THE APPLICATION OF SCIENCE AND TECHNOLOGY TO SOCIO-ECONOMIC DEVELOPMENT

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"Free Enterprise was born with man and shall survive as long as man survives."

—A. D. Shroff

(1899-1965)

Founder-President,

Forum of Free Enterprise.

Sixth A. D. Shroff Memorial Lecture

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by

Prof. M. S. Thacker

I begin by repeating a part of my Presidential address to the United Nation's Conference, which met at Geneva in 1963 with nearly two thousand delegates and over ninety countries represented, on Application of Science and Technology for the benefit of the Developing Areas of the World.

"Perhaps the most important of these various revolutions will prove to have been due to the upsurge of science and technology. In the last century, science was essentially the concern of a few private individuals and institutions. It has emerged as the most important element of national development and economic uplift. And need I mention the widespread and almost ubiquitous influence of technology in all fields of human endeavour, whether public or private. Advances in nuclear science inspire hopes that mankind may have at his command before very long, historically speaking, vast and cheap sources of energy. Radio astronomers and optical astronomers have extended estimates of the age of our galaxy and are striking farther and farther out into the boundaries of the universe. Man has encompassed his world with artificial satellites and has made challenges of reaching the inviolate moon. The arts of agriculture and medicine are vastly improved and the same can be said for almost every

* This is the text of a public lecture delivered under the auspices of the Forum of Free Enterprise on 28th October, 1971, in Bombay. Prof. Thacker was the Director of the Indian Institute of Science, Bangalore member of the Planning Commission. Secretary of Union Ministry of Science and Cultural Affairs and Chairman of United Nations Conference on Application of Science and technology for benefit of Developing Areas.

field of human endeavour. We have much deeper understanding of the biological processes. The sciences dealing with the earth and its environment are in an equally lively state. The air, the earth, the oceans and the sun contain riches which can support increases in population at higher and higher standards of living."

What I said was eight years ago. The frontiers of science and technology are widening and deepening every day and at such a rate that we are constantly under pressure to alter our perspective to come to terms with the newly discovered truths. There was a time when people could afford to ignore the results of science or scorn at them or even be brutally opposed to the scientific truth as at the time of Galileo. However, the temper is different today since science and technology are so intimately tied with our daily life. They have become the essence of economic behaviour and we almost, as it were, take for granted conditions created by the technological change. Newer products of research are affecting national economy, the national security is becoming more and more dependent upon technology, books and even day-to-day newspapers are preoccupied with the increasing power of technology; and even art and architecture are being drawn into its vortex. These changes have imperceptibly become a part of our life and we have, unconsciously, if not consciously, learnt to live with them.

Compartmentalization of science, which was so in earlier years, is becoming obsolete in the present era of rapid change. Let me illustrate. A branch of nuclear physics now is also a part of astronautics and astronomy. Optics theory, so typically a physics subject, in the earlier days, has, with the invention of lasers, become a branch of communication engineering. Magnetic resonance today is a branch of biology. Fourier transforms, a stable technique which the engineers used, is presently being used in economics to discover important trade cycles and to develop more logically consistent and empirically well founded economic planning models.

The esoteric research, which used to be the brunt of jokes and mirth — a topic such as "mating habits of the Papuan insects" — has led to a major scientific breakthrough in pest-control and agricultural crop care. The "moon-walk" training, that U.S. astronauts underwent prior to stepping on the moon, has yielded rich data and technological breakthroughs in the treatment of paralysis, polio, and disabled persons. The application of new radar techniques, to distinguish real H-bomb missile wareheads from fake decoys, has opened up a new vista in brain surgery. Boolean algebra, considered once "useless intellectual gymnastics", has laid the foundation for computer sciences. A recent article quotes: "Out of the growing wealth of space technology, ever-expanding lists of practical applications are coming. Already, instruments in space are greatly enhancing weather forecasting and global communications, especially television. The use of the latter was strikingly demonstrated when, in 1969, millions around the world saw the astronauts walk on the moon. In the future, techniques will be improved and new applications developed that will include worldwide navigation aids, air traffic control, detection and measurement of Earth's resources, as well as the mapping and measurement of air and water pollution. The very act of reaching into space can help man to improve the quality of life on Earth.

