed along with the data from automated unattended data collection platforms located in inaccessible areas to derive products like cloud motion vectors, sea surface temperature and rain precipitation. The processed data along with cloud pictures are transmitted to about 40 Secondary Data Utilization Centres (SDUC) located in various parts of the country for further dissemination. During cyclones and other emergency situations, INSAT VHRR is capable of imaging every 5 min in the sector scan mode. Beginning with the INSAT- 2 series, a search and rescue payload was also added, which complements the efforts of COSPAS-SARSAT system and provides real time detection of 406 MHz distress alerts within the Indian Ocean Region. Combining the communication capability with meteorological inputs, INSAT's have been successfully providing locale specific disaster warnings to the entire Eastern and Western coastal areas since last 20 years.

IRS system has brought a sea change in India's capability in monitoring and management of its natural resources. As of today India has the largest constellation of seven remote sensing satellites (IRS-1 C, 1D, P3, Oceansat, TES, Resourcesat and Cartosat)in orbit, providing synoptic, high-resolution imageries over the sub-continent. These form the backbone for mapping spatial as well as temporal changes in soil characteristics, land use pattern, forest resource, agricultural inventory, fisheries and wasteland. Methodologies have been developed to identify underground water aquifiers, map surface water bodies, estimate snow melt run-off, delineate water logged regions and predict acreage and yield of all major crops using IRS imageries. Regular bi-weekly bulletins demarcating potential fishing zones in the ocean, based on ocean temperature and phytoplankton distribution, are routinely distributed to all the fishing centres in the coastal areas to enable fishermen to obtain improved fish catch. Space remote sensing has become the most important tool for urban planning, wasteland monitoring and environmental management. Space imageries are extensively used for mineral prospecting, coastal management and proper scheduling of command area irrigation. Extensive use of space remote sensinq has led to the development of National (Natural) Resources Information System (NRIS) around GIS for facilitating developmental planning and decision making at National/District levels. Establishment of 6 Regional Remote Sensing Service Centres and a number of state level centers has ensured optimal usage of space imageries for carrying out a variety of developmental tasks.

An unique application of IRS data is in the Integrated Mission for Sustainable Development (IMSD), aimed at generating locale-specific prescription for the sustainable development of the land resource at micro-level. Indian scientists have been able to successfully demonstrate the feasibility of substantially enhancing agricultural productivity on a sustainable basis at each watershed level through IMSD strategy by combining space remote sensing inputs, using GIS based precision farming techniques and site specific agricultural practices based on recent advances in biotechnology.

In order to provide basic services such as healthcare, education and information related to land and water resources, agriculture and animal husbandry to the rural areas, ISRO has recently initiated establishment of Village Resource Centers (VRC), in partnership with concerned state, central agencies, institutions, universities, research organisations, selfhelp groups and Non Governmental Organisations. The VRCs are meant for delivering the benefits of space technology directly to the communities at the grass root level, through a single window delivery system for improving the quality of rural life. The VRCs can handle both dynamic and generic information to empower rural communities by initiating acknowledge revolution in rural India and enable them to enhance their economic security through sustainable development and creation of agrobased industry.

As a part of its continuing quest to enhance capability and self-reliance ISRO has also been carrying out development of air-breathing engines and reusable launchers for meeting the challenge of drastically reducing the cost of space launchers. To-date ISRO has launched over 42 satellites, 21 of which have been from Sriharikota Space Port (Satish Dhawan Space Center) using our own launch vehicles. The entire cost of India's Space Program since 1962 including the total infrastructure built at various centers and the extensive user applications and services in communication, broadcasting, management of natural resources, meteorological forecasting and disaster management systems is just about Rs 25 000 crores (or 9 billion US $), which is half an year's budget of NASA.

Future of Space

In spite of the tremendous scientific discoveries since the onset of space age, there exist a large number of unanswered questions on the origin and evolution of the universe with many more new ones being posed afresh as we to unravel the mysteries of the universe. While we continue to debate on the important subject of the existence of life and intelligence elsewhere in the universe, scientists are still seeking answers to the question of availability of even life supporting water on our nearest celestial neighbour Moon or planets like Mars. In the coming two decades we will see a large number of Moon as well as planetary missions for detailed exploration of their atmosphere, mineral resources, presence of water and He3' and geophysical characteristics with the view to exploit their valuable resources to support human activities on our own planet and eventually establish human habitats outside our earth.

India has scheduled the launch of ASTROSAT-1 in 2008, a multiwavelength observatory capable of exploring celestial objects in the visible, ultra-violet and x-ray wavelengths as a part of its Astrophysical research. India has also scheduled a Moon Mission Chandrayaan in 2007-2008 which should provide some answers to the important questions of presence of water and mineral resources on the Moon. Indian scientists have already started planning follow-up missions to Chandrayaan, for intensive investigation of the Moon and exploration of Mars and Asteroids.

In addition to exploitation of mineral resources including He3 on other planets to satisfy the needs of growing earthlings, large scale utilization of solar energy to meet the energy demands on earth has been engaging the attention of all space scientists since last two to three decades. The technologies for collection of solar energy using high efficiency solar cells (with nano-technology it is believed that the solar cells of over 50% efficiency can be manufactured) at geostationary altitudes where the solar radiation is available practically all the time, conversion into microwaves for beaming back to the earth wherever energy is needed and reconverting the microwave energy back into electricity at suitably located microwave farms, have been already developed. It is only a simple matter of economics which is holding up this project which can be solved by drastically reducing the cost of space launches.

Furious attempts are going on everywhere to reduce the cost of space transportation by developing reusable launchers involving Two Stage to Orbit (TSTO) or even Single Stage to Orbit (SSTO) launchers. Such launchers will also have to be air-breathing systems, which carry only the propellant and acquire the needed oxidiser through air breathing at lower altitudes, thus increasing the payload-carrying fraction from the present 2%-3% to at least 15%-20%. A reduction in the cost of transportation using reusable air-breathing rocket system, from the present $30, 000 / kg to $3000/ kg or even less will of course reduce the cost of space travel from the present $20 million to say $20000 per person which will naturally boost space tourism in a big way.

Even on the question of life on other Planetary Systems, it is only about 10 years ago, that scientists were able to actually discover exo-solar planets. Even though over 200 planets have been discovered during the last decade, most of them are gaseous planets like Jupiter orbiting around neutron stars. Only recently an earth like planet has been discovered but it is too cold to support life, as it orbits around a red dwarf. We are probably eons away from discovering life let alone our intelligent cousins, but when we do so we will probably achieve our crowning glory.

Even more exotic is the concept of space elevator to the geostationary orbit, first proposed by Arthur C Clarke about twenty years ago, which now seems feasible with the availability of very high strength nano-technology materials. An elevator to the geostationary orbit or even to the Moon can be used as a staging point not only for space exploration but also for two way, large scale transport of men and materials. This will eventually help in large-scale colonisation of Mars, which in principle is feasible to achieve in a thousand years. The global human congestion in the energy, resource and opportunity starved earth can then be relieved by large scale colonisation of Mars, hoping that peace will prevail between the earthlings and Martians of 3000.

Space, with all its challenges, excitement and infinite variety is and will continue to be the most exciting new frontier. Space technology is no doubt multi-disciplinary, exacting, demanding and highly complex but very challenging and satisfying physically and intellectually. I firmly believe that the younger generation who are seeking challenges and who dare to dream and back up their dream with hard work and commitment should get into space for the benefit of entire humankind.

The Twenty-ninth Sir Rajendra Nath Mookerjee Memorial Lecture was delivered during the Twenty-second Indian Engineering Congress, Udaipur, December 13-16, 2007

Space Technology and Applications in India

Dr G Madhavan Nair

Chairman
Space Commission, Secretary, Department of Space

I am extremely happy to deliver the 29th Sir R N Mookerjee Memorial Lecture. I consider it as a rare honour and proud privilege to have been invited to deliver this lecture. Sir R N Mookerjee, one of the illustrious sons of Bengal, starting from humble beginnings rose to positions of eminence in the engineering scenario of the country through hard work and established himself as one of the leading engineers of the country. Some of the projects executed under his guidance still stand as testimony to his yeoman contribution to the field of engineering. I pay my humble tribute to this great luminary who was the first President of The Institution of Engineers (India). I have chosen the topic for my lecture on the challenges posed in developing the space technology and services in the country and how we harness this high technology for the benefit of common man.

INTRODUCTION

India has carved out a niche for itself in the area of space technology in the international arena through remarkable achievements in mastering complex technologies in a self-reliant manner. The space programme started in the early 1960s to conduct scientific investigation of upper atmosphere and ionosphere over the magnetic equator that passes over Thumba near Thiruvananthapuram using small sounding rockets. But soon, the visionary founder of Indian Space Programme, Dr Vikram Sarabhai, realised the potential of space technology for national development. He believed that: 'We must be second to none in the application of advanced technologies to the real problems of man and society'.

The space programme was well orchestrated through a planned strategy of first demonstrating the efficacy of space systems using foreign satellites and developing experimental satellites, establishing indigenous operational satellite systems with foreign launch services and finally launch these satellites also using indigenously designed and developed launch vehicles.

DEMONSTRATION OF SPACE APPLICATIONS

In order to demonstrate the potential of space systems for national development, the US Application Technology Satellite, ATS-6 was used in the Satellite Instructional Television Experiment (SITE) conducted during 1975-76. SITE involved deployment of direct reception TV sets in about 2400 villages across six states of India to receive educational programmes covering agriculture, family planning, health and hygiene, etc. This was hailed as the world's largest sociological experiment using space technology and has played a significant role in demonstrating the application of satellites for development of education for a large country like India.

Satellite Telecommunication Experimental Project (STEP) using Franco-German 'Symphony' satellite, was another major effort undertaken during 1977-79 to gain experience in use of satellites for providing connectivity to remote and far flung areas for domestic telecommunications.

In the field of remote sensing, India was one of the first few countries to establish a reception station for receiving data from US remote sensing satellite LANDSAT. This helped India to gain first hand experience in the reception, processing and application of space-based remote sensing data. A number of joint experiment projects in remote sensing were undertaken using the LANDSAT data with the participation of user departments in the country. Several remote sensing experiments using aircraft mounted cameras were also conducted.

EXPERIMENTAL SPACE SYSTEMS

While demonstration of space systems for several innovative developmental applications was continuing, simultaneous development of space hardware was also undertaken. Aryabhata, the first Indian satellite launched on April 19, 1975 by an Intercosmos rocket of the erstwhile USSR provided experience in design, fabrication and operation of a satellite system. It was followed by two experimental remote sensing satellites, namely, Bhaskara-1 and Bhaskara-2 and experimental communication satellite Ariane Passenger Pay Load Experiment (APPLE), which were launched in the time frame of 1979-81. APPLE was built in a record time in order to utilize the free launch provided by M/s Arianespace in one of their developmental flights. APPLE provided valuable experience in design, development, fabrication, integration, testing and in-orbit operation of satellite based systems and their applications in various fields for national development. The indigenous development of the first Indian Satellite Launch Vehicle

(SLV-3) and its successful launch on July 18, 1980 was a landmark in making Indian space programme self-reliant. SLV-3 paved the way for the subsequent Augmented Satellite Launch Vehicle (ASLV) and operational launch vehicles, such as, Polar Satellite Launch Vehicle (PSLV) and Geo-synchronous Satellite Launch Vehicle (GSLV).

OPERATIONAL SPACE SYSTEMS

Indian National Satellite System

Today, space has become an inseparable part of national infrastructure for providing reliable, uninterrupted services in the area of TV broadcasting, telecommunications, meteorology and management of natural resources. India has established its own operational space systems — Indian National Satellite (INSAT) system and Indian Remote Sensing Satellites (IRS) to provide these services.

INSAT system established in 1983 is the largest domestic communication satellite system in the Asia Pacific region with ten satellites in operation carrying more than 200 transponders for communication and broadcasting services including direct-tohome service besides meteorological instruments for providing meteorological services.

Today, more than 55 000 VSATs — both in private and government sectors — are operating through INSAT. INSAT has enabled the expansion of television coverage with more than 100 Doordarshan TV and 100 private TV channels. Direct-to-home (DTH) television services have become a reality. More importantly, there have been several innovative applications of INSAT system. EDUSAT, launched in September 2004, is the first thematic satellite dedicated exclusively for educational services. It is providing a wide range of educational delivery modes like one-way TV broadcast, interactive TV, video conferencing, computer connectivity, web-based instructions, etc. More than 30000 classrooms are connected in the EDUSAT network. Telemedicine is another example. Space-based telemedicine has enabled the people in the remotest parts to access super speciality medical care. Already, there are 258 hospitals connected in the telemedicine network including 216 in remote and rural areas and 42 super speciality hospitals in major cities. Meteorological data from INSAT is used for weather forecasting and specially designed disaster warning receivers have been installed in vulnerable coastal areas for direct transmission of warnings against impending disaster like cyclones The major emphasis in the coming years will be to meet the growing demand for transponders by progressively increasing the capacity to about 500 transponders.

An Indian Regional Navigational Satellite System (IRNSS), with a constellation of seven satellites is also being established over the next six to seven years to provide navigation and timing services over the Indian subcontinent. IRNSS will be an important component of the Indian strategy for establishing an indigenous and independent satellite navigation system.

Empowering the Society — Developmental Communications and Training

India is faced with the enormous task of carrying out development oriented education to the masses at their lower strata of the society. Empowering this section of the society with developmental communication, awareness programmes and training is very crucial to achieve progress. Satellite communication technology has the capability to simultaneously reach out to large population spread over long distances and is a powerful tool to support development of education and training.

INSAT based one-way video and two-way audio interactive networks have been used for distance education, training, continuing education and developmental communication.

Extending the Reach — EDUSAT Programme

The Indian education system is very vast and has many unique requirements. Some of the issues include reaching the un-reached, continuing education, resource crunches and the need for lifelong enrichment. For a great majority of people living in the countryside and in small towns, it is often difficult to gain access to the benefits of quality higher education.

With the successful demonstration of several developmental and educational programmes, a satellite for educational services, EDUSAT was conceived. Prior to the launch of EDUSAT, a pilot project was undertaken through Visvesvaraya Technological University (VTU), Belgaum, by networking about 100 engineering colleges using an existing INSAT satellite.

EDUSAT was launched by GSLV on September 20, 2004. With five Ku-band transponders providing spot beams, one Ku-band transponder providing national beam and six extended C-band transponders with national coverage beams, EDUSAT is specially configured for audio-visual medium, employing digital interactive classroom and multimedia multi-centric system. It is primarily meant for providing connectivity to school, college and higher levels of education and also to support non-formal education including developmental communication.

Important institutions making use of EDUSAT are, Indira Gandhi National Open University (IGNOU), University Grants Commission (UGC), National Council for Educational Research and Training (NCERT) etc. At present, about 30 000 classrooms are in the EDUSAT network.

Providing a Healing Touch — Telemedicine

Providing healthcare to India's over one billion population, of which 75% live in villages, is a formidable challenge. Satellite communication technology, combined with Information Technology, provides the means to take the benefit of medical sciences to large sections of people spread out in remote and inaccessible villages. Telemedicine is a confluence of communication technology, information technology, medical engineering and medical science. The telemedicine system consists of customized hardware and software at both the patient and doctor's end with diagnostic tools like ECG, X-ray and pathology provided at the patient end linked through digital connectivity via INSAT satellites by VSATs. The medical record/history of the patient is sent to the specialist doctors who, in-turn, will study and provide diagnosis and treatment through video conference with the local doctor and patient.

Satellite based telemedicine network now connects more than 250 hospitals in remote and rural hospitals including those in Jammu and Kashmir, North-Eastern region and Andaman and Nicobar Islands with 34 super speciality hospitals in major cities as well as a few hospitals of the Indian Air Force. More than 3 00 000 patients have been provided tele-consultation and treatment using ISRO's telemedicine network.

INDIAN REMOTE SENSING SATELLITE SYSTEM

Indian Remote Sensing satellite system (IRS) was commissioned with the launch of IRS-1A, in 1988. With seven satellites in operation, IRS is the largest civilian remote sensing satellite constellation in the world providing imageries in a variety of spatial resolution and spectral bands. The latest, CARTOSAT-2, launched on January 10, 2007, provides 1 m spatial resolution.

The data from IRS is used for a variety of applications including groundwater prospect, large scale mapping, crop acreage and production estimation, potential fishing zone forecasting, biodiversity characterization, detailed impact assessment of watershed development projects, generation of natural resources data/information, etc.

In order to reach space-based services directly to the rural population, establishment of Village Resource Centres (VRC) has been recently initiated with the participation of NGOs. VRCs provide a variety of space based products and services, such as, teleeducation, telemedicine, information on natural resources, interactive advisories on agriculture, fisheries, land and water resources management, livestock management, interactive vocational training towards livelihood support, etc. So far, about 300 VRCs have been set up.

Space systems also help in disaster management through creation of database for facilitating hazard zonation and damage assessment, monitoring of major natural disasters using satellite and aerial data and strengthening the communication backbone for timely dissemination of information and emergency support.

An important addition in the coming years will be the Microwave Remote Sensing satellite, which will provide all-weather remote sensing capability important for applications in agriculture and disaster management.

Monitoring Natural Resources — Remote Sensing Applications

Remote sensing from satellites has opened up a new dimension of spatial data gathering for inventory and monitoring of natural resources. The advantages of satellite-based remote sensing techniques include synoptic view and repetitive coverage enabling change detection, multi-sensor and multi-spectral data enriching the information content and digital capture of the data for objective and rapid interpretation using computers.

Several national missions in the key areas of social development have been carried out using the IRS data. The applications cover diverse field of interest like water, agriculture, land use, minerals, watershed development, disaster management, etc.

Towards Quenching the Thirst

More than 90% of rural and nearly 30% of the urban population in India depend on groundwater for meeting their drinking and domestic requirements. Groundwater also accounts for nearly 60% of the irrigation potential in the country.

Remote sensing data provides information on landform, structure, lithology, land use/land cover, soil, drainage, topography, etc, which controls the occurrence/movement of groundwater.

Groundwater prospects of an area can be assessed using these parameters by integrating them with the collateral data and field observations. Remote sensing based groundwater prospect zone map serves as a base for further exploration using hydro-geological and geophysical methods to locate well sites. Under the National Drinking Water

Mission, launched in 1986, remote sensing technology has been used for preparation of hydrogeomorphological maps (showing groundwater prospects) of the entire country on 1:250000 scale. Further, under the Rajiv Gandhi

National Drinking Water Mission (RGNDWM), groundwater prospect maps on 1:50000 scale are being generated for selection of well sites in all the habitations having drinking water problem. So far, about 200000 wells have been drilled and 4000 recharge structures have been constructed. The success rate achieved in hitting bore wells based on remote sensing technology is about 90% compared to 30% to 40% before application of this technology.

Ensuring Food Security — Forecasting Agricultural Output

India produces about 210 Mt of food grains from about 145 MHa cultivated area (both irrigated and rain-fed). Timely availability of reliable information of agricultural output and other related aspects is of significance for planning and policy making. Capabilities of the existing system of crop forecasts and crop estimation have been greatly enhanced with the use of Remote Sensing (RS) and Geographic Information System (GIS).

Crop Acreage and Production Estimation (CAPE) using Remote Sensing was started in 1986. Production estimates for principal crops like wheat, rice, sorghum, cotton, mustard and groundnut are made using stratified random sampling approach. Under CAPE project, acreage is estimated based on the discrimination of major crops using multi-date data and yield models. Basic procedures, models and software packages for crop area and production forecasting, using remote sensing and weather data have been developed.

The scope of the CAPE project has been further expanded by the project 'Forecasting Agricultural Output using Space, Agro-Meteorology and Land based Observations' or FASAL. Remote sensing, weather and field observations are also used for making crop forecasts under FASAL. CAPE has shown considerable improvements in terms of accuracy, coverage and timeliness.

Potential Fishing Zone Forecast

About seven million people living along the 7500 km coastline of India are dependant on fishing for their livelihood. A reliable and timely forecast on potential zones of fishing can benefit the fishing community to reduce time and effort in fishing. Data from remote sensing satellites, which have a synoptic view of the oceanic area, provides information on distribution and abundance of fish. Satellite based Potential Fishing Zone (PFZ) forecast helps in deepsea fishing. An integrated approach has been developed for PFZ identification using chlorophyll and Sea Surface Temperature (SST) data.

The PFZ advisory is generated and disseminated at present to Gujarat, Maharashtra, Karnataka, Goa, Kerala, Tamil Nadu, Andhra Pradesh, Orissa, West Bengal, Andaman and Nicobar and Lakshadweep Islands. Presently, more than 225 nodes are receiving the forecasts regularly. The feedback from Gujarat indicates an increase of about 100% in the catch in PFZs located in 30 m to 50 m depth and 70% increase in catch in PFZs located at 50 m to 100 m depth.

Optimising use of Land and Water

With nearly 65% of the net sown area in India being rain-fed, characterisation and prioritisation of watersheds are essential steps towards an integrated management of land and water resources. Watershed characterisation involves measurement of parameters of geological, hydrogeological, geo-morphological, hydrological, soil, land cover, etc, which is possible through remote sensing. Remote sensing data facilitates mapping of land use/cover, geology, soils and other features of watershed, which would assist in the study of land use pattern, water potential, degradation, etc. This data, along with the ground based information, can be used for assessing the land capability, irrigation suitability classes, potential land uses, suitable water harvesting measures, monitoring effects of watershed conservation and development measures, correlation of runoff and sediment yields from different watersheds and monitoring land use changes and land degradation.

Space imagery has been used for watershed planning, development and monitoring. Important initiatives undertaken so far are integrated Mission for Sustainable Development (IMSD) carried out during 1997-2001, monitoring and evaluation of watersheds treated under National Watershed Development Programme for rain-fed areas, monitoring and evaluation of Sujala Watershed Development Programme of Karnataka since 2002 and Development Planning for Kachchh District, Gujarat during 2003-04 after the Earthquake.

Reclaiming Precious Land

India has a diversity of physical landscapes and different types of land that have various types of utilisation. Due to increasing population, there is an excessive demand for land for agricultural and non-agricultural applications. Wastelands can be brought under vegetative cover with reasonable efforts.

Mapping of wastelands has been carried out for the entire country using IRS data. The maps, organized topographic sheet-wise, provide details on 13 different types of wastelands at district and village level. The Wasteland Atlas of

India was released in 2000. These maps are invaluable to retrieve information at village/watershed level for implementation of watershed development programmes.

Protecting Biodiversity

With wide variations in the altitude and temperature, India has one of the most diversified landmasses and is among the 12 countries identified as mega-centres of biological diversity. The panorama of Indian forests ranges from evergreen tropical rain forests in the Andaman and Nicobar Islands, the Western Ghats, and the Northeast region, to dry alpine scrub high in the Himalayas to the north. Of the estimated 45 000 plant species, some 15 000 species of flowering plants has been so far described. It is third in Asia and eleventh in the world with a share of around 11% of total floristic diversity.

India has taken many steps in strengthening the measures of biodiversity conservation and sustainable use. Satellite imageries have been effectively used in biodiversity characterisation at landscape level to create geospatial database on vegetation cover types, disturbance regimes and biological richness. Four main biodiversity rich regions of the country — North-Eastern Region, Western Himalaya, Western Ghats and Andaman and Nicobar Islands have been covered. The information system evolved facilitates in quick assessment of biodiversity and its monitoring, assessment of nature of habitats and disturbance regimes therein, evolving species — habitat relationship, mapping biological richness and gap analysis and prioritising conservation and bioprospecting.

SELF-RELIANCE IN ADVANCED LAUNCH VEHICLES TECHNOLOGIES

Indian space programme has become self-reliant with the operationalisation of two satellite launch vehicles, PSLV, mainly for launching IRS class of satellites in polar orbits and GSLV for launching communication satellites into geo-synchronous transfer orbit. So far, PSLV had ten consecutively successful flights including the one in April 2007 that launched the Italian AGILE. GSLV can launch 2t to 2.5t satellite into Geo-synchronous Transfer Orbit (GTO) 200 km by 36 000 km. GSLV with four successful launches out of five launches has established itself as reliable vehicle.

When India's Polar Satellite Launch Vehicle (PSLV-C8) successfully launched AGILE, a satellite of the Italian Space Agency, in April 2007 under a commercial agreement, the Indian space programme achieved a rare distinction. From using the satellites of other nations to demonstrate the application of space technology for societal benefits in the 1970s, using rockets of other space agencies to launch Indian experimental satellite and, later, operational satellites, to the present enviable status of building its own rockets to launch not only for Indian users but also of other countries. The 350 kg AGILE was precisely injected in the intended 550 km circular orbit, unequivocally demonstrating the maturity in this complex technology.

Earlier, in January 2007, there was another major landmark achievement. The Space Capsule Recovery Experiment (SRE-1) was launched by PSLV and later successfully recovered from the Bay of Bengal. This marked the beginning of a new era for the Indian space programme — that of not only providing a platform for the scientists to conduct experiments in the micro-gravity environment of space and return the samples safely back to earth, but also, demonstrating India's capability in mastering critical technologies like aerothermodynamics, recovery through deceleration and floatation system, navigation, guidance and control. All these technologies are important for re-recoverable and reusable launch vehicles as well as to undertake manned space missions.

Another major achievement which gave the country coveted status was the recent successful testing of the cryogenic upper stage on November 15, 2007. Development of cryogenic technology involved apart from the complexities in the fabrication of stage tanks, structures, engine and its sub-systems and control components, CUS employs special materials like aluminium, titanium, nickel and their alloys, bi-metallic materials and polyamides.

The immediate target is to complete the development of GSLV Mk III capable of launching 4t class communication satellites. Technology development and demonstration missions on reusable launch vehicle including space recovery technologies and air breathing propulsion are also envisaged.

Supporting Disaster Management

India, with around 80% of its geographical areas vulnerable to cyclones, floods, landslides, drought, earthquakes and other localized hazards, has been one of the most disaster-prone countries in the world. In recent years, disaster management has attracted greater attention. The emphasis is on risk reduction through mitigation, preparedness, prediction and early warning. Space systems, INSAT and IRS, provide disaster management support for early warning, risk information, impact/ damage assessment, preparedness and emergency communication. A Decision Support Centre (DSC) has been established at National Remote Sensing Agency (NRSA), Hyderabad, as a single window service provider to deliver the space services for disaster management.

INSAT Mobile Satellite Services (MSS) terminals are being put to use during emergencies. The effectiveness of this system has been demonstrated successfully during the floods in Assam and tsunami in Andaman and Nicobar Islands.

In the aftermath of the tsunami that struck southern parts of India on December 26, 2004, transportable VSATs and INSAT Mobile Satellite Services (MSS) systems were deployed to provide vital connectivity between the main land and Andaman and Nicobar Islands. Telemedicine facilities, set up in the Andaman and Nicobar hospitals of these islands could be effectively used for providing connectivity to super speciality hospitals on the main land. To facilitate relief operations, satellite remote sensing data over the tsunami affected areas in Tamil Nadu, Andhra Pradesh, Kerala and Andaman and Nicobar were generated. To mitigate the hazards of land slides in parts of Himalayas, a project on land slide risk zonation has been carried out along the important tourist and pilgrim routes in Himalayas.

IMPARTING KNOWLEDGE TO RURAL SOCIETY — VILLAGE RESOURCE CENTRES

There are more than 6 00 000 villages in India and around 700 million people live in villages. Many villages are relatively deprived in terms of basic amenities and services, especially those related to education, health, sanitation and empowerment. Use of satellite based communication and remote sensing can help in providing services related to health care, education, weather, land and water resources, agriculture, etc. To provide these space-based services to the rural areas, setting up of Village Resource Centres (VRC) in partnership with state, central agencies and NGOs, Trusts was initiated in 2004.

VRCs are envisaged as the single window delivery mechanism for a variety of space based services and deliverables, such as, telemedicine, tele-education, information on natural resources for planning and development at local level, interactive advisories on agriculture, fisheries, land and water resources management, livestock management, interactive vocational training towards alternate livelihood, e-governance services, weather information, etc. The VRCs also address variety of social aspects locally and even act as helplines.

CONTRIBUTING TO SCIENTIFIC KNOWLEDGE

Scientific exploration of space has gained impetus under the Indian space programme with the initiation of the first mission to moon, Chandrayaan-1. The basic objective of Chandrayaan-1 is the physical and chemical mapping of the lunar surface and to look for minerals and also possibility of existence of water. Chandrayaan-1 will be followed by a multi-wavelength astronomy satellite, Astrosat and climatic research satellite Megha- Tropiques.

COMMERCIAL SUCCESSES

The capabilities established under the Indian space programme have been used for commercial gains which include leasing INSAT transponders to Indian and International customers, providing access to data from Indian remote sensing satellites and launch services. A recent foray has been the contract with a European company for joint development of communication satellites for the international market.

CONCLUSION

The Indian space programme is unique in the world in that it aims at establishing space systems that are of direct relevance to national development. Designed and established in a self-reliant manner, the space systems are tuned to India’s specific needs. The application of the space systems in almost all facets of human endeavour — communication, broadcasting, weather watch, disaster management, tele-health, tele-education and optimum management of natural resources, has made the space programme inseparable part of the infrastructure in the country.

ICT and Innovation — Enablers for Economic Transformation

Shri S Ramadorai

Chief Executive Officer (CEO) & Managing Director (MD)
Tata Consultancy Services (TCS)

I travel far and wide in the course of my duties, but it not often that I get to see hidden treasures as those at Warangal. This is my first visit to Warangal and I am truly amazed by what this town has to offer. Obviously it takes more than a lifetime to discover India.

It is only befitting to host the 23rd Indian Engineering Congress here, in Warangal, in commemoration of the golden jubilee of the National Institute of Technology (NIT), Warangal. Prof Rao, I would like to congratulate you on this occasion. I am honored to be invited amongst intellectuals from the field of Engineering, in a town that was once the seat of power, culture and intellectual activity of the Kakatiya Dynasty.

Warangal symbolizes an engineering feat that was accomplished centuries ago, when the entire city was carved out from a single rock, lending it the name Orugallu or Ekasila Nagaram — a feat that even found a mention in the travel diaries of Marco Polo.

Since time immemorial, engineering accomplishments have had a profound influence on societies and the advancement of civilization. Engineering has a common language across the world, and a common goal- improving the quality of life. Organizations such as the Institution of Engineers play an important role in not only celebrating Engineers but, more importantly, bringing them together as a fraternity to collaborate with each other.

India — Opportunities and Challenges

Never before in time has the world, and indeed India, required the services of this fraternity to work on the challenges posed by our times:

Firstly, while our country has made great advances in the field of science and technology (our nuclear capabilities and the recent launch of Chandrayaan bear testimony to this), we face a challenging time at present due to the US recession. However, I believe that as a nation we have reached a certain momentum of growth that will resume itself. Sectors such as IT, Power, Infrastructure, Steel and Automotives will lead this growth. All of them are being forced to transform themselves by the frenetic pace of market dynamics. These sectors need Change Leaders that will bring in innovation and a new work culture.

Secondly, while the global ICT ecosystem is helping to build a more inclusive society, we still face basic problems including poverty, illiteracy, low agricultural productivity, unemployment and disease. India needs its best minds to address these problems.

Thirdly, at a global level, we have callously abused the abundant resources of the planet, disturbing the delicate balance of nature. Nature is now fighting back. Collective action of scientists, governments and engineers across the world is called forto address this issue.

Addressing these three issues are the biggest challenges faced by the engineers today. Fortunately, most engineers love challenges; in fact, they thrive on them. Today we are empowered with new knowledge and new tools, including IT, which enable new solutions. The scale and enormity of these challenges demands multi-stakeholder models involving IT experts, domain experts, businesses and the government to come together in private-public partnerships.