Thus science and, in its application, technology have in the recent years acquired new horizons, broken old compartments and barriers and have reached the unforeseen possibilities. "In the United States of America, science and technology and economy together over the last quarter century have had the longest period of sustained growth, innovation and the new industry in the recent history. These may not have brought on the millennium. Science's very success, one might say, has added some age-old problems and created new ones, has measurably widened options and potentials of human life on earth, but one cannot deny the pinnacle of this period when man stepped on the moon, a feat that will rank in history among the few clear, large and positive achievements of the 'last decade'."

The "moon-feat" was perceived as a technological feat. It may be so but science was behind it. Technology represents the practical embodiment and apparent manifestation of science. The Third Law of Newton which states that action and reaction are opposite and equal is obviously science. But the rocket that sped the astronauts to the moon was technology, the practical embodiment of Newton's Third Law or its manifastation in rocket thrust. Hence technology and science are interrelated and mutually causative. The relationship in the age of empiricism was confounded. But, in the modern era, it is clear, explicit and bi-directional.

Historically, it was in the 16th century that the beginnings of what we now have become familiar with — the application of science to technology — are to be sought when a committee of mathematicians were entrusted with the task of suggesting repairs to the Basilica of St. Paul in Rome and that incident may also be said to mark the beginning of engineering in the modern sense of the word — until then architecture was an art unrelated to the science of mechanics and was based on practical experience handed down from the earliest times. The next incident of major importance was the application, again of mathematics and astronomy, to navigation with the heralding of the age of discovery. Similarly, there were several others which brought science and the useful arts together without, however, allowing for the birth and growth of science-based technologies. In fact, right down to the discovery by Faraday of the principles of electromagnetic induction and the birth of electrical engineering there continued to be a yawning gulf between science and technology and even the word "science" did not find a place in everyday vocabulary. The universities were tied down to metaphysics and science to them was just another branch of philosophy. It is not surprising, therefore, that until the crafts had given birth to the sciences — chemistry from the textile industry that was looking for an effective bleaching agent and physics from the needs of having to sail across the open seas — technology had to depend upon the crafts instead of the sciences for its progress. Till the end of the nineteenth century, the connection between science and technology was itself very loose and tenuous. The periods when science flourished did not coincide with those when technology was moving ahead most rapidly. When they did flourish together, it was not necessarily in the same place. On balance, till mid-nineteenth century, science was far more indebted to technology than technology to science. Science and technology started moving closer as the experience with the Industrial Revolution grew and science began to take the lead in some areas.

The commercial interests, as this relationship between science and technology grew, realized that research, science and science-based technology, were essential for revolution. The outcome of this realization was the emergence of industrial laboratories, especially in the West. These commercial industrial laboratories continued to be the main agency through which scientific and technological knowledge was processed for economic exploitation. But if an idea had no apparent or explicit commercial application, it was not taken up for investigation. If a scientific study discovered some major break-through, it was not shared with others and hence its potentiality to do any social good remained dormant. Such research laboratories neither interested themselves in basic research nor did they consider it worthwhile to finance it. Basic research was left largely to be pursued in universities, but under almost similar conditions that the inventor faced in the early part of the nineteenth century.

It was world War I that brought into sharp focus the overwhelming need for the application of science to the art of war which until then was dominated by the belief, as expressed by Lloyd George of the rulers of the world, that "the seat of intelligence lay in the chin and that this feature in the physiognomy was to be sought for in military leadership." But the submarine compelled Great Britain to seek the help of Sir William H. Bragg to find a solution for their detection. France looked to Langevis for devising a means for the detection land-mines. The outstanding contribution of science to the art of war, however, was Haber's achievement in fixing the nitrogen of the atmosphere for the manufacture of explosives that enabled Imperial Germany to carry on the war. The inter-war years enabled this realisation to make massive investments in the aeronautical industry as providing, with the submarine, a third dimension for national war machines, and it reached its climax with the historic decision of Franklin D. Roosevelt that the USA should give the highest priority to the manufacture of the atomic bomb. The researches into the structure of the atoms, which were hitherto considered only of theoretical interest, began attracting Government's attention when men like Dr. Albert Einstein were able to convince the public policy-makers that national security of the United States could be enhanced by the application of such basic research. In any case, no private laboratory could conduct such basic research as it involved very large resources and, besides, carried a high risk of failure. With the entry of Government on national security grounds into the activity of basic research a new phase commenced in the history of science and technology and its impact on economic development has been far reaching and fundamental.