When it comes to private-public partnerships in the country, TCS has been leading the effort in large transformational programs that impact the general public. We work with the Government to implement these. TCS has helped metamorphose the working of the National Stock Exchange and National Securities and Depositories Ltd, to ease the worries of India's shareholders.

Over one Crore people in Andhra Pradesh have benefitted through the National Rural Employment Guarantee Scheme. The Scheme guarantees 100 days of wage employment in a year to every rural household across the country. TCS has provided an end-to-end IT solution that integrates processes such as Enrolment of a Wage Seeker, Management of Funds and Social Auditing into a single framework, thus minimizing frauds.

The lives of entrepreneurs and businessmen in the country have been greatly eased by making registration and other company related processes available online, via the MCA 21 project implemented by TCS. This model demonstrates that Government, technology experts and community development staff can work together successfully.

Shortage of Talent

All the private-public partnership projects I cited earlier are highly complex, are high tech and impact a phenomenal number of Indians. As more such initiatives get under way, the effort will require an enormous increase in the engineering workforce.

Corporate India is becoming professional; it is also eager to go global, in several industry sectors. In the sunrise sectors, the scale and ambition of vision are very different from what they were about a decade ago. As these sectors transform themselves, there is a golden opportunity for professionals to lead this transformation, build world-class companies, and create enduring value. Along with this are financial gains. The opportunities available in India, together with the recession in the US, are in fact luring Indians working overseas back home, to join Indian companies.

This pace of growth is not without challenges. Because organizations and the environment in which they operate are changing fast, the chasm between the skills required and skills available is widening rapidly. In the Power sector, for example, the total additional manpower required for the 11^{th} plan period is of the order of one Million. In 'Power Generation' related projects the requirement for entry level people is 7,308 but only 5,040 are available. The shortfall is about 31%. At senior levels the shortfall goes up to 34%.

There is a demand for 8,000-10,000 engineers in the embedded software and chip design space, but the supply is just a third of that number. In telecom, the wireless segment, there is an annual shortfall of 8,000 engineers. Howwill we as a nation address this shortfall?

IIT Bombay Study

To get a better handle on the problem by IIT Bombay undertook a study on the engineering landscape in India. The study aimed to answer questions such as:

• Has the engineering education system been able to provide, quantitatively and qualitatively, the engineers required for the growth ofthe Indian economy?

• Has it provided the research and development leadership required for our industry?

• In the context of globalization, is there a need to modify the higher engineering education system in India?

The study shows that against the sanctioned seats of 6.57 Lakh for Under Graduate Engineering education in India, only 2.37 Lakh Engineering degrees were awarded in 2007-08. This very clearly highlights the shortfall. In 2006, India awarded about 2.37 Lakh Engineering degrees, 20,000 Engineering Masters degrees and 1000 Engineering PhDs, which means a total of 2.58 Lakh Engineering degrees of all types. This is clearly not enough! The awarding of degrees is also not evenly distributed across India. Five states — Tamil Nadu, Andhra Pradesh, Maharashtra, Karnataka and Kerala — are said to account for almost 69% ofthe country's Engineers.

It is estimated that about 30% of the fresh Engineering graduates are unemployed even one year after graduation; and this is even as many sectors complain of lack of talent. This clearly points that there is definite scope to improve quality of Engineering education.

Let us also look at the gender factor. At IIT Bombay, the percentage of women graduates to the total is about 8% at the B.Tech level, 9% at the M.Tech level and about 17% at the Doctoral level including Science, Humanities and Management. Similar disparity exists among the facultyonly about 10% of the IIT Bombay faculty comprises women.

Gender disparity in the Engineering stream exists around the world, not just in India, and special efforts are being made by institutions, Governments and professional organizations to rectify these. Some Indian states have provided incentives like free tuition for women studying Engineering.

Overall, the study rightly points out that India has the potential to be a leading research and design hub in the world. For this, we need to have a mechanism to identify important areas and disciplines that should grow, and develop policies and institutions accordingly.

New kind of Engineer

Globalization has enabled a new place for India, the challenges facing our country are new, and the market is highly dynamic and complex. In this scenario, the industry demands a new kind of Engineer.

Systems Thinking

This complexity demands a new way of thinking — it requires a Systems Thinking approach to macro level challenges and requires Engineers to keep one eye on the big picture even as they tackle specific tasks. Systems Thinking provides a conceptual framework that helps make full patterns clearer and helps one to see how to modify these patterns more effectively. As Peter Senge says, it is a "discipline for seeing the whole". This type of thinking is tricky to most of us because we are taught to break problems apart, to fragment the world! This appears initially to make complex tasks more manageable; but we pay a hidden price: we can no longer see the consequences of our actions, and we lose our intrinsic sense of connection to a larger whole. When we want to see the big picture, we try to reassemble the fragments and organize all the pieces. The task is futile-similartotryingto reassemble the fragments of a broken mirror!

Multi-disciplinary Approach

Today's Engineers must also be able to view management activities through different lenses and work with people from different disciplines and diverse fields such as business, banking services and medicine. Even the software development process can incorporate complementary techniques from other disciplines such as accounting, product management, marketing, project management, economics, and organizational behavior.

Situations and problems we confront today demand composite responses and solutions. A multi-disciplinary approach involves absorbing from multiple disciplines to define and apply new ways of understanding complex situations.

The great advances of recent times - nano devices, telecommunication communications and genetic engineering — affirm that these come about from people who understand engineering systems as a whole.

Innovation-led Growth

India's future growth will be driven not by cost but by innovation - innovation in terms of product offerings, process efficiency, value engineering and cost reduction. This has resulted in areas such as engineering design and product development becoming a focus. An example of how India is demonstrating its innovation capabilities is the work of Computational Research Laboratories, a Tata Group company in the Supercomputing arena. You may have heard about the 170 Terraflop supercomputer EKA, Asia's fastest and till recently the 4th fastest supercomputer in the World, built indigenously in the city of Pune. An interesting innovation has been achieved in the architecture of this supercomputer. Normally, rows of computer racks have alternating hot and cold aisles, cold air seeps through perforations through the floor, cooling the blades and coming out as hot air through the hot aisles. In the case of EKA, the racks were arranged in a circle with another concentric circle arrangement for coolers which blow cool air directly onto the blades and into the center. The resultant hot air is sucked out from the ceiling. This way the cooling is far more efficient, uses less power and the winning point is that the whole set up could fit into a 4000 sq ft area. Simple, but ingenious!

The creation of the TATA Nano, a great feat of engineering, was possible because conventional wisdom was challenged. Similar handles and mechanisms for the left and right-side doors; a small engine which could sit under the rear seat enabling a smaller overall package; putting the instrument cluster in the middle, not in front of the driver - all of these are innovations that are low-cost and future-oriented.

The Chandrayaan at 360 Crore Rupees is the world's cheapest Moon Mission. Its success is also a testament to the importance of innovation and planning in the success of low-gestation 'drawing board-to deployment' projects.

All of these signal the era of Innovation in Indian engineering; they also have had the world look at us with renewed respect.

TCS — Addressing Developmental Challenges

Even as we reach for the moon, there are millions here on earth for whom basic needs are elusive. No country can afford a skewed growth. If India has to achieve a 7-8 % sustained growth, it needs not just Corporate India butthe rural sector, the agricultural sector to grow as well.

It is these areas that badly need Engineering talent. The Government, we and all of us together have to find ways to make it an attractive option for Engineers to take up these challenges.

At TCS, we have participated in nation building and large scale developmental projects right from our inception 40 years ago. Our technology expertise is used to live upto the values and commitment of the larger goals of our business.

Even as we worked with the top banks across the world, we realized that India's rural population of almost over 700 million is heavily "underbanked". The urban model would not work here. So TCS built a prototype model for extending banking services to rural segments at a minimal cost. Proving that banking can be conducted without a brick and mortar branch, agents are provided with a handheld device to carry out the transactions at the field. Smart Cards were issued to-unbanked customers and agents. These smart cards would store all the demographic details of the customer and financial accounts like Loan, Deposit etc. Finger print would be used for user authentication. This is a good example of an innovative solution arising out of deprivation.

Last week I was speaking at the United Nations' Internet Governance Forum in Hyderabad, where world leaders discussed how Internet Technologies should become more accessible to embrace the next billion new users, including their availability in local languages.

Equity of access to technologies is on the global agenda, and for developing countries this is a great opportunity which is yet to be exploited.

Health is an area of great concern especially in the rural areas. Capitalizing on the power of the Internet, TCShas created one of the web's largest TeleHealth portals. The portal completed more than 26,000 Tele consultations and currently stores more than 45,000 Medical records online. The site is used by more than 40,000 unique visitors each month. However, this is not enough! Such initiatives need to be replicated and scaled up in every state until every remote corner of the country is covered.

The agricultural sector is another area that has not benefitted enough from technology. We at TCSare using the expertise gained from working with Telecom global giants in implementing a project called M Krishi which means 'mobile farmers'. We are using the mobile technology to improve farmers' access to agriculture expertise including soil sensors and automatic weather stations, Government schemes and market knowledge, in the process demonstrating improvement in productivity and efficiency of farming operations. The software, in a local Indian language, is used by the farmer through easily affordable mobile phones. This project has been recognized as one of this year's most innovative use of technologies by the Wall Street Journal.

The dichotomy within India is, in fact, a large opportunity waiting to be exploited by Engineers. The approach needs to envelope both the mind and the heart. While the problems are old, the solutions can be new and path breaking and must exploit technology.

The mind and heart approach has seen some unusual results. The last thing you would expect from an IT company is to devise a low cost water filter using rice husk that costs fewer than 100 rupees. This was the result of the enthusiasm and passion of scientists at TCS' TRDDC in Pune. Today, the filter program is jointly undertaken by TCS, Tata chemicals and Tata Sons and the team is working on the use of nano silver coated rice husk ash as a filtration medium. This cutting edge technology has helped produce an inexpensive but essential utility for the masses. When commercialized, this will help meet the need of over 6 Lakh villages for safe drinkingwater.

Climate- The Global Challenge

One challenge that extends beyond the Indian shores is that of climate change. The Himalayas and North Pole glaciers are melting and according to experts, parts of cities such as New Orleans, countries like Mauritius and my own city, Mumbai, may no longer exist a few decades from now. The threat is real and we are all directly or indirectly affected by changes in availability of energy, power and water and are thus responsible for them.

This is an area which calls for engineering talent in capacity building and innovation in eco efficient and less polluting outcomes in the practice of engineering. Engineers must plan, design and construct infrastructure and systems keeping this in mind. They must develop and adapt technologies to reduce emission. Whatever we do now will have long lead times and the effects will be seen only decades later, but we must act now.

Businesses too have realized their responsibility towards this cause. The 'triple bottom line' which includes environmental and social performance, is rapidly gaining recognition as a framework for measuring business performance. It's not just about stacking UP your revenues, it's also about stacking DOWN your carbon footprint!

In my industry, greening of IT involves practices such as energy efficient hardware, hosted architecture and data center virtualization. Virtualization, as you may already know, refers to many computers performing as one. It may also include making a single physical resource such as a server, an operating system, an application, or storage device appear to function as multiple virtual resources. This leads to significant cost savings and optimizes resource utilization and can improve power efficiency to about 98% from the 80% that exists today.

At TCSwe take Green IT seriously and are working towards a zero carbon footprint in the next 10 years. We have Green Building Initiatives for 3 new centers in India, waste water treatment and rain water harvesting at our facilities. With tropical temperatures that we enjoy, in several centers solar energy is used in the kitchens. As a result 22 Delivery Centers have been ISO14001 : 2004 certified.

Conclusion

I am sure the Institution of Engineers would already be addressing many of the issues, through a variety of technical activities and functions. I am also sure that Climate, Energy, Environment, Education, Communications, Digital Divide, Transportation, Agriculture, Robotics are all areas where you are drawing focus.

However, one responsibility that rests with all of us is to ensure that the best minds enter this field in the future. Your institution has the power to propagate to young professionals the need for a new mindset for future engineers.

For school going students, we must pose future challenges that will inspire them to take up this profession. We must attract their attention and then excite their interests by identifying rewarding future opportunities in the field of engineering. Igniting curiosity and expanding their learning horizons iswhat our schools should do.

The hunger for knowledge, the habit of questioning, the passion for doing things, the exponential benefits of collaboration, a multi-disclplinary mind set achieved by inculcating varied reading habits combined with a social consciousness is what this country needs from its Engineers.

We are living in the hyperspace of four dimensional space consisting of Science, Technology, Economics and Society. There is a very integral link among these four which needs to be promoted consciously. Society uses Technology for promoting Wealth and Economy. Engineering is the practice of technology and it is through technology Science flows. So, this kind of link is to be very consciously built by Engineers and Scientists, working together. The technologies that need to be developed should address such issues like poverty, pollution, illiteracy, congestion in urban areas etc. TCS designed and developed an internationally recognized "Adult Literacy Program". Its development has taken into account cognitive and linguistic principles, cutting-edge software technologies and some standard hardware platforms. Similarly, it is not low technology but cutting edge high-technologies that are going into making simple utilities that addresses needs ofthe rural people.

In India, due to our size, diversity and complexity, we do not have to go looking around for challenges; these are in plenty. We just have to look around and we will find something that needs improvement. We also have great minds and great thinkers. We just have to find ways to bring these together.

It is your fraternity that will determine the India of the future and its role on the Global Stage. The IEI as a respected opinion leader can lead the way in inspiring and enthusing the community towards the field, influence the Government and academia to enhance quality of education and mould young professionals to industry needs.

The world's eyes are upon us, India has the opportunity to become a superpower and we all owe it to ourselves to take responsibility for it.

Thank you

Engineers — the Harbingers of Change

Lt Gen I J Singh, *AVSM*, *VSM*

Director General, EME

INTRODUCTION

Ladies and gentlemen,

It is my proud privilege to be here today to deliver the 32 Rajendra Nath Mookerjee Memorial Lecture.

Before I begin, it would only be apt forme to bring to your attention Sir Rajendra Nath Mookerjee[1] — the inaugural President of The Institution of Engineers (India). Sir Rajendra Nath Mookerjee, KCIE[2], KCVO[3], was a pioneering Indian industrialist. Among his achievements were the construction of Palta Water Works and the Victoria Memorial at Kolkata. He pioneered the laying down and operations of Martin Light Railway. He contributed to the success of Bengal Iron at Kulti. Later he co-founded the iron works of The Indian Iron and Steel Company at Burnpur. In recognition of his achievements, he was bestowed the honour of presiding over the 8 session of Indian Science Congress held at Kolkata in 1921.

Today, as I embark to deliver a talk nearly three quarters of a century after the passing away of this great luminary, I am humbled by the occasion, and wonder what ground to cover as a fitting tribute to him.

In more ways than one, Sir Rajendra Nath Mookerjee was an agent of change. The Palta Water Works brought treated water from Barrackpore to Kolkata in the early twentieth century, and perhaps laid the grounds for rapid industrialisation of the city of Kolkata. That pretty much was at the vanguard of industry and business in this country in the first half of the twentieth century.

I will take that thread to deliver this Memorial Lecture today. I will talk about how Engineers at large, a tribe of whom Dr Rajendra Nath Mookerjee was a shining example of, are the prime movers and harbingers of change. I will delve on the grand challenges that face engineers in the twenty-first century. I will also give a few thoughts on how the noble profession of engineering can contribute to a shining India in the years ahead.

ENGINEERS –THE HARBINGERS OF CHANGE

Since the invention of the wheel in the neolithic age, engineering has been the most powerful driving force behind the evolution of mankind. The progressive force of engineering has propelled our societies from primitive disarray to the sophisticated world order thatweseetoday.

May it be fundamental in ventions of electricity, steam engine or the cutting-edge realms of nano-technology, the ceaseless growth of engineering has always created a revolutionary change in the human race. The networks of road, rail, electricity, communication and irrigation are a few of the vital infrastructural arteries which keep our lives galvanized, and are the essential unsung engineering applications that we at times take for granted. Engineering has nurtured sustained growth in every conceivable field of our day-to-day lives, like education, economy, agriculture, transportation, etc. The early warning systems against the vagary of natural calamities like tsunami are engineering marvels which are capable of saving thousands of human lives.

The core purpose of engineering of any genus is to foster technological innovation and excellence for the benefit of humanity. Implied in this benefit, is the recognition of the importance to maintain healthy symbiotic relationship with the earth. Looking back at the world order in retrospect, we will find that every change in the society was triggered not by an impassioned demagogue or amilitary leader, but by an engineering mind which had concern for humanity.

Engineers are not only the harbingers of human evolution, but have successfully brought about many revolutionary changes that transformed the very way world lives. The industrial revolution, military technologies, communication and the internet proliferation are a few of the significant examples of these striking changes.

FUTURECHALLENGES[4]

The twenty-first century ahead poses challenges as formidable as any from millennia past.As the population grows and its needs and desires expand, the problem of sustaining civilization's continuing advancement, while still improving the quality of life, looms more immediate. Old and new threats to personal and public health demand more effective and more readily available treatments. Vulnerabilities to pandemic diseases, terrorist violence, and natural disasters require serious searches for new methods of protection and prevention. Products and processes that enhance the joy of living remain a top priority of engineering innovation, as they have been since the taming of fire and the invention of the wheel.

In each of these broad realms of human concern-sustainability, health, vulnerability, and joy of living-specific grand challenges await engineering solutions. The world's cadre of engineers will seek ways to put knowledge into practice to meet these grand challenges. Applying the rules of reason, the findings of science, the aesthetics of art, and the spark of creative imagination, engineers will continue the tradition of forging a better future.

Capturing Solar Power

Foremost among the challenges are those that must be met to ensure the future itself. The Earth is a planet of finite resources, and its growing population currently consumes them at a rate that cannot be sustained. Widely reported warnings have emphasized the need to develop new sources of energy, at the sametime as preventing or reversing the degradation of the environment.

Sunshine has long offered a tantalizing source of environment-

friendly power, bathing the Earth with more energy each hour than the planet's population consumes in a year. But capturing that power, converting it into useful forms, and especially storing it for a rainy day, poses provocative engineering challenges.

Nuclear Fusion

Another popular proposal for long-term energy supplies is nuclear fusion, the artificial re-creation of the sun's source of power on Earth. The quest for fusion has stretched the limits of engineering ingenuity, but hopeful developments suggest the goal of practical fusion power may yet be attainable.

Nitrogen Cycle

A further but less publicized environmental concern involves the atmosphere's dominant component, the element nitrogen. The biogeochemical cycle that extracts nitrogen from the air for its incorporation into plants and hence food has become altered by human activity. With widespread use of fertilizers and high- temperature industrial combustion, humans have doubled the rate at which nitrogen is removed from the air relative to pre-industrial times, contributing to smog and acidrain, polluting drinking water, and even worsening global warming. Engineers must design counter measures for nitrogen cycle problems, while maintaining the ability of agriculture to produce adequate food supplies.

Water

Chief among concerns in this regard is the quality and quantity of water, which is in seriously short supply in many regions of the world. Both for personal use drinking, cleaning, cooking and removal of waste and large-scale use, such as, irrigation for agriculture, water must be available and sustainably provided to maintain quality of life. New technologies for desalinating sea water may be helpful, but small-scale technologies for local water purification may be even more effective for personal needs.

Reverse-engineering the Brain

One goal of biomedical engineering today is fulfilling the promise of personalized medicine. Doctors have long recognized that individuals differ in their susceptibility to disease and their response to treatments, but medical technologies have generally been offered as ‘one size fits all’. Recent cataloging of the human genetic endowment, and deeper understanding of the body’s complement of proteins and their biochemical interactions, offer the prospect of identifying the specific factors that determine sickness and wellness in any individual.

An important way of exploiting such information would be the development of methods that allow doctors to forecast the benefits and side effects of potential treatments or cures. ‘Reverse-engineering’ the brain, to determine how it performs its magic, should offer the dual benefits of helping treat diseases while providing clues for new approaches to computerized artificial intelligence. Advanced computer intelligence, in turn, should enable automated diagnosis and prescriptions for treatment. Computerized catalogs of health information should enhance the medical system's ability to track the spread of disease and analyze the comparative effectiveness of different approaches to prevention and therapy.

Another reason to develop new medicines is the growing danger of attacks from novel disease-causing agents.Certain deadly bacteria, for instance, have repeatedly evolved new properties, conferring resistance against even the most powerful antibiotics. New viruses arise with the power to kill and spread more rapidly than disease-prevention systems are designed to counteract.

Averting Biological Disaster

As a consequence,vulnerability to biological disaster ranks high on the list of unmet challenges for biomedical engineers, just as engineering solutions are badly needed to counter the violence of terrorists and the destructiveness of earthquakes, hurricanes and other natural dangers. Technologies for early detection of such threats and rapid deployment of counter-measures (such as, vaccines and antiviral drugs) rank among the most urgent of today's engineering challenges.

Revival of Infrastructure

Even as terrorist attacks, medical epidemics and natural disasters represent acute threats to the quality of life, more general concerns pose challenges for the continued enhancement of living. Engineers face the grand challenge of renewing and sustaining the aging infrastructures of cities and services, while preserving ecological balances and enhancing the aesthetic appeal of living spaces.

Training and Education

The external world is not the only place where engineering matters; the inner world of the mind should benefit from improved methods of instruction and learning, including ways to tailor the mind's growth to its owner's propensities and abilities. Some new methods of instruction, such as computer-created virtual realities, will no doubt also be adopted for entertainment and leisure, furthering engineer's contributions to the joy of living.

All of these examples merely scratch the surface of the challenges that engineers will face in the 21 century.The problems described here merely illustrate the magnitude and complexity of the tasks that must be mastered to ensure the sustainability of civilization and the health of its citizens, while reducing individual and societal vulnerabilities and enhancing the joy of living in the modern world.

In pursuing the century's great challenges, engineers must frame their work with the ultimate goal of universal accessibility in the mind. Just as a house divided against itself cannot stand[5], a world divided by wealth and poverty, health and sickness, food and hunger, cannot for long remain a stable place for civilization to thrive.

Through the engineering accomplishments of the past, the world has become smaller, more inclusive, and more connected. The challenges facing engineering today are not those of isolated locales, but of the planet as a whole and all the planet's people. Meeting all those challenges must make the world not only a more technologically advanced and connected place, but also a more sustainable, safe, healthy and joyous, in other words, better-place.

ENGINEERS IN THE INDIAN CONTEXT

In Indian context, engineers have, in the past, shied away from social issues interfacing with technology development. They have been picking up knowledge and skills required for dealing with, in addition to technical matters, issues internal to the organisation, eg, employees unions, group dynamics, leadership, communication, etc, and thus transforming themselves into managers as they went up the hierarchical ladder. They have equipped themselves to deal with technical aspects of policy issues, eg, globalisation, sustainable development, environment, employment generation and the like. But, in future, they will have to deal with greater sensitivity to issues of social concern and contribute more effectively to national development.

Many of the most important societal issues that we are facing have strong technological and scientific elements; the environment is one of them. Still, it should be realized that much would be gained, if technology is also seen as part of the solution, and not just as all or part of the problem.

It may be noted that in the era gone by, India produced quite a few engineers who influenced significantly development policies. People like K L Rao, or, still earlier, M Visvesvaraya assumed iconic levels. In recent years, such outstanding examples have become rare. It is not that talent or capabilities have been lacking. But the scene of action has shifted to the corporate sector. People like V Krishnamurthy and N R Narayanamurthy are amongst many who provided excellent leadership to the Indian industry. Some Indian engineers, working in the corporate sector in the USA, have become widely known names in that country. They have found a new space for making outstanding contributions. Gratifying though it may be, there is no reason why Indian engineers should not be contributing at the policy level in their own country. Once the growth of the corporate sector and foreign markets stabilizes, there will be leaders emerging on the domestic policy making scene as well.

It is important for our engineering community to contribute more meaningfully to the nation's development. The choice of research problems that are relevant in the Indian context is important to realise this. The Indian science and engineering community also has a key responsibility in guiding the nations technology choices and providing directions to science and technology policy. The engineering institutions should play a role in educating the community on the impact of different technologies and alternative development paths. In order to develop sustainable futures, engineering colleges should attempt to educate school teacher sand communityleaders.

There are several immediate challenges facing India, power shortages, flooding, water shortages, etc. In many cases, there is a need for development for cost effective technologies based on India's resources, for example, in the energy sector technologies for gasification of high ash, low sulphur coal (that occurs in India) and nuclear power cycles based on Thorium are India specific needs that are not technologies required for other countries. The linkage and commitment of engineering institutions to the nation's development is essential before the engineering colleges can aspire to make a global impact. The history of development of most leading global institutions shows strong links to regional and national development.

SUGGESTIONS FOR ENHANCING ENGINEERING AND ITSCONTRIBUTIONINNATIONALGROWTH

It is imperative that we identify specific areas of concern in National Growth and provide specific solutions for them. Towards this, I would like to delve on a few possible suggestions for enhancing engineering and its contribution to National Growth in India. One may perceive them as the few of the deliverables in our discussion here.

Evolution in Engineering Education

It will be pertinent to analyse the paradigm shift that the engineering education system in India has undergone. Initially, the focus of the engineering education in our country was to produce engineering graduates to implement, operate and manage the growing industry that mainly relied on imported technology. Subsequently, as the economy grew, there emerged a need for technology development and then for research and development. The engineering institutions that were primarily set-up for undergraduate teaching started emphasising research and evolved Masters and doctoral programmes.

Technological changes are becoming ever faster. Half life of technologies is diminishing. Education will need to respond to these changes in terms of content as well as pace. With the emergence of interdisciplinary areas of study, boundaries amongst disciplines will become hazy. Overlapping will increase not only with science subjects but also with social sciences. Interfaces with health issues and Intellectual Property Rights, for instance, will come up as topics of wide interest. Industry-institute interaction, which was hitherto informal and limited to a few institutions, will spread and get relatively formalised. In order to provide for a variety of combinations of subjects, curricul as hall have to become modular offering wide choices. Additional modules may have to be picked up by engineers while working. Formal and non-formal modes of education will expand at the postgraduate level. Learning will become a continuous process stretching into the entire period of employmentas indicated later.

Detoxifying Engineering as Perceived

Engineering has traditionally been looked upon as an 'Imposed Profession'. Popular culture, I will say, is best perceived through the medium of movies. Going by that standard, the current crop of movies, be it '3 Idiots' or be it 'Udaan', portray 'Engineering' as the Big Villain thrust upon unwilling students. Engineering is stigmatised as a secure and structured money garnering career wherein Engineers are portrayed as dreary bookworms with lack lustre approach towards life. Engineering learning is associated with too much cramming with no creativity involved. In light of redefined engineering, the society needs to be compelled to accept engineering to be as exciting and imaginative as, say Fashion designing. There is a strong need to decontaminate the society's perception of engineering. This will encourage engineers to focus on contributing to society more.

Networking ofAcademia, Industry and Defence Forces

In order to share the best practices of these diverse looking elements for evolving the comprehensive, unified and cohesive approach policy for National Growth based on a common platform of engineering, we may resort to creating a robust knowledge management system to facilitate this networking. Army Technology Board (ATB) and Army Management Study Board (AMSB) are classic partnership models which are driving many ambitious projects.

This kind of paradigms for industry, academia partnerships extendable to defence forces may include following specific factors:

(i) Industry's recognition of the need of user and facilitating linkagewithacademia.

(ii) Industry’s role in defining key research areas and potential research problems specific to the requirement of the defence forces.

(iii) Academia to be responsive to the industry’s future manpower and special training needs.

(iv) Sponsorships of MTechs and PhDs with attractive fellowships.

(v) Establishment of research consortiums in different areas (eg, automobile design, VLSI) of interest to industry groups to provide the long-range research thrust that would provide Indian industry a future competitive advantage especially in defence technologies.

(vi) Encourage experienced army and industry engineers / managers to associate with engineering institutions as adjunct faculty / or as advisors and encourage experienced faculty to associate with industry in advisory/ visiting. Though, the interactions between academia and industry have improved in the last decade, there is significant scope for Defence Industries (including PSUs) for further improvement.

(vii) Institute industry meets, discipline specific open days (consisting of exhibitions, lectures, discussions) can be organised where industry professionals get an idea of the current courses offered, ongoing research and technology development and future plans. These exchanges can also provide useful feedback to the engineering departments.

Contribute to Indian Defence Preparedness

There is a strong need of enabling greater participation of private sector in defence production for strengthening self-reliance in defence preparedness. We need to evolve a policy based on encouraging involvement of country's best firms in defence capability building along with pursuing offsets policy to bring in technology and investment, exploring synergies amongst private sector, Defence Public Sector Undertakings (DPSUs), Ordnance Factories (OFs) and the Defence Research and Development Organisation (DRDO), to promote high technology capabilities and creating an environment for quantum jump in export of defence equipment and services. Following aspects need implementations at the national level:

(a) information sharing of the requirements of armed forces withtheindustry;

(b) identification of entry points for the private sector in the acquisition process;

(c) accreditation and fostering of Raksha Udyog Ratna/Champion;

(d) evolve policy framework to promote participation of small and medium enterprises indefence production;

(e) providing Defence Research and Development opportunities, both to the DRDO and the industry; and

(f) encouraging optimumutilization of existing capacity.

We may think of emulating adoption of the South Korean model to identify Raksha Udyog Ratna (RUR) on the basis of their performance. Only firms of proven excellence, which are capable of contributing, depending on their technical, managerial and financial strength should be declared RURs. These firms would be essentially platform producers and system integrators and should be treated at par with the Defence Public Sector Undertakings.We may think of giving greater freedom to the PSUs to form joint ventures and consortiums. The concerns related to liberalising the FDI regime for the defence sector may not be grave. The major reason for reluctance in encouraging the private sector into defence production and welcome FDI in the sector is on account of concern for the defence PSUs and the ordinance factories. However, it is clear that if the import continues at the present level, the role of the defence PSUs and the ordinance factories would only be further marginalised. If on the other hand, the major arms and weapon manufacturer companies set-up their manufacturing units in India, there is strong possibility that they will collaborate in National Growth in asymbiotic model.

Proactive Energy Security Policy

India's energy security concerns have, thus far, been largely defined by a narrow focus on supply disruptions and the consequent need to increase redundancy in our stocks of crude oil and petroleum products through the creation of a strategic storage. Inreality,India'senergysecurityconcernsgowellbeyondanarrow focus on a likely supply disruption in our crude oil imports. India's energy security, at its broadest level, has to do with the continuous availability of primary commercial energy at a competitive price to fuel our economic growth and to provide reliable access to modern formsofprimaryandsecondaryenergyandenergyservicesneeded for lifeline support. Again, energy security requires that such access to lifeline energy be ensured even if it requires directed subsidies. We can reduce risk to our energy security by way of policies aimed at reducing our energy requirements and import dependence (through efficient production, transmission, distribution and use of energy, development of efficient energy markets, instituting well-targeted 'lifeline' entitlements, and diversifying/expanding the domestic resource base using commercial or near-commercial technologies). India's ability to effectively manage such risks can only grow with her rising economic and political stature in the world economy.

Creation of Centres of Excellence

On the lines of various universities and industries, we need to create Centres of Excellence in different fields of Defence Engineering.These Centres of Excellence will act as a Core Group of Domain Experts enabled with the requisite infrastructure and authority to link with academia and relevant commercial industries.

CONCLUSION

In the last forty odd minutes, I have tried to give you abroad view of what you can expect to see in the world at large, and what we need to do to further enhance the discipline of engineering in our country.

As you will no doubt realise, the scope for us to do is very very huge.

I can only end with aquote from Robert Frost:-

The Woods are Lovely,
Dark and Deep
But I have promises to keep,
And miles to go before I sleep.

ThankYou.