"Out of World War II, in what has been called the greatest mobilization of scientists and technologists in history, came a great victory over a clearly evil tyranny, and a cornucopia of great technical developments to build and keep the pace. None of these developments could be economically 'afforded' in the depressed period of the 'THIRTIES', but in war the men and wherewithal were quickly found to develop them, largely out of the banked-up store of European science. From these wartime projects in due time came the antibiotics, atomic power, cryogenics, computers, jet planes, rocket vehicles, radar, transistors, masers, lasers, and other projects that became the new industrial face of the mid-century," and the recent progress, have accumulated enormous capital inventory upon which technology can draw.

To give one brief example, nuclear energy, thought still in its early stages, is most promising in its possible effects on economic development. Only nuclear power possesses the necessary explosive force to release petroleum fluids which are often trapped in what geologists call "tight" rocks, since chemical explosives are quite ineffective for such purpose. Low grade copper ores could be mined economically for the first time by the application of nuclear explosives. In fact, nuclear energy is cheaper by several multiples than any other source, and vast new vistas of technology towards economic development will open once the radio-active factors are tamed.

The above briefly outline the relationship between science and technology, the economic implications of the concomitant development and the three phases it went through in its historical role. The first was an unsystematic and erratic application of mechanical inventions to economic activity characterised by a tenuous and weak causative relationship between science and technology, which gave way, in the second phase, to a definite causative relationship between science and science-based technology. Concurrently, scientific research began to get organised in commercial industrial laboratories which, as it grew, gave the impetus, in its application, to economic production. The third phase which intensively began with and after World War II brought with it the participation of the Governments.

Viewed against this historical development of the impact of science and technology, our recent experience poses some thought-provoking questions. No doubt, technological change that results from this impact is one of the most important determinants of the shape and evolution of our socio-economic growth.

One very important and direct consequence of technological change in the 20th century is the communication revolution. In fact the growth of modern communication is itself a function of social and economic development. Industries, transport, and modern communication media such as radio, TV and satellites (like Telstar) are the indices of general social and economic growth which ultimately reflects in individual betterment.

Improved working conditions permitting reduction of working hours and an increased flow of products, old and new, have added many new factors to our consumption pattern and way of life. New machines and processes and the advent of factory automation have strengthened the measure of our growth and productivity. However, structural changes show that the introduction of new industrial technology changes the relative importance of individual supplying sectors in the economy. New machines and techniques of production alter the amounts and kind of materials, of parts and components, of energy, of labour skills, and of supporting services that each industry uses to manufacture its products. A couple of instances of this kind, one might cite, are the shift from coal to oil and natural gas, and marked displacement of steel and tin by plastics and paper in the container industry.

But though most people would agree that on the whole technological impact has been beneficial, could one say it has been without any cost to society? Advances in military technology, for example, have made possible considerable beneficial changes in many sectors. However, the same technology has made possible the destruction of mankind on an unprecendented scale, bringing into a serious question the survival of the human species! Modern civilian technology has also inflicted costs in terms of air and water pollution, radio-activity, urban sprawl, crowded cities and increased social and psychological tensions.

I would point out the remarks Sir Solly Zuckerman, Scientific Adviser to the British Government, made at the XXIII Congress of the International Chamber of Commerce, Vienna, April 1971, at which some of our leading industrialists were present: "...... over the past few years more and more voices have been sounding warnings about the adverse secondary effects of the continued growth of our industrial civilisation. In some quarters even the desirability of economic growth itself is being questioned. This particular issue has crystallised in the terms 'environment' and 'pollution'. In the more developed countries of the world an increasing number of people are asking whether the adverse environmental effects which industrialisation and modern technology can bring in their train may not counter-balance the primary beneficial effects for which they are also responsible, and indeed whether environmental damage is not an inevitable consequence of industrial growth."

We are, in one way, fortunate, so to speak, in not having simultaneously developed with the Western countries. That is in having many of our options open on the choice of technology which provides us an opportunity to make rational allocation. In the West, these options are no longer open, and, in fact, were closed, rather unwillingly, in the aggressive pursuit of individual profit-maximization. Policy-makers, scientists and technologists in the West are today agonizing over the question of costs of technology, costs that accrue to society! What all societies, therefore, need is a system of social accounting that will make clear the total costs to the society of each possible outcome of the decision-making process and the incidence of gains and benefits to all concerned. Such accounting is no longer impossible, thanks to refinements in data collecting and computerization of results.

Undoubtedly, science and technology have a clear impact on economic development. But are the social benefits from this impact worth the social cost? This question leads us to two interesting thoughts. First, it is possible that the social benefits of a technology may not be worth its social cost. Yet, the private benefits from this technology may greatly exceed the private costs.