1. *Born June 23, 1854; Died May 15, 1936*
2. *Knight Commander, one of the ranks of the Order of the Indian Empire.*
3. *Knight Commander of the Royal Victorian Order, a British Honour.*
4. *http://engineeringchallenges.org/cms/8996/9221.aspx*
5. *Quote by Abraham Lincoln*

The 33rd Sir R N Mookerjee Memorial Lecture

H E Shri Shekhar Dutt

Governor of Chhattisgarh

It is my privilege and honour to be here on the occasion of the 33rd Sir R N Mookerjee Memorial Lecture organized by The Institution of Engineers (India). It is a great Institution with 92 years of relentless journey. At the outset, I congratulate all of you on this occasion.

Sir R N Mookerjee was an engineer by education but his area of operation was not confined to engineering only. He was a businessmen, industrialist and built a trading conglomerate. His involvement in social welfare activities created many charitable institutions which was a remarkable achievement in the times when India was not a free country. In short, Sir Mookerjee worked for allround welfare and development of the people and the country, therefore is the true representative of the Indian Engineers who work for the growth and development of the country. We can say that the story of success of Engineers of India is the story of success of India.

India has over the years developed tremendously in the field of agriculture, industry and technology. Engineers of various disciplines have played a major role in all its achievements. When we talk of development in the field of agriculture, we think of green revolution and green revolution would never have been possible without the irrigation provided by dams like Bhakra, Hirakund, Nagarjuna Sagar etc. Pt Jawaharlal Nehru described Bhakra dam as India's modern temple. New agricultural equipment designed by engineers also played a vital role in agricultural development. As a result, we are selfsufficient in food grain production and have the problem of plenty, godowns are overflowing with grains. Credit for the green revolution goes to scientists, farmers and engineers. Similarly, industrial growth in the recent past has been phenomenal. The index of industrial production has gone up from 7.9 in 1950-51 to 154.7 in 1999-2000. Electricity generation went up from 5.1 billion kWh to 480.7 billion kWh in the same period. Credit for this also goes to our engineers.

Whatever field we discuss, be it atomic research, space programme, infrastructure development, defence production, missiles, communication, computers, information technology, the contributions of Indian engineers is not only visible but is remarkable. Indian engineers have a reputation of their own in the world and they can rub shoulders with anybody in the world. It is said that Indians have a logical mind perhaps that coupled with engineering education gives an edge over others.

It may be noted that the engineers have not confined themselves to the field of engineering only but have penetrated all walks of life, they have excelled in industry, business, management and administration as well. Most of the students in the best management schools are engineers, many central government administrative services like IAS, IPS, IFS have engineers as their members. Likewise is the case of defence services and state administrative services. In this way, engineers play a vital role in the progress, development, safety, security welfare and administration of our nation and the world over. Key to their success is the education they receive as engineers which develops an analytical and methodical mind and these methods, scientific principles and theories learnt over the years help them in finding solutions to the problems in whatever area they choose as their profession. Engineering along with science and technology have a close connection with day to day life of a common man and the society at large. All the hallmarks of a civilized society i.e. clothes, transport, kitchen and household equipments were discovered and invented by or with the help of engineers and invariably manufactured with their help.

However, I feel that when it comes to innovations, creativity, discovering or inventing new, we lag behind miserably. In todays competitive world, innovation and creativeness is the key to success. With increasing complications in management or administrative issues, no two situations are alike and to tackle an issue with new dimensions, innovative methods are required. Similarly, to be different from others, one has to be consistently creative in approach. Creativity is the difference between ordinary and extraordinary. Innovations and creativeness are not the only key to personal success but also to the success of society and the nation. Therefore, need of the hour is to inculcate these qualities in our youth and engineers of today have a special responsibility of providing encouragement to them.

Another attribute which takes a nation forward is the capacity for new discoveries and inventions. Western world which also includes Japan has become developed and rich because of their discoveries and inventions. Almost all the modern day equipments and machineries of today whether providing comfort or entertainment in the form of making available electricity for air-conditioning, cars, planes, television, movies, etc and any other household equipments, industrial machinery or arms and ammunitions were discovered or invented, patented and manufactured in the western world and were key to their progress, development and affluence. All these activities are productive in themselves and also cause establishment of a chain of other subsidiary smaller industries providing employment with increased growth. Today it is not enough to discover or invent an equipment, it is also necessary to upgrade its quality continuously and to make improvements to reduce the price to remain competitive in the market. Computers, television and cars are the prime examples of continuous evolution, improvement and price reduction. When one generation of these products is in the market, the next generation is already ready for introduction and the next is in the final stages of testing. China and South Korea are the eastern countries which lead in inventions and manufacturing of equipments. We also need to promote these qualities in our youth by encouraging them in this area.

This century belongs to India and feelingly we are being looked at as one of the future leader of the world. To reach that position, all the Indians will have to be at their innovative best, work hard and contribute their utmost. In my opinion, engineers have the capability, capacity and the responsibility upon their shoulders to lead India to that coveted position.

Similarly, we can very well say that the engineers collectively have the responsibility towards improving the lives of people of not only their own country but people all over the world. So far the development and growth was led by the developments in the western world however, that development has resulted in a polluted world with ozone holes. Our ecology has been negatively effected, the balance gone, flora and fauna whether land based or water based are adversely affected many of the species already extinct and many on the verge of extinction. Sustainable development is the word often being used but hardly practiced. Engineers, I think, being single largest group having their presence in almost all professions, have greater responsibilitytowards maintaining ecological balance, to make the world less polluted, to make our planet more livable, in short to make the world better in all respects.This is high time we realized that science and technology is not about controlling nature but to flow and fly with nature so that we can harness its energy without any negative side effects. We should learn from our past mistake, of our attempts to control the nature. We have made the world a dangerous place, everyday people of one or the other part of the planet are facing calamities like earthquakes, floods, Tsunamis etc. Change in climate is being witnessed by the people all over the world. Indiscriminate and thoughtless use of natural resources like forests and minerals have depleted our resources. We have become selfish, greedy and near sighted with no thought towards its consequences. We have forgotten that there are many more generations to come and we must plan for their well being. I think this is a very difficult situation and the world is looking at your community for answers. I am sure, you all will rise to the occasion and meet the challenge.

In the end, my sincere thanks to the "The Institution of Engineers (India)" for providing me this opportunity to share my views with you. I wish you all a bright future.

Thank you,

Jai Hind.

Technology Security and Inclusive Growth

Lt Gen N B Singh

Director General & Senior Colonel
Directorate General of Electronics and Mechanical Engineers, New Delhi

What is Technology?

1. The term technology has become a global abracadabra. It is like beauty. Those who have it worry about keeping it. Those who do not have it feel deprived and strive to get it. In more prosaic terms, technology is universally accepted as central to economic growth and the creation of jobs; it is the foundation for improved health, longevity and quality of life. Viewed from another perspective, it is the wellspring of good but at the same time also has a dark mirror image. It threatens the loss of jobs and careers, degradation of the environment, frightening violation of life itself, and even destruction of civilization.

2. Despite great advances that have been made and the dramatic contribution that technology has already provided, there is also the fact that management of technology falls well short of that we must achieve. The 'we' is universal; not limited to any specific country. Clearly, technology is too important to be left to the technologistswhoever they are. Politicians, diplomats, social scientists, ethicists-all see a need to help guide, constrain, support or condemn technology because technology has always had social, economic and political dimensions. Thus, the directions and priorities and technology have always reflected perceptions of what is needed or desired for society.

Defining Technology

3. Technology is also the vital underpinning of national security and economic vitality. Harvard University relates technology and the wealth of a nation in the following equation:-

$We = PT^n$

We - Wealth
P - Physical Resources
T - Technology
n - Exponential

4. A nation's economic and military power and its competitive position in world affairs are benchmarked against its ability to develop and use technology. Technology and wealth creation are strongly linked. Generation of new technology and its adaptation for use increases the wealth of a nation exponentially.

5. In short, technology is about knowledge and, therefore, a valid definition of technology is, the 'knowledge of how to do things'. We can use the metaphor of a growing tree to development of technology. The tree draws upon its roots, the underlying knowledge base and develops branches-the structured arrangement of technological knowledge, on which fruits (new products), processes and services can grow. However, it will only continue to grow and yield fruit if the roots are nourished, that is, if the organization continues to learn.

6. Technology has also been defined as, "A tool to meet the customers need and organizational goals. It is a process which turns input into an output at a predetermined cost through scientific parameters with engineering skills to meet the social needs in this era of globalization with least human intervention. It is a process or a tool that helps companies to get a better market share."

Technology Security

7. An important development of recent times is that it is becoming increasingly difficult to define the concept of military-related technology. Technology spillovers have in the past typically gone from military technology to civil technology. Now there are many instances of civil products with military applications, the so-called dual-use products. Concerns have risen regarding the destabilizing effects that exports of state-of-the-art military and dual-use products, in particular, might cause on regions in conflict. Following this concern, export control systems for dual-use goods have been developed by most of the main exporters of dual-use equipment. The implementation of such controls is increasingly difficult due to two major reasons:

Firstly, economic concerns, such as competition for the export market with rival countries, clash with security concerns. Secondly, the growing importance of dual-use products adds to the difficulty, of monitoring and regulating exports.

8. Nationalism in technology promotion has been labeled as techno-nationalism usually contrasted with techno-globalism. Although no agreed definition exists, in common usage, technonationalism refers to such public policies that 'target' strategic (usually high-tech) industries and give them various governmental support: government procurement, import restrictions, export subsidies, research and development, subsidies, R&D tax credits, controls on inward foreign direct investments, protection of intellectual property rights, government funded R&D projects, control over private take overs and mergers and others. All supports are given only to domestic firms, for their aim is to strengthen the competitiveness of domestic industries against foreign rivals in a growing world market. By contrast, techno-globalism refers to such ideas that globalization of technology is both unavoidable and desirable for all nations, firms and citizens.

The Critical Technology Supply Chain

9. There is a significant interplay of activities amongst main stakeholders in ensuring the security of critical technologies. The supply chain consists of the Government who cause the populace to participate in the school system to acquire the basic education. From this stock is derived the set of people who will take up the challenge of higher education in institutions fostered by the government and industry. The research carried at these universities facilitates the basic and applied domains. The output from the research will aid external research institutions or the industry. From these sources, and sometimes from the University itself, the critical technologies will emerge. The application of these critical technologies will result in enhanced security. The education, research and the industrial system are all synergized in the legislative framework created by the government, which sets the environment that aids or inhibits innovation. The process that has been articulated in can be essentially represented by a supply chain model. Deep defence is the concept where in the Government, Academia, Research Institutions and the Industry need to work together to realize the benefits of critical technologies, which have a direct bearing on the security.

The Role of Government

10. There are three broad categories where government can play a significant role. These are:-

(a) Government as a leader and catalyst with respect to the public and industry.

(b) Government as the steward and financier of the basic physical and intellectual capital that is the prerequisite for innovation; and

(c) Government in the somewhat more circumscribed role of promoter of the fruits of the national innovation system.

Indian Context

11. The Indian effort to seek Technology Security need to come from initiatives and investments in high technology industries driven by IT. High-technology industries are driving economic growth around the world. The global market for hightechnology goods is growing faster than that for other manufactured goods. Over the past 22 years (1980-2001), output by high-technology manufacturing industries grew at an inflation-adjusted average annual rate of 6.5%. Output by other manufacturing industries grew at just 2.4%. For this to happen the framework needs to address the following issues:-

(a) Policy and legislative framework to give fillip to domestic efforts, primarily in the context of defense procurement, and thereby invigorating economic growth.

(b) Investment in Industrial R&D with private sector to fuel such growth.

(c) Strengthening the IPR mechanisms to ensure that the Indian companies are encouraged to develop Patents to generate intellectual wealth and fuel innovation.

(d) Developing an aggressive venture capital initiative targeted at the Small Business initiative, to spur development of high technology products, especially software and hardware design of value added systems. A matching policy framework to channelize acquisition from Small Business Unit for all Government procurements.

(e) Dual use technology based initiatives to fuel domestic idiom that inherently enhance national security, and sets up a selfreinforcing spiral of national development and technological security.

(f) Cluster Formation like in US, Israel, China, Germany etc.

Innovation

12. For fueling entrepreneurship, a culture of innovation has to be sustained as these do not happen in a vacuum. An innovation system has to be created with an Innovation policy to raise the quantity, quality & efficiency of such systems. It has to now get more distributed & not restricted to Govt affiliated enterprises only. A talent pool & venture capital market have to be generated. Science & Technology policy has to sync with industrial, financial, tax & fiscal policies. An increase in R&D expenditure has to occur to 2.5 - 3% of GDPgradually in next 5-10 yrs from the current 0.8% (1.23% for China)

13. Most countries (USA, Russia) had adopted the concept of science cities or Knowledge cities to fuel innovation. Industrial clusters/lnnovation cluster like Silicon Valley, Maryland, Hsinchu cluster of Taiwan, Tel Aviv to Haifa corridor, Akademicagorada of Russia, have been created. Three stages of financing have played a role in these clusters: R&D funding, pre commercialization funding & venture capital.

Israel has the highest GDP expenditure amongst countries of OECD. It has the highest fraction of R&D expenditure by business enterprises (nearly 80%) & the share of R&D expenditure borne by Govt (5% or less). In India it is 80% by public sector & 20% by private sector.

14. The Israeli Defence forces contribute in a large way to human capital development. Recruits get to handle hi-tech & work on weapons, ICT, technology & electronics. After the military, most Israelis attend college & their quality of technical education is the finest. MNCs provide the ground & workspace for niche & differential skill development. Approximately 8,00,000 Soviet immigrants who came in the nineties have also helped in establishing the cache of knowledge workers. Grounds for attraction of MNC have been created. In Israel it was not tax reductions or concessions, but rather the enormous skills of the workforce & the work culture and practice of relationship management with Governments and industries in USA, Canada, Korea, Singapore etc that gave the competitive advantage. The number of researchers in India are 156 per million population as compared to 7000 in Scandinavia & 4700 per million in US.

15. Destructive creativity is a sin qua non for innovation. Demand for products is important to sustain innovation & entrepreneurial spirit. India's burgeoning defence needs can provide the catalyst for this massive exercise to take off & provide the demand. The vast network of SMEs will provide downstream industrial capability to construct sub-systems & components cost effectively. The fairly capable base of private industries can adorn the role of systems integrators to evolve a self sustaining conveyer belt which transforms innovation into products for defence & products for the society. This commercialization will produce substantial net social benefits. The growth will become inclusive since a large amount of employment opportunities get generated, the demand for skilled persons goes up & the education sector is required to expand to sustain talent pool needs. Need for infrastructure, schools, quality of life at the cluster, need for a logistics supply chain will all end up raising the tempo of industrial activities that will help make the nation secure, retain its wealth within the country, help raise the intellectual capital of the country & provide opportunity for wealth creation & dissemination. The positive impact on civilian end use products will also be phenomenal. Needless to mention, this development has to be Clean & Green so as not disturb the entropy of our ecosystem.

Leveraging Engineering Advancements and Innovation for Nation Building: The India Experience

Mr K Venkataraman

Chief Executive Officer and Managing Director
Larsen & Toubro Limited

I sincerely thank you for giving me the honour of delivering the 35th Sir R. N. Mookerjee Memorial Lecture at the 28th Indian Engineering Congress, being held during 20 -22 December 2013 at Chennai. For all of us from the engineering fraternity, doyens like Sir R. N. Mookerjee have been trailblazers in engineering excellence and a great source of inspiration.

I have been fortunate to join, straight from the IIT Delhi campus, a powerhouse of engineering and innovation – Larsen & Toubro (L&T). I also have the privilege of being a part of this unique organization for over four decades.

Larsen & Toubro has made a conscious decision to work in the core areas like infrastructure, high-end manufacturing, defence, nuclear power and space research. With seventyfive years of dedicated service to nation building and many "first-of-its-kind" achievements and global benchmarks to its credit, L&T today is justifiably considered as a bellwether of India's growth story.

My talk, therefore, draws from these experiences and presents to you a holistic view of how engineering advancement and innovation can drive the country's progress. I am indeed honoured to stand before this august gathering and I feel particularly happy to share my thoughts with our young generation of engineers who will write the India success story, going forward.