I refer to the controversies of the 1950s, in this country, on whether India should build the heavy engineering projects, atomic reactors, etc., which arose out of a confusion between private cost-benefit calculations and social cost-benefit calculations. If one were to calculate the net benefits from these public sector projects in terms of the classical accounting concepts, then, clearly, the rate of return would be small. However, from the social point of view, these public sector projects, when managed and run efficiently, provide an industrial base and make possible a variety of private industrial activity. These public sector projects provide social benefits which in value terms exceed social costs and even if they do not provide sufficient return from the private point of view, they, nevertheless, have "social profitability".

I argue that no matter how profound may be the impact of a particular technology on economic development, if the costs it imposes socially are large compared to the benefits it provides socially, then the society in a group decision may find it beneficial to forgo it. This is one of the new issues that has been raised by dissenters in the West. Yet another issue could be raised. That is the distributive justice of the technology. By this I mean that those who enjoy the benefits of the impact of science and technology are not necessarily the persons who pay the costs, or pay proportionately to the benefits enjoyed. One might refer to cases such as pollution, traffic congestions, "brain-drain", etc.

I am tempted to refer to "brain-drain". Our young men are getting trained in State-financed universities, technological and research institutions. They go abroad and settle down there. According to one estimate up to 1967 the number of Indian scientific and technical personnel abroad was 39,000 (20,000 engineers, 11,000 medical doctors and 8,000 scientists*). Of these, a large number was for study and training with a small number for employment and on emigration. As a percentage of this total in 1967, it worked out to about 17% in the case of engineers, 11% in the case of doctors and 9% in the case of scientists. There are several causes for the brain-drain but I am sure many young men would probably return if the job satisfaction level in India was raised. In this context, if programmes of action are formulated for specific groups, there are better chances of such men returning to India instead of trying to line up such cases with the problems of brain-drain in its entirety. For example, in areas such as electronics, design engineering, instruments, etc., greater progress as well as large employment for scientists and technologists now working abroad are possible. But the point is that sooner we realise that we are paying the costs for this training and that because of the socio-economic atmosphere we are unable to reap the benefits of these sunken cost, the better will it be for the country.

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* Source - Institute of Applied Manpower Research, New Delhi, March 1971. Pages 14 & 26.

What I have said, is neither new nor revolutionary! No doubt science and technology have a profound impact on economic development, but have the benefits been without their costs? Do we not in the future need a more conscious calculation of these costs and benefits before we accept a technology? Should we or should we not seriously consider, in the application of technology, the issues of social costs and benefits and of the distributive justice of technology? These are some of the crucial questions we must answer.

However, in several questions I have so far posed, I would like to emphasise not the past but the future. Do we, on the basis of the historical experience of other countries, want to follow the same known but beaten path of science and technology, or do we want to chart a new approach on the basis of the urgent requirements of our country?

Let me not be misunderstood. I do not at all advocate the exclusion of everything foreign. Quite the contrary, I believe science and technology have no national boundaries, and, in fact, there has to be a free exchange of scientific ideas and information in a rational world. However, science and technology while universal, nevertheless, have a relevance and specificity. Technology generally cannot be successfully uprooted from the environment and planted in another. To be successful in this transfer, there have to be adaptations and assimilation. It is only after we have passed through this phase that we could provide the infrastructure for a nationally suitably technology, innovative in its own environment. Every leader of technology in the world today has passed through this phase, the U.S.A. in the 19th century, the Soviet Union between 1925 and 1940 and China between 1950 and 1970.

I would say, and readily accept, and I again quote from my presidential address to the United Nation Conference at Geneva, that totally imported science and technology may not be relevant to the needs of the less developed countries. I would also accept that the development of science in these areas should be such that it is suited to the material needs and genius of the people concerned and that such a development of science should gather momentum gradually. I would accept that view, but we must not make a fetish of it or find in the absence of such a science an excuse to delay action.

However, we will have to review our technological import policy, so that we would not unnecessarily import quite so much and in duplication. We are buying the same technology many times over. In spite of our long experience of industries such as iron and steel, aluminium, paper, etc., we have imported the same or similar technologies from a number of countries. Even today, we are repeating the same process to some extent. It would be better for the nation's economic development if we were to analyse cost-benefits, if we imported a technology once, and then use the existing know-how from our existing industries or engage our national laboratories and technical institutions to find a relevant specific adaptation of that technology in tune with the national requirements. This would of course entail a greater R & D effort than is being conducted at present.