Introduction

India is a vast country with unmatched diversity – not only in culture, heritage, religion, food and customs but also in literacy, growth, social development and economic prosperity. There are several reasons for this disparity, some historic and some contemporary. Though India's biodiversity is abundant, the natural resources we have per person are low due to our huge population. India cannot simply follow the western model for economic growth. As we grow and as our consumption attains global standards, we will have to develop several India-specific models to conserve our natural resources as well as enable inclusive development. We need to create an ecosystem that can deliver the fruits of growth to the bottom of the pyramid, while sustaining the progress at the apex level of science, technology and economy. This requires a mindset change in the urban and educated India. Sustainable development at national level lies in social equity and a framework that can deliver requisite products, services and resources to cater to a more broad-based demand.

Progress of human civilization has always been fuelled by scientific and technological developments. Nations which nurtured the habit of scientific enquiry and applied engineering ingenuity to improve the quality of life have always dominated others in socio-economic progress. This fact has been reinforced since prehistoric days through the modern era of industrial revolution, the space age and beyond. Fundamental Research unveils the basic scientific principles; Applied Research shapes this knowledge into technology and know-how while Engineering converts the technologies into tangible products, services and infrastructure to support the nation's growth.

Macro Economic Environment

While Indian GDP has been increasing steadily, the growth is on a downward trend in recent years. Comparison with China shows that Indian GDP growth rate has been much lower (Figure 1). However, from the future projections it is expected that India would show a comparable growth rate with China, thereby infusing much optimism in the Indian growth story.

Contribution of manufacturing sector's share in the GDPis in the range of 15% to 17% and has remained low despite phases of high economic growth in the previous years (Figure 2). There is a wide difference with our peer group of countries, which clearly highlights the shortfall in this aspect of our development.

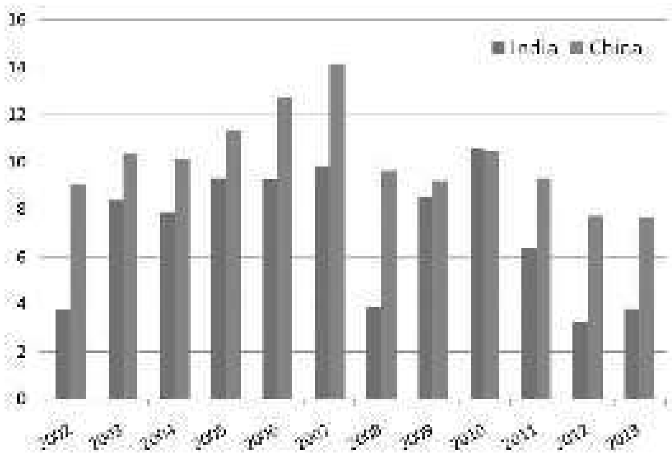

Figure 1: GDP growth rate in comparison with China (Source: http://data.worldbank.org/)

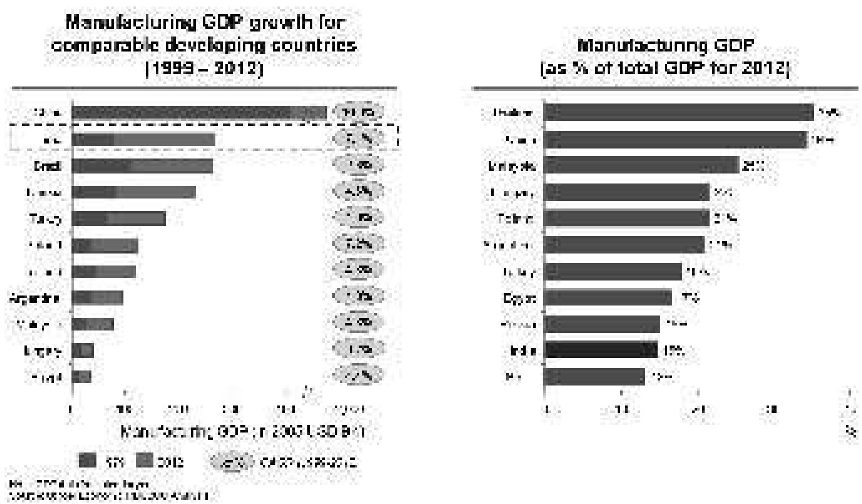

Figure 2: Contribution of manufacturing sector to India's GDP (Source: XII Five Year Plan – Manufacturing, August 2012)

If we consider the case of our trade with China, our imports from China have grown over the years while our exports have been stagnant. Trade deficit with China has grown from 16.3 billion USD in 2008 to 38.7 billion USD in 2013. If the share of manufacturing sector goes up, trade deficit will decrease and the increased share of manufacturing will lead to more employment, income and consumption. It is, therefore, imperative that our manufacturing industry is made more cost effective and growth oriented.

The construction sector, which has the next major share in the overall industry contribution to the country's GDP, also needs to grow in tandem so as to provide the necessary infrastructure, which would serve as an essential backbone for achieving the kind of growth targeted in the manufacturing sector.

Leveraging Engineering Advancements

In today's highly competitive and globalized economy, it is imperative for us as a nation to harness the power of technological and engineering advancements, not only to meet the needs of people and overcome developmental hurdles, but also to attain and sustain a level of progress that can match and surpass the global benchmark of being a “Developed” Nation. The ambit of areas where engineering advancements can contribute to nation building is very wide – from core sectors such as Infrastructure, Power, Transportation and Hydrocarbon to the strategic sectors such as Defence, Nuclear and Aerospace.

Indian Industry has to synthesize engineering talent, strong customercentric approach, constant quest for top-class quality and safety, together with key focus on innovation to contribute significantly to nation building, through application of state-of-the-art technology and beyond as seen in the following.

Infrastructure

Airports

The recent years have seen major expansions and new international airports coming up in the metros and other premium cities of India. Some of the biggest terminal buildings and tallest ATC (Air Traffic Control) towers in the country have been designed and built recently. Some of the major airport projects executed are India's first private Greenfield airports. Airport expansion projects are all the more challenging, considering that most of the time these are to be executed in the operating airport environment.

Engineering innovation in space planning and design of integrated facilities is essential to the success of modern airports. ATC towers are getting larger to handle modern aircraft and application of 3D analysis has contributed to improvements such as column-free hangar design, optimized drainage systems and design of pavements to handle complex aircraft loading, to mention a few (Figures 3 & 4).

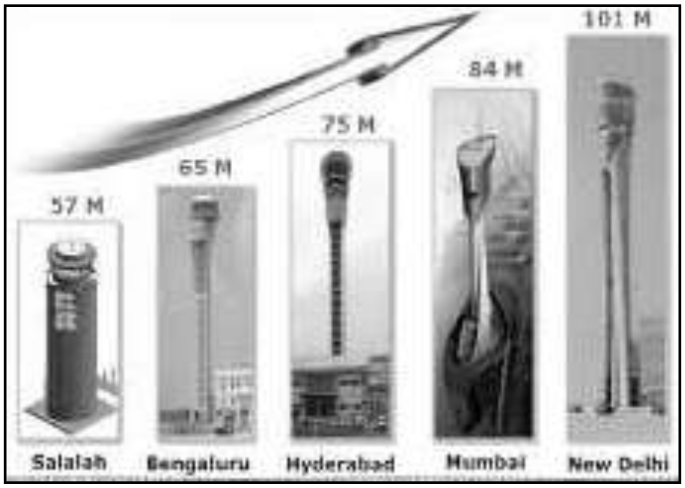

Figure 3: ATC towers are getting taller

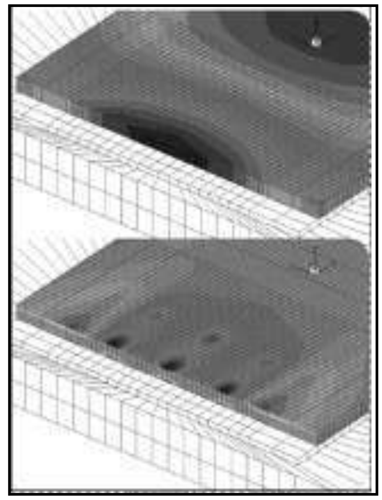

Figure 4: Use of FEA for design of pavements for aircraft loading

IT and Institutional Buildings

Indian construction majors have been actively involved in creating some of the largest IT and institutional buildings within the country. The design features demand environment-friendly concepts. Precise HVAC system, data centre planning and interior space planning are essential to successfully conceptualise huge IT and institutional facilities having built-up area of 20 to 40 lakh sq ft.

Residential Buildings — Precast Concrete Applications for Mass Housing

India is urbanizing at a pace that is higher than the world average. Its cities today are unable to cope with burgeoning population. India has a housing shortfall of nearly 27 million homes. The project execution challenges include shortages in skilled manpower and modern construction equipment as well as time constraints.

To meet the demands of large construction of affordable housing in shorter duration, there is a need for fast-track technology in mass housing. Prefabrication with industrialized building systems, with its adaptability and quality consciousness, provides speedy, cost efficient and sustainable solution. Prefabrication enhances quality of the product due to its production done in controlled environment and supports eco-friendly construction methods as green initiative.

The construction industry needs to make greater use of prefabrication and industrialized production for projects, in order to overcome the shortage of skilled man power and modern equipment, mitigate time constraints and reduce material wastage.

Pragati Towers, a 23-floor, high-rise Rehab Housing Project at Bhoiwada is the first completely prefabricated system designed and built in India for a Seismic Zone III location. Residential buildings are getting taller, with the current buildings having about 300 m height (Figure 5).

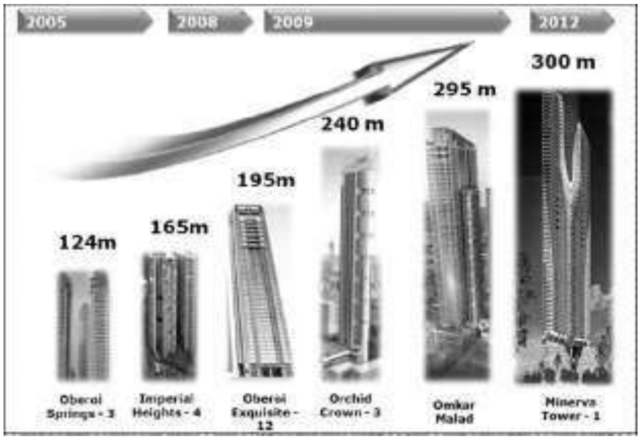

Figure 5: Residential buildings are growing in height

The concept of Centralized & Mechanized Steel Service Centre is being popularized by building such centres at key locations. These centres supply ready-to-use reinforcement steel bars which are cut and bent as per the individual requirements of each project site.

Innovation in Building of Roads and Bridges

As India's road network is fast expanding with the economic growth, several innovations in materials are being applied: such as cement stabilization; breaking and crushing of concrete from demolished structures for reuse as granular sub-base; reclaimed asphalt pavement for roads as base layer and modified bitumen with additives for road construction (Figure 6). Material characterization of pavements is done using facilities such as Heavy Falling Weight Deflectometer. Integral type flyovers are being built without any bearings for improved weight distribution and wire rope barriers are being used for minimizing impact (Figure 7).

Figure 6: Blending and mixing for cement Stabilization

Figure 7: Wire rope safety barriers for minimizing impact

Manufacturing and Heavy Engineering

Manufacturing and Heavy Engineering has contributed immensely to the development of Process Plant industry (viz. Fertilizer, Refinery, Petrochemical, Chemical industries etc.), Power industry (both Thermal and Nuclear) and Oil & Gas Industry through the supply of critical process plant equipment and capital goods.

The developments in this sector mainly started with the need for import substitution of critical process plant equipment in the 1960s and 1970s. There was constant need for indigenous development, with India looking for entry into new industrial sectors. Over the years this industry has matured and has now migrated to top end of high-tech products. The industry has expanded not only to cater to our import needs on critical process equipment, but also enabled us to manufacture and export these critical equipment to some of the developed nations.

The heavy engineering and manufacturing sector have contributed in a big way in import substitution of critical equipment, thus saving precious foreign exchange for the nation. This was possible because of the advancements that have taken place in all fronts: design, engineering, manufacturing, quality control and testing techniques. Advanced stress analysis and simulation techniques are being used extensively in optimizing the equipment design and their manufacturing process continually. Conventional testing techniques are being substituted by modern NDT techniques, viz. Phased Array and Time of Flight Diffraction (TOFD) Ultrasonic Testing. The recent efforts are focused towards developing superior metallurgy for critical process plant equipment, so as to provide enhanced durability and equipment safety, automating the manufacturing processes and also towards developing operator-friendly equipment with minimum maintenance and downtime.

Energy and Power

Post liberalization era promised rapid growth of power business in India. In 2006, at the time of finalization of the 11th Five Year Plan (2007-2012), Union Government gave thrust for power sector reforms and accelerated growth of the power sector. It was felt that the country needed to increase manufacturing capacity of power equipment drastically. Accordingly, several key players have entered the business of manufacturing boilers, turbines and other power plant equipment.

In order to leverage engineering and technological advancements in our power projects, current focus is on emerging technologies like Ultra Supercritical Design for more fuel and energy efficient plants, Integrated Gasification Combined Cycle (IGCC) Plants with Advanced Class Gas Turbines, Flue Gas Desulphurization (FGD) and Zero Liquid Discharge (ZLD) technology. On power distribution side, improved power evacuation technologies as well as smart grids for intelligent power distribution have come to good use.

Supercritical Boilers

Supercritical technology has been brought into India in a big way through establishment of joint ventures with global leaders. Boiler design is key to success of this technology and advanced boiler design methods enable the use of blended as well as Indian coals. Lower fuel consumption as well as lower emissions contributes towards reducing the green house effects. Integrated 3D modeling enables accurate design and this coupled with features such as twin fire vortex and modular boiler design results in state-of-the-art combustion technology. Dynamic simulation of complete power plants, using sophisticated software tools, now allow the designers to predict operational upsets, define plant control philosophy, mitigate operational hazards and incorporate specific measures for safety of equipment and personnel.

Computer Integrated Manufacturing (CIM) techniques ensure accurate profiling. Establishing new critical piping center and forging units at strategic locations have also helped in optimizing the manufacturing process (Figures 8 & 9).

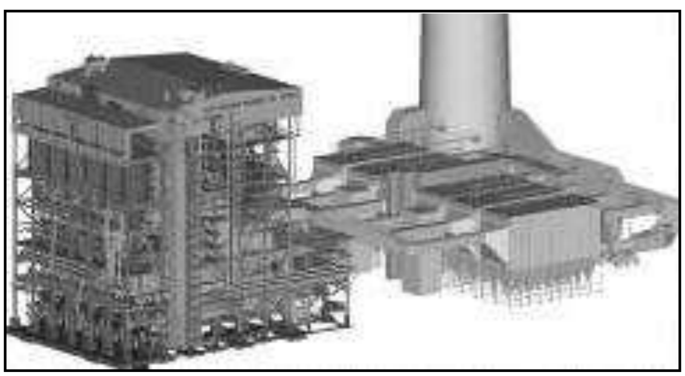

Figure 8: Completely integrated plant 3D model

Figure 9: System detailing and modelling

Power Distribution

Power transmission and distribution is increasingly being done with smart grids to maximize utilization and achieve better management of demand and outage. Transmission Line Testing and Research Stations facilitate reduction in steel and footprint. Application of GIS technology helps to optimize route alignment and selection.

Nuclear Industry

Indian Nuclear Power Program envisages a healthy increase in share of nuclear power in the overall power generation, from the current value of 3% to 15% by 2040. Leading companies have intensively participated in the ambitious Indian Nuclear Program from the late Nineteen Sixties.

Establishing indigenous capability requires development of expertise in design engineering, using sophisticated 3D modelling and stress analysis of complex nuclear equipment, such as the nuclear steam generator. Equipment manufacture involves setting up a comprehensive facility with requisite ASME stamps (Figures 10 & 11).

Figure 10: Steam generator 3D model and stress analysis

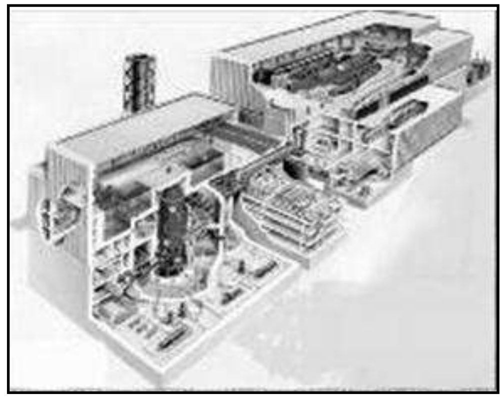

Figure 11: 3D plant model

Nuclear construction industry has gone for a number of innovations, such as production and pumping of heavy concrete with higher density to reduce construction time of nuclear vault; use of high performance concrete with special ingredients and pre-assembled ring liner for inner containment wall, and so on.

Strategic Sectors (Defence and Aerospace)

Defence & Aerospace is a multidisciplinary domain, wherein the technology base is continuously evolving rapidly over time. Efforts for indigenization in the defence sector started at a very sub-system level in the late 1980s, like the low voltage servo drives required for Anti Tank Guided Missile (ATGM) launcher and slowly graduated to larger systems such as the high speed tracking system for surface-to-air missile launchers. The in-house expertise gained with the exposure to these multiple programs led to the development of unique stabilization technologies, which have now been applied across platforms of various weapon systems, radars as well as huge ships for steering and stabilizing functions.

For many systems, there is a need for performing complex analysis which involves simultaneous solving of problems in areas of computational fluid dynamics, structural analysis and heat transfer. A good example is in design of plume ducts for ship-based missile launchers. State-of-the-art analysis methodologies developed for High Mach Number Plume Ducting Management (Multispecies & Supersonic Flow) help in optimizing the design of such ducting systems.

A key enabler in the area of "first-of-its-kind" product development is use of sophisticated digital technologies for conceptualizing, modeling, designing and testing a product entirely in "virtual" environment (Figure 12). Such capabilities have significantly reduced the developmental time for critical products, while enhancing the accuracy and performance.

From the point of view of value addition, BTR (Built to Requirement) and BTS (Built to Specifications) are the models which are applied in Defence Projects to add value significantly. Development of launcher systems and LCAs has been done based on the above models.

For all of the above there are three wheels that drive each other: Technology – that provides an elegant solution to the technical challenges posed by national needs, thereby transforming it to business needs; Process – which ensures a perfect balance between cost, quality and Delivery and Culture – that promotes continuous learning and ensures a healthy, vibrant working environment.

An excellent showcase for high Innovation Quotient is the development of a first-of-its-kind, land based underwater firing facility with a novel arrestor system.

The indigenous development of SLV and subsequently ASLV and PSLV has made Indian Space Program self-reliant. Indian companies have benefitted greatly towards honing their innovation orientation through participation in such high-technology programs. Precision manufacturing capability for mission-critical components is one of the direct benefits of such exposure (Figure 13). This has resulted in the success of significantly more challenging and prestigious ventures, like the unmanned lunar probe missions "Chandrayaan-1" and maiden mars orbiter mission "Mangalyaan" (Figures 14 & 15).

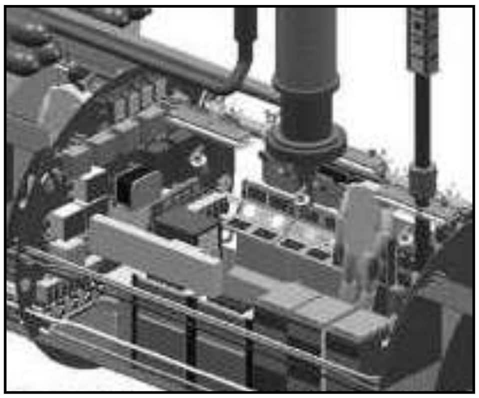

Figure 12: Visualization through digital mock-up

Figure 13: Manufacturing of critical components for PSLV

Figure 14: Successful launch of mars orbiter mission spacecraft

Figure 15: A view of the S-band radar used for mars orbiter mission

Hydrocarbon and Chemicals

The demand for oil and gas in India is growing at a rapid rate. Not only isIndia's market potential huge, but in recent years India has emerged as one of the most prospective regions in the world with major oil and gas discoveries, both onshore and offshore.

The refining capacity of the oil refineries in India has undergone nearly a three-fold increase in recent years. India's petroleum product consumption has grown by 4%-5% over the past 10 years and the oil demand in India is expected to be on rise for the next ten years. With widening gap between demand and supply, both for oil and gas, the outlook for both Hydrocarbon Upstream and Mid & Downstream sector is extremely positive.

In the Upstream sector, as E&P companies venture into the deep and ultra Deep territories of the domestic waters, the engineering companies have made breakthrough advancements in technologies required to execute projects in such extreme environments. The focus has shifted from the Fixed Platform based production and processing in shallow waters to the Floating Production (FPSOs/FLNGs) and Subsea Production systems for deep and ultra deep waters (Figures 16 & 17).

Figure 16: Floating Production Storage and Offloading (FPSO) unit

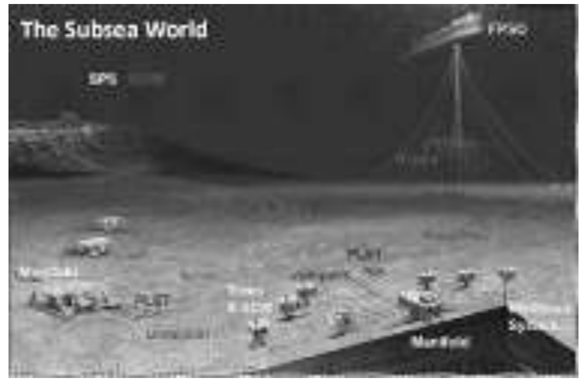

Figure 17: Sub-sea systems for ultra deep water oil & gas production

On the Hydrocarbon Downstream sector, with India already having excess refining capacity, the focus is now on fuel quality upgrade to match the global standards. In the fertilizer sector the focus is now towards feedstock conversion technologies, integrated ammonia-urea complex and energy optimization. In most of the modern plants the total energy demand (feed/fuel/power) has been drastically reduced. On the demand side important savings have been achieved in the carbon dioxide removal section by switching from old, heat-thirsty processes like MEA Scrubbing to low-energy processes like the newer versions of the Benfield Process or a MDEA. Fuel is saved by air preheat and feed by hydrogen recovery from the purge gas of the synloop by cryogenic, membrane or pressure swing adsorption (PSA) technology.

The energy intensive nature of ammonia process is the key driving force for technology up-gradation, use of energy efficient systems/equipment and reducing the overall manufacturing costs. Key developments in this area include the use of gas heat reformers/auto thermal reformers, hydrogen separation, carbon dioxide removal technology, product ammonia separation and high activity synthesis catalyst. These have resulted in a significant reduction in energy consumption.

While oil and gas will continue to play a substantial role in the total energy mix, there is more and more emphasis being laid on the need for harnessing alternative energy sources like Coal Bed Methane (CBM), Underground Coal Gasification (UCG) and Shale Gas (gas locked in sedimentary rocks), which will become crucial to balance the demand and supply in future.

The efforts are on towards promoting widespread use of cleaner fuels such as hydrogen, thereby gradually reducing our dependency on fossil fuels. This is driving the research and development towards sustainable technologies for hydrogen production, storage, distribution and utilization. Hydrogen Economy is a proposed system of delivering energy using hydrogen produced from renewable energy sources, with advantages of a reduced dependency on oil and gas and reduced greenhouse gas emissions. According to National Hydrogen Energy Road Map prepared by Ministry of New and Renewable Energy, it is projected that around 1 million hydrogen fuelled vehicles would be on Indian roads and 1000 MW aggregate hydrogen based power generating capacity would be set up in the country by the year 2020 (Figure 18).

Innovation: The Key Enabler for Inclusive Growth

For leading Engineering Companies, Innovation is the credo in all the diverse businesses and is integral to their culture. As an example, L&T's unique tagline, “It's all about magineering”, aptly captures the innovative spirit. The Vision Statement of L&T envisages all employees to be “Innovative, Entrepreneurial and Empowered”.

Today leading industries believe that, as a business imperative, innovation needs to be nurtured at every stage of a business / product life cycle and creative potential of the workforce at large needs to be fully exploited for gaining competitive advantage. The leadership in top Indian companies is consciously striving to inspire a culture of creative thinking and enabling the institutionalization of innovation across functional hierarchies, geographies and businesses. Recognizing innovation and effectively prioritizing innovative ideas for action are the real differentiators. Mutual trust and respect for one another's capability, empowerment and delegation are the key enablers.

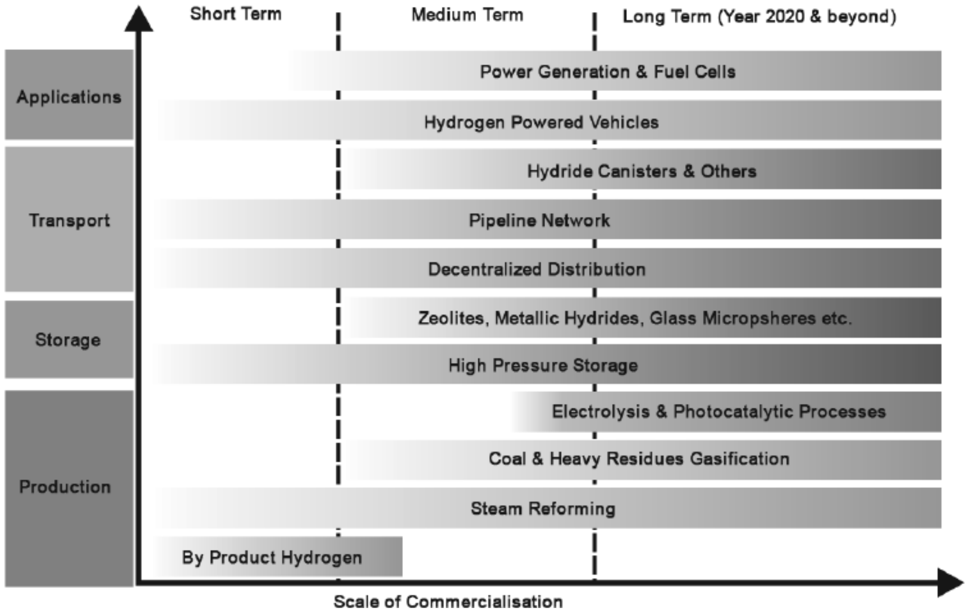

Figure 18: Transition towards hydrogen economy (Source: Chemical Engineering World, January 2013)

Managing the Human Dimension of Progress

Talent Management

In order to nurture potential business and technology leaders at an early stage of their careers, leading companies have entered into collaboration with a number of premier institutions like IIMs and IITs to imbibe holistic leadership qualities in future generation of leaders. With businesses expanding exponentially and aspiring to be globally competitive, talent management has emerged as the key issue for most corporates. Learning & Development have been the main focus in L&Tfor managing its human resources. Comprehensive training programs for graduate and postgraduate engineers together with "Build India Scholarship" schemes with IITs and leading engineering colleges provide the nurturing environment for young talent. In order to take care of career aspirations and professional enrichment of employees, L&T offers well-designed programs focussed on leadership development in both business and technology domains. To ensure leadership availability, L&T has instituted a comprehensive 5-Step Leadership Pipeline Development process. L&T's Leadership Development Academy (LDA) at Lonavala and L&T Institute of Project Management (L&T-IPM) at Vadodara are world-class facilities set up with the aim of developing global leaders.

As a result of such skills and competence building interventions, employees are better equipped to perform their role by applying innovative ideas, introducing superior safety, quality and productivity standards and adopting best management practices - thus contributing meaningfully towards organizational objectives and making significant contribution in our nation building. In L&T, top performers are increasingly being provided with higher responsibilities in their domain at a relatively younger age, because of their superior performance.

Training and Skill Building

The foundation of training and development scheme for major companies lies in the comprehensive in-house skill development program, which is integral part of their major businesses. For example, in case of L&T, the vocational skill development efforts have resulted in significant value addition to operations in domains such as Infrastructure Construction Projects, Heavy Engineering & Fabrication, Construction Machinery, Electrical Products and Industrial Machinery.

L&T has done pioneering work in Vocational Training in Construction sector. Construction Skill Training Institutes (CSTI) was set up in 1995 at multiple locations, focusing on 6 key construction trades. Till now 8 such state-of-the-art Institutes have been set up with a capital investment of around ₹ 85 cr. These Institutes are playing a key role in enhancing the on job performance and skill sets of large workforce. Over 36000 unemployed youths have been able to get gainful employment through this initiative. Most of them are school drop-outs and come from socially backward and economically weaker sections.

Directorate General of Employment & Training (DGET) have undertaken steps for the formulation of course curriculum for Modular Employable Scheme (MES), with active contribution from L&T. L&T has also played a major role in setting up the National Skill Training Park at Chhindwara. In-house Manufacturing Skills Training Centre at Hazira and L&T Institute of Technology (LTIT) at Mumbai, offering full-fledged Diploma Courses in engineering disciplines, help to further the cause of appropriate skill building.

Introducing innovative methods and techniques in skill building is essential to cater to a large workforce like that of L&T. Business diversity demands a holistic and multi-disciplinary approach to training and development, covering areas such as construction, equipment fabrication and product manufacturing. Well-structured skill training programs are conducted round the year by all business divisions of L&T, under the guidance and active support from Corporate Management. In-house training programs demonstrate a comprehensive mix of theoretical knowledge, hands-on practice, graded evaluation and continuous improvement.

Industry-Academia Collaboration

Productive partnership between the Industry and Academia is a prerequisite for development. At the national level, L&Thas been playing a leading role towards promoting Industry-Academia collaboration through a pioneering initiative called the National Knowledge Functional Hub (NKFH). A joint initiative of FICCI Capital Goods Committee and FICCI Higher Education Committee, the NKFH initiative is implementing a collaborative framework of leading Industries and Academic Institutions across the country, to promote multi-dimensional partnership. This is aimed at enhancing the quality, skills and employability of engineering graduates through a unique "Hub-and-Spoke" Model (Figure 19). Four Regional Hubs have already been set up under this initiative and several others are being planned. The initiative has attracted nation-wide attention. The Narayanamurthy Task Force on Industry – Academia Collaboration, set up under the aegis of the Planning Commission, has recommended inclusion of the NKFH Model in the 12th Five-Year Plan, to support skill-building efforts at the national level.

Skill Development is a holistic process that requires a balanced approach at the grass root level (for vocational and trade skills) as well as at the apex level (for high-end engineering skills) (Figure 20). L&T is actively collaborating with the National Skill Development Corporation (NSDC) and the Department of Heavy Industries (DHI), Govt. of India, in setting up a Sector Skill Council for India's Capital Goods Sector. Such skill development endeavours will be essential to attain global benchmarks in the manufacturing sector.

Corporate Social Responsibility

A prerequisite for nation building is Inclusive Growth across diverse socio-economic strata, ensuring equitable distribution of opportunities and wealth. Like most of the large Indian Corporates, L&T has been an active player in Corporate Social Responsibility (CSR) initiative by undertaking community development programs in partnership with a number of Government Agencies and Non-Governmental Organizations (NGOs). Contribution in such collaborative efforts includes domain knowledge, training resources as well as financial support.