A target for total national expenditure on research and experimental development was proposed by a UNESCO conference on the Application of Science and Technology to the Development of Asia (CASTASIA) held in Delhi in 1968, when the Ministers for Education, Science and Technology, and the leaders in the field from all Asian countries were present.

The Conference recommended participating governments of Asia to endeavour to reach a minimum national expenditure on research and experimental development of 1 per cent of their gross national product as soon as possible, but not later than1980*.

Japan is often cited as an example of a country experiencing rapid advances in technology. This is no doubt valid; however, a deeper look at Japan reveals that Japan rarely

* This total national expenditure comprises current as well as capital expenditure on research and development financed by both governmental and private sources.

imported the same technology twice. In fact, technologies that were imported in Japan were combined with intense research to make it adaptable to Japanese conditions. Some figures would illustrate this. For 1950-62, the Japanese import of chemical technology constituted 22% of total import of technology. Over similar period, R & D on chemical technology constituted 24% of total R & D. The same is true of other imported technologies such as electrical machinery, transport equipment, etc.

In other words, in Japan the larger the fraction of imported technology, the larger was the domestic R & D effort to enable Japanese engineers to understand and adapt the technology. During 1957-65, in India, non-electrical machinery constituted 29% of the imported technology through foreign collaboration. Yet the R & D expenditure on non-electrical machinery was barely 6% of the total R & D effort; similarly, electrical machinery technology imports were 11% of total imported technology, whereas the R & D effort in electrical machinery was about 4%. The results of the policies of the two countries are clearly visible.

Recent estimates on R & D expenditure have shown that the contribution of the private sector is negligible.* For example, out of the total annual expenditure of Rs. 146 crores on R & D during 1969-70, the private sector has invested about Rs. 11 crores which is about 7% of total. In advanced countries, these figures vary from 36 to 74%, Japan showing the maximum. In a recent survey carried out by the Indian Chemical Manufacturers' Association, in a large number of cases, the R & D expenditure is well below 1% and in some cases even below 0.5% of total sales, whereas in the UK, it is about 6%.

In addition, this conference recommended some guidelines for science policy which I reproduce in full.

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* Source - Annual Report on Science and Technology (1969-70) Cabinet Secretariat - New Delhi - 1970.

The preamble recognised the vital role of science and technology in relation to growth, and recommended that the country should:

1. formulate and implement a purposeful National Science Policy as a high priority measure in any government programme;

2. extend the scope of their science policies to the whole chain of activities ranging from basic research to the innovation processes whereby the results of research and experimental development are translated through engineering and design into products and techniques of immediate socio-economic value;

3. recognize as a basic option of their national science policies the principle of "endogenous development" whereby economic growth and technological change are being oriented and sustained by the nation's own scientific and technological community;

4. ensure appropriate integration and harmonization of the national science policy at the highest level of government, while attaching major importance to the adjustment mechanisms of the science planning system which should provide for immediate reaction to error or charging circumstances;

5. secure effective participation of the research scientists and technologists in the governing organs of the national science policy-making bodies;

6. create or maintain strong government structures for the formulation of scientific policy as well as for the co-ordination, financing and performance of research and development, and related scientific activities;

7. establish and expand the research and development base such as laboratories, scientific equipment, etc., in order to meet the need of the national economy including the need for choice, assimilation and efficient utilization of imported technology;

8. formulate the national science policy in such a way as:
   (a) to create favourable conditions for the application of science and technology to national development;
   (b) to reduce social disparity or adverse side-effects when adopting new technology, and in particular not to aggravate unemployment;
9. adopt, publish and keep under constant review, a set of basic criteria for the allocation of national resources to science and technology, and in particular to research and development activities;
10. promote, as a priority sector of the national science policy, the development of adequate scientific and technical information organization and services at the national level.

While considering the excellence of these recommendations, it is salutary to recall that in 1958 the late Prime Minister, Mr. Jawaharlal Nehru, enunciated the Scientific Policy Resolution to Parliament, to affirm its faith in the vital role of science and technology in the transformation of our society. It is an admirable document and emphasises what science can do in providing new conceptual frame-works and analytical tools for tackling socio-economic problems and in promoting the spread of a scientific temper among the community at large. But I might comment after 13 years that there has been not much visible impact of science on our society.

Advanced countries demonstrate an extraordinary and expanding array of new companies whose very life-blood is research and development. Their field of operations lies along the farthest frontiers of scientific discovery. Their business is to exploit the advances of science, to translate them rapidly and economically into useful products and services. On our industrial horizon, relatively few of these new enterprises yet bulk large. Perhaps, the talent that could be profitably harnessed for R & D projects is busy in absorbing and stabilizing the repeatedly borrowed technical know-how. There is, therefore, no incentive and urge for creative efforts. Hence the role of R & D in the current technological revolution, its significance for the future economic strength of this country in the face of rising international competition are wholly out of proportion to its individual size.

At this juncture, may I enter and say a few words about the big industry — small industry controversy? There is no doubt that heavy capital outlay (hence 'big') industries are most necessary for economic growth. We have set up large industries, big dams, etc., and made a beginning in nuclear technology. But that is only half the story. The other half suggests that for effective and efficient exploitation of these big industries, we need a dense cluster of small but efficient industries that are suppliers of various inputs to these big units, and also are users of the output of the big units. Unless such a structural transformation takes place, industrialization would be superficial. This has been our experience of the last twenty years of planning. Thus, while there have been heavy capital investments in some of our States, they have acquired a very marginal industrial base, as for example in Bihar. On the other hand, some of our other States which have received a small share of the heavy public sector capital outlays such as Punjab, Tamil Nadu, have, nevertheless, developed an industrial base largely through setting up of small and medium industries.

Let me say that it is axiomatic in economic planning for a developing country like ours that science and technology should play a decisive role in increasing agricultural and industrial productivity. This is more so, because TIME is against us. We must do in a few decades what it has taken several centuries to achieve in the developed countries. The mere availability of science and technology, however, does not guarantee that the economic development of a country will automatically take place. If science and technology are to contribute to productive processes, special talents must be trained and developed. The people must be trained to apply the knowledge and techniques effectively on a broad front. The availability of people with the necessary skills determine the direction and pace of economic growth in developing countries. In the last analysis, it will be the ambitions and know-how of the people of developing countries that will determine whether minerals stay underground or are transformed into goods useful to man; whether oil remains hidden or becomes a major source of power and heat; whether roads remain mud-tracks or are transformed into arteries of trade and commerce. In brief, the most important investment any country can make, whatever may be its stage of economic development, is in its human resources, and in the education and training of its population in institutions which create incentives, and make it possible for the individual to realise his aspirations and in the process effect a revolution, economic and social, for the benefit of everyone.

The tremendous growth which we have witnessed in science and technology is a result of one thing — a better use by man of his mental capacities. No aspect of the development process has been more stressed here than this one — human resources. Developing human resources, training of minds, has emerged as the most pivotal aspect. I would like to say again, with the utmost conviction, that it is human resources, still largely untapped, which constitute man's real hope for the future. For all his inventions and calculating machines, man remains the principal tool of economic development, as his welfare should be its only objective.

Our investments in human resources will pay dividends only if we develop adequate political wisdom to exploit this kind of investment. Otherwise, the human skills and knowledge generated become sterile. Here, I am not anxious to talk about our politics or about the complexion of our economic and social ideologies, whether we choose private initiative or state initiative or a judicious combination of the two to suit our special circumstances in our efforts to usher in social justice — and social justice is no more than a translation of this ethical imperative — our salvation, in the final analysis, rests in a down-to-earth effort to increase our total national productivity, save enough for investment on a continuing basis and accelerate the process of development. It will be poor consolation to us if we only render lip service to this ethical imperative of socialism by reducing it merely to one of controlling the means of production and distribution and set up gigantic state enterprises unless we run them efficiently and profitably. As an engineer concerned with the practical aspects of building a new and prosperous society in our country, I find it difficult to agree with the thesis that the profitability of a state enterprise and socialistic philosophy are opposed to each other or even that the former, namely profitability, is a secondary consideration. We have to only acquaint ourselves with what is today happening in professedly socialist economies like Yugoslavia, Czechoslovakia and Poland, not to speak of U.S.S.R. and China. Even in a socialist system, enterprises must stay in business, make enough profits to insure against future risks, though the quantum of benefits may not be at a level which one would expect in the private sector, since obviously a part of the benefits that accrue to society would not be measurable in economic terms. It is only out of today's profits that we can protect ourselves against tomorrow's losses on the one hand, and on the other, save enough for future investment. I, therefore, attach the highest importance to the question of increasing national productivity since it is only through higher productivity that we can wipe out the poverty of the millions of our people and extend to them hope of a new life.