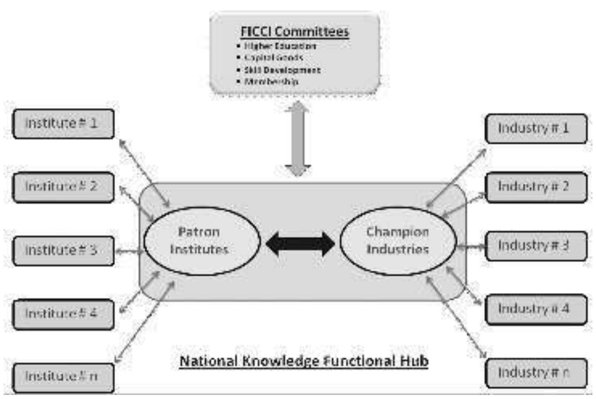

Figure 19 : Hub-&-spoke model for industry – academia collaboration

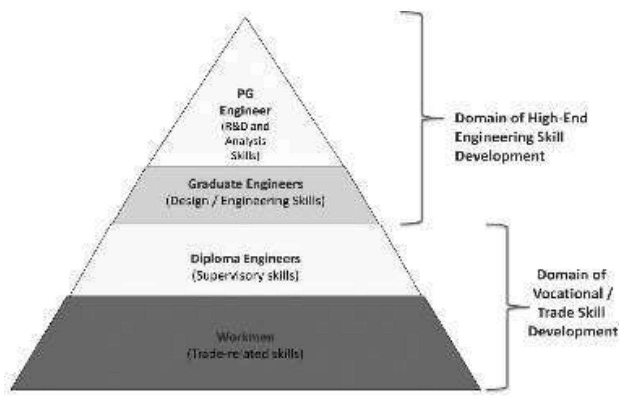

Figure 20 : The skill development pyramid

In the area of skill development and employability enhancement efforts at community level, L&Tis now working with 22 NGOs across the country. Some of the key partnerships are: Savitribai Phule Trusts – Aurangabad, Kotwalwadi Trust – Neral, Sri Sri University – Bhubaneswar, Kharel Education Trust – Kharel and Pratham Initiative at Latur. In all 41 vocational training centres have been set up with training capacity of 8000 youths, focusing on construction / industrial trades and agricultural trades for men as well as domestic trades for women. Over 10000 beneficiaries have gained from these initiatives so far.

Conclusion

Engineering advancements directly contribute towards accelerated growth in various industrial sectors that are vital for our overall economic growth. This will substantially improve the share of contribution from the core sectors like manufacturing in the overall GDPof India and bring us at par with our peer nations.

As India aspires to become a global economic superpower in the coming decades, it will be imperative to strike a judicious balance between excelling in engineering and technology front and ensuring that the fruits of such progress benefit the common man. L&T, as a responsible Corporate Citizen with a highly diversified business portfolio, has been striving to harness the power of engineering ingenuity for nation building, while promoting inclusive growth through well-managed programs aimed at social sector innovation.

Make in India — Challenges an NRL's Journey for the Last 17 Years

Dr Krishna Chivukula

Chairman, INDO-MIM Tee Pvt. Ltd., Bangalore

Good Afternoon Ladies and Gentlemen, I am indeed personally and professionally honored to be invited to give the 37th Annual Sir Mukherjee address. First, a little brief about our company INDO-US MIM Tec.

Our company INDO-US MIM Tec has been "Making in India" for the past 16 years and exporting 95% of its production to more than 35 countries in the world. It has repeatedly won between 4 to 6 (out of 8) DESIGN EXCELLENCE AWARDS from the Metal Powder Injection Federation, Princeton, New Jersey, U.S.A. These awards were given in competition with leading companies in Japan, U.S.A Germany, France, Spain and Italy. I take this opportunity to thank all our employees, suppliers in India and publicly let them know how proud I and the country are of them — for helping build a World Number One Company in a very complex area of Manufacturing Technology like Metal Injection Moulding IN INDIA. As we all well know, being "World Number One" in any area of human endeavor is a non-trivial matter- especially considering that the World Number Two Company in USA is less than half our size and, UNLIKE US, is experiencing negative growth. Also I, as Chairman, take this opportunity to announce that our U.S.A Manufacturing facility in Texas will be in production in the next twelve months.

A brief introduction to Metal Injection Moulding Technology

MIM Technology came out of the Universities in U.S.A in the mid to late 1980s and slowly gained acceptance in U.S.A as a cost effective way of producing small metal components that are of three dimensionally complex geometries in very high volumes and with a great degree of precision. In the 1990s it was still an emerging technology where there were more questions than answers. "Answers needed to be discovered through skillful Engineering and Scientific knowhow". We brought this technology which was still in its incubation stage to India in 1999. Expectedly the company lost money for the first few years. There were more questions-than answers. The domestic market in India did not have the scale required to utilize the technology and the diversity of the manufacturing base in India was still in its infancy. In 2001-2002 our Annual Turnover was somewhere around Rs 3 Crores. This year we expect to touch Rs 1000 Crores! Since the potential market in India was miniscule, we decided early on to be local but think global and establish company owned Sales, Marketing and Customer Service locations in key markets abroad. These offices were and still are predominantly manned by Indian engineers and scientists. We invested heavily in R&D, one the best Tool rooms in India and State of the Art equipment which unfortunately had to be imported. We invested heavily in Sales and Marketing to convince highly quality conscious customers in U.S.A, Germany etc that an Indian company, located in India can indeed master this complex technology, produce high precision components and overcome supply chain issues to deliver on time. One other important aspect that deserves mention is that THIS INDIAN COMPAY does not compete on cost but we do compete on Engineering knowhow, quality, creative Customer service and ONTIME delivery to about 35 countries in the world.

We have proven that "Make in India" can happen, even in an emerging and complex manufacturing technology such as Metal Injection Moulding. What is even more interesting that needs to be shared with you is that there are only four graduates of the world famous IITs (including me), out of a total workforce of 2800. The rest of the engineers were recruited from relatively unknown engineering colleges- all over India.

Our Management team has demonstrated great leadership in taking ordinary people in India and making them perform extraordinarythings, making themselves and their country proud. It certainly makes me feel very gratified when I see these relatively young and sparky men and women Engineers walking up to the dais to receive various awards for design excellence all over the world. They have certainly given a great name for Indian engineers in India in the non- IT sector.

Forthe campaign "Make in India" come to fruition certain ground realities must be recognized and certain proactive measures need to be taken by the State Governments and Central Governments in India. Let us dwell on these for a few minutes.

Ground Reality Number 1 is that India, for the last ten years has had a huge demographic dividend, which was largely-squandered. This dividend is expected to continue for the next 15-20 years where a significant portion of our population is under 30 Years old. These young peopfe need to be trained and employed productively- not as boys and girls sitting in elevators pressing buttons for various floors as the famous ECONOMIST MAGAZINE deridingly once pointed out. There has been a window of opportunity for the last 10 years which has largely been wasted by our grid locked political- economic system. Most advanced countries do have a consensus among the elites of different parties as to national identity, national purpose and national direction. There is a general agreement among all the parties in these countries whether the country should go generally east or generally west, plus or minus a few degrees. Unfortunately this consensus at the top seems to be lacking, to the extent needed, in India. This consensus needs to evolve urgently so that this blessing of a demographic dividend is not frittered away AGAIN.

Ground Reality Number 2: Being a graduate of IIT myself, I am all for creating more IITs and Engineering colleges across the country. This certainly must be done. But what is equally important is that we create a very large pool of labour with a high degree of "hands on" technical skills. When was the last time you or I was totally happy with the electrlcian or the painter or the plumber or the mason or the carpenter that came to your house to perform a function? I certainly was not very happy. So I would advocate creation of many more ITls than IITs. In fact I would even go to the extent of saying that there should be an I.T.I in every Taluk in the country to provide subsidized skills training for the young children. The brightest and the best of them will certainly go to IITs and Engineering colleges, but the 2nd and 3rd Tier children also do deserve a chance to contribute productively to the country. Otherwise we will continue to see them hanging around by the side of the road, loitering around petty shops. The creation of a very large pool of skilled labour will provide a ground swell like fillip to the country's economy. A bottom up approach to progress is not only much more lasting and sustainable but also provides social justice. Having worked in U.S.A all my life the first thing I learnt there was dignity of labour. This is one aspect of the West that we in India may choose to imbibe. When respected, a human being will be proud of his work and accomplishments like all of us in this room. Being proud of a job well done is more important that what the job is.

Ground Reality Number 3: China obviously has industrialized tremendously in a very short span of time. As we all know, almost every consumer product or appliance that we all touch is made in China — starting with dinner plates to smart phones. Of course this has come at a tremendous cost in environmental degradation and societal instability. For us to blindly copy the China model, in my opinion would be a strategic blunder. The history, culture, philosophy and mental makeup of India are significantly different than that of China. We are a functional democracy and not a command-control politico-economic system.

All the great religious faiths that are Non-Abrahamic started in India. We are not prone to violent revolutions that result in mass killing of our own people, like in China or USSR. We achieved independence not by armed struggle but entirely through peaceful means. So for us to blindly ape the Chinese model would be a great folly- rather we should recognize our strengths and play to our strengths while trying to correct our weaknesses. I am sure that there are plenty of people in India that, working together, can come up with the right strategies that are suitable to who we are and WHAT WE ARE. Just like you, I also read the newspapers, the Editorials and business journals and do see a healthy debate discussing the pros and cons of various approaches to "MAKE IN INDIA" and gradually a consensus will evolve as to how we solve our problems our way and not the American way or the Chinese way.

Ground Reality Number 4: Thanks to our founding fathers like Mahatma Gandhi, Jawaharlal Nehru, Sardar Patel and others, despite the phenomenal diversity of India, India was forged into one country offering up huge opportunities for economies of scale. Unfortunately these opportunities remain relatively untapped and China has filled the void and usurped the role of the production hub for the world. The dilemma, simply put, is thus. Massive employment opportunities can be rapidly created only in low skill industries such as textiles and toys. But right now most of these products can be affordably imported from China. As we go up the food chain of skill level, the number of jobs that can be created becomes lesser and lesser. Also our Federal and States political structure plus the Parliamentary Democracy takes away quite a bit from the gains to be realized from a unified economy. Movement of goods across state boundaries is quite cumbersome. AAAH, how I wish our founding fathers studied at Harvard and Yale in USA, rather than Oxford and Cambridge in UK!

What I have tried to do above is to outline some strategic considerations for our polity to consider. Of course there are detailed recommendations that can be made, all of which can be picked up easily just by reading the newspapers and business journals that we all read. I do believe that this is not the right forum to list out detailed recommendations — most of which, a distinguished audience such as you, are already aware of. I don't want to bore you with lots of statistics, charts and graphs. I am sure you are already aware of these things. However a short list may be in order.

1) A Tax regime that is predictable in the long term. Business investments, whether domestic or foreign are made looking at a time horizon of more than seven to ten years. The taxing authorities in India need to be cognizant of this - irrespective of the political party in power. Also retro-active taxation is unpardonable - it is like turning a Test Match in Cricket into a One day game on the third day. Consistency and predictability in taxation are crucial for business investments.

2) Of course, as is widely recognized, the infrastructure needs to be improved, labour laws need to be more rational, the role of Government in Industry reduced, private enterprise encouraged, bills like G.S.T need to be discussed and passed without parochial considerations, rivers need to be cleaned up, bureaucracy needs to be simplified and corruption brought under control. We all know what needs to be done; the trick is how we get it done and how fast we should target to get it done. India is an elephant- not a Cheetah. It is in our nature to move slowly and deliberately, keeping national unity and social justice in mind. These values need to be preserved as we pursue prosperity and GDP growth rate. Fortunately we do seem to have a political dispensation at the Centre that wants to do this. Hopefully they will have the political savvy and support from a "Responsible Opposition" to accomplish it.

3) Self sufficiency in key sectors of the economy such as defence, electronics etc. This is important for national security.

4) Focus on the construction industry for job creation.

5) Seriously examine the idea of increasing the tariffs on imports from China for certain category of products; for say 10 years? This will provide the necessary breathing room for domestic industry in the low-skill space to catch up.

6) Remove all duties and excise taxes on import of capital equipment, again for just 10 years. This will catalyze the establishment of new factories and create the required jobs.

7) Focus on job creation as the center piece/starting point for designing national strategy — at least forthe short term.

My sincere thanks to the Institution of Engineers (India) for providing methis opportunityto share myviews with you.

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Evolution of Machines: From Steam Engines to Mechatronics

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Devices which are used to transform and transmit motion and power are called machines. If the idea of transmission of motion rather than power dominates, then the device is usually called a mechanism. An automobile wiper 'mechanism' transforms the rotary motion of a motor into the linear or angular oscillatory motions of the wiper blades and we do not call it a machine. From ancient times some machines were used in different civilizations. Those included some forms of drills, levers, pulleys, crude gears and so on. They were used for lighting a fire, moving great weights, irrigating agricultural fields, for mining, milling grains, moving special chariots or just simply running a fountain for luxury. The sources of energy or the prime movers were windmills, water wheels or animals. No wonder that the capacity of a machine is expressed in horsepower. It must be noted that as the flow of wind or water acted as the power source, the location of the machine was immovable and its performance was dependent on the seasonal variations of the natural power source. The present lecture commences with a discussion on some of the famous machines of antiquity.

A systematic study and evolution of machines followed from the birth of the steam engine. In fact, the discipline of mechanical engineering, different from the practice of instrument making, was born with the goal of improving the performance of steam engines. The subjects of heat power (thermodynamics), kinematics and dynamics, manufacturing and production, control etc, which broadly define the discipline of Mechanical Engineering, all were intimately related to the same goal. We may recall that the 'governor' of an engine, which acted both as a sensor and an actuator, was probably the first automatic control device. The invention of steam engines gave birth to what is now called the first industrial revolution. Coal became the most important fuel as the supplies of the easily available wood were almost exhausted. In this lecture, we briefly touch upon the birth and development of early steam engines and discuss how they gave rise to the different subjects which define the discipline of Mechanical Engineering.

We then concentrate on the subject 'Theory of Machines'. The first textbook discussing the basic principles of motion transmission through various types of connections between rigid machine elements was published in the German language in the year 1875. The very next year, the book was translated into English. Linkages, cams and gears constituted machine parts of a huge number of new machines, which had applications in various fields, including agriculture, printing, textile, transportation and what not. For the first time, a large part of the western world found employment in non-agriculture based activities. With the advent of electrical motors, internal combustion engines, hydraulic actuators, etc., the characteristics of the prime movers changed substantially. In this lecture, we demonstrate some models of earth moving machinery, tipper dumper, transporters to carry an object through various stations. In all these machines, the substantial movements of various elements are controlled by 'geometry', that is, by the locations and by the natures of the interconnections.

Another class of mechanisms was invented to generate movements on a finer scale. In these mechanisms, the deformation of an elastic continuum is utilized to generate very counter-intuitive small movements. These are known as compliant mechanisms. Such compliant mechanisms are applied to constitute bi-stable micro-switches, and other machines at the micro-scale. Machines in micro and nano scales have wide applications, such as, in minimal invasive surgery, drug delivery device, micromachining and nano positioning devices. Micro machines use different prime movers or actuators. These actuators are made of special materials known as 'smart' materials, such as piezoelectric materials, shape memory alloys, electro- or magneto-rheological fluids and so on. In this talk, we demonstrate some models of such compliant mechanisms.

With the advent of electronics, specially its digital version and computers, machineries underwent a sea change. The geometric control was replaced by control at the input level. Machines went beyond the exclusive field of mechanical engineers. Machines now began to belong to the interdisciplinary area of mechanical, electrical, electronics and computer engineering. A new subject called mechatronics was born. An example of a complicated engine management system of the present day automobiles will be discussed to emphasize this interdisciplinary aspect of modern machines.

Another type of machinery development gave rise to a new interdisciplinary subject area called robotics. Robots are flexible or programmable machines, which can be easily reconfigured to undertake different tasks. Tremendous developments have taken place in the fields of sensors and actuators to support the robotics activity. Some examples of series, parallel and hybrid robots will be considered. Series robots have relatively large work-space and low payload, whereas the parallel robots have large payload and limited range of movement. Applications of such parallel robots as a flight simulator and for micropositioning of the secondary mirror of a special telescope will be shown. Recently, the capability of decision making is being added to some machines known as 'intelligent' machines. These autonomous machines can study their work environment and take correct decisions for proper functioning. Autonomous robots in the form of human beings have occupied the fancy of nontechnical people. The talk ends with discussions on some walking machines having various numbers of legs such as six, four, two and even one. A model of a six legged wall climbing robot will be demonstrated.

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