In the country today, there is considerable unemployment. Naturally, therefore, there is a widespread demand for labour-intensive technology, presumably for the technology that generates the most jobs. In the light of remarks I made earlier, I would like to offer some cautionary remarks that seem relevant to me. Need the labour-intensive technology be the technology which generates the most jobs? This conceptual confusion has, in my opinion, led to some unnecessary controversies. A jet plane which is certainly not as labour-intensive as a bullock cart actually generates more jobs than the latter. A computer may in many situations generate more jobs than manual labour.

The confusion has arisen because labour-intensity has been interpreted as the number of jobs directly created per unit investment. By this criterion, the bullock carts and manual labour certainly create more employment than modern technology. However, when we consider the indirect employment generation, the employment generated in other industries, as a consequence, modern technology generally far outstrips the more primitive technology.

For some projects, the direct effect is large but the indirect or linkage effect is small. For others, it is the other way round. For bullock carts, for example, the direct effect is large compared to the jet engine, but the linkage effect is small compared to jet. Generally speaking, the more modern technology has a high linkage effect but a low direct effect. The more primitive technology has a low linkage effect but high direct effect. The correct strategy for maximum employment is, therefore, to elect those technologies which maximise the direct plus linkage employment effects.

One very important effect of technological progress, which, though apparently social, has serious economic implications. The widespread technological environments have resulted in enormous growth of population of our cities and states, to which I have referred earlier very briefly, with a corresponding expansion in the economic units of agriculture, industry and labour. Increasing speed of transportation and communication has accelerated this expansion bringing together larger groups of people and giving rise to more complex and unmanageably large organizations, and the largeness of an organization, without a matching ability to plan, co-ordinate and execute, must affect efficiency.

A highly technological society in necessarily an alert society. Hence progress and change in one field almost immediately induces corresponding currents of progress in others. The science of management could not remain aloof from the new ideas, new methods and new products of science and engineering. This process of give-and-take between the science of management and large technological organizations, appears to be very slow in our country. I see a great deal of activity, recently, in the field of management. But I wonder, how far the ideas and sophisticated tools provided by the science of management have become functional in our large organizations!

Thus ultimately the essence of the scientific and technological progress lies in its use towards increasing efficiency. Hence if individuals composing society are incapable of using technological innovations, a great deal of technology will be fallow. I do not want to go deeper into the complex question of the effect of technology on society because it demands much more knowledge and understanding than is suggested by the currently fashionable — and contrasting — popular views about technology. But before I close, I would like to touch one important social component of technological influence, viz. "the strains that technology places on our values and beliefs, finally, are reflected in economic, political and ideological conflict. That is, they raise questions about the proper goals of society and about the proper ways of pursuing those goals. In the end, therefore, the problems that technology poses (and the opportunity it offers) will be resolved (and realized) in the political arena, construing 'political' broadly to include economic and ideological considerations as well as questions of more narrowly political organization and tactics. Technological innovation, therefore, leads ultimately to a need for social and political innovation if its benefits are to be fully realized and its negative effects kept to a minimum."

"Technology can even create a new society composed of individuals who themselves are the products of a technological process. By the use of chemicals and radiation the biologists can induce mutations in genes and chromosomes, and so, by an appropriate handling of genetic materials, create new strains of living organisms. The same genetic laws govern the evolution of human beings. Conceivably someone may have the arrogance ultimately to undertake the breeding of a strain of 'good men'. But who then shall determine the new model of the 'good' man?"

"If, then, we are to preserve the ideal of the cherished individual we will need wise men more than we will need technically skilled men, though obviously we will also need more and more technically skilled men too. As it is, we do not know how to produce them with an environment that will encourage their wisdom to blossom and act. Yet, without wise men, the chances are that the democratic concept and demolratic traditions built around the obligations and rights of the individual will be lost under the crush of the vast needs of the society and the enormous potency of the technologies put into operation in a massive society to meet those needs."

The views expressed in this booklet are not necessarily the view of the Forum of Free Enterprise.

APPENDIX*

The world today is at a cross-roads created by the mighty forces of science and technology—one road showing promise of leading up to peace and plenty and equal opportunities for all peoples; the other—one does not need to elaborate. And much will depend on the wisdom of our deliberations in this Conference to meet the challenge and opportunties of the future.

"For the poor, the economic is the spiritual; to them God can only appear as bread or a bowl of rice." These are words of the Father of my Nation, Mahatma Gandhi. And these words come appropriately to one's mind in a conferance like this gathered to discuss an attack on the hunger, poverty, disease and squalor that affect nearly three-quarters of the world's population.

I am not attempting to define the terms "less developed areas", "underprivileged" and "under-developed". For one thing, many of these developing nations of the world may be poor in material and economic prosperity but are certainly not poor in thought, ideologies, art or culture. I am thinking now in economic terms. We have a few countries where, thanks to the harnessing of science and technology over several decades in various fields of human endeavour and to the combination of several fortuitous circumstances, an economy of affluence has been built up. Elsewhere, we find the rest of mankind struggling in different stages of development.

The wide, and in some cases, tragic gap can easily be gauged when one realizes that one-tenth of the peoples of the world enjoy 60 per cent of the world's income while 57 per cent of them have less than 10 per cent at their disposal. If the present trends are to continue, the gulf between the poor and the rich nations of the world will widen still fur-

* Excerpt from the presidential address to U.N. conference on Application of Science and Technology to Developing Areas of the World.

ther and this at a time when great continents have awoken to freedom and their populations are clamouring for certain minimum standards of life. These enormous disparities among the peoples of the world are a problem not only for the poorer nations, but for the world as a whole. Prosperity, like peace, is indivisible.

The most important feature of our world is perhaps that it is passing through a period of revolutionary change. Today we are in the midst not of one revolution, but of several. All of them are rapidly and visibly changing our ways of life, our sense of values and our attitudes in the political, social and economic fields.

Perhaps the most important of these various revolutions will prove to have been due to the upsurge of science and technology. In the last century, science was essentially the concern of a few private individuals and institutions. It has emerged as the most important implement of national development and economic uplift. And need I mention the widespread and almost ubiquitous influence of technology in all fields of human endeavour, whether public or private. Advances in nuclear science inspire hopes that mankind may have at his command before very long, historically speaking, vast and cheap sources of energy. Radio astronomers and optical astronomers have extended estimates of the age of our galaxy and are striking farther and farther out into the boundaries of the universe. Man has encompassed his world with artificial satellites and has made challenges of reaching the "inviolate" moon. The arts of agriculture and medicine are vastly improved and the same can be said for almost every field of human endeavour. We have much deeper understanding of the biological processes. The sciences dealing with the earth and its environment are in an equally lively state. The air, the earth, the oceans and the sun contain riches which can support increases in population at higher and higher standards of living.

As I am talking, new entrants are being ushered into this world. It has taken man probably half a million years, perhaps longer, to reach his present status. He is now approaching 3,000 million in numbers.

By A.D. 2000, his numbers may well double. Here again he will face a problem of immense dimensions to find food, clothing and shelter for the newcomers, and, besides, all these people must be able to live in a world which preserves standards of human dignity and individual worth.

Today's advanced countries have absorbed the revolutionary discoveries of science and technology. In the less developed areas the deliberate adoption of science and technology as a means of progress has today to contend against various odds—lack of capital, social inhibitions, over-population, inadequate know-how.

What is the strategy of development to be adopted? In my thinking, a broad strategy must allow for three essential elements: (*a*) a survey of physical resources and their exploitation; (*b*) the encouragement of capital formation; and (*c*) the development of human resources. While all three elements are important for growth, I consider human resources as pivotal.

A problem of considerable importance which the leaders and planners face is the relative weight to be given to the development of physical, and of human, resources. There are multi-purpose river valley projects, and plans for roads, factories, airlines which are essential and which cannot be postponed. There are pressing and contending forces within every country for early development of these facilities. But these are, as it were, symbols of a modernizing State. They constitute the external manifestation of the people's urge of action and for a higher standard of living. The planners in these countries have to relate such development in a balanced manner to other needs and priorities. In all this, I would give the highest priority to the development of human resources. Education, the training of scientists, technologists and engineers, technicians and craftsmen, managerial and administrative personnel and a host of professional and semi-professional workers of all kinds are perhaps still more of a "must".

"People must come to accept private enterprise not as a necessary evil, but as an affirmative good."

—Eugene Black

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The Forum of Free Enterprise is a non-political and non-partisan organisation, started in 1956, to educate public opinion in India on economic issues, specially on free enterprise and its close relationship with the democratic way of life. The Forum seeks to stimulate public thinking on vital economic problems of the day through booklets and leaflets, meetings, essay competitions, and other means as befit a democratic society.

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