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EDITORIAL

THE NEED FOR A SCIENCE PLAN

Science in India is growing through a process of unplanned and unregulated expansion. Scientific and industrial research programmes bear no relevance and are not integrated with the industrial and economic needs. Science education has come in for criticism as it produces scientists, technologists and engineers who swell the ranks of the unemployed. It would appear that the most rational of the human activities viz. pursuit of science is left to ad-hocism and vagaries of the fancy of those in control of the affairs of science.

Planning was accepted as the correct methodology for the optimum utilisation and development of the country's mineral, agricultural and manpower resources to build a modern, secular and democratic India. Notwithstanding the plan holiday since the last four years and the general set back that the planning process has received, the people and the Government have not given up their faith in the planned approach to development. There appears to be a mis-conception that industrial and economic development is a self-generating process based upon import of know-how from other countries and setting up of manufacturing units. The politicians, economists, administrators and even some scientists seem to believe that economic growth has no direct relationship with scientific research. Blackett is repeatedly quoted that 'for India and other developing countries economic growth is almost everything.' Exhortations are made by the top scientists that we should have more and more of economic growth without making the least refer-

ence to the factors which generate economic growth, particularly if economic growth is also to fulfil the national objectives of self-reliance. Most of our scientists have little familiarity with the economic process and lack appreciation of the inter-dependence of technology and economy. Most of them prefer to follow in the foot-steps of politicians in giving lectures and slogans on the need to link industrial research and economic growth. The farthest they are able to think is to tell the research scientists that they cannot have an absolute liberty to choose their own problems but should subordinate their individual curiosity to economic needs. While doing so, they have no real problems to suggest but end up in platitudes.

In a developing country where the market is sheltered and scarcity of consumer and capital goods is acute, the conditions are opportune for the unscrupulous entrepreneur to make quick money with minimum investment. While a number of industries have come up in the country in the public, private and small scale sectors, they have neither the technological infrastructure nor the research base for growth based on a self-reliant effort. Merely turning the wheels of industry based on borrowed technology would not amount to building a free and self-reliant country. The industry in its allure for easy money does not feel the need or the compulsion for research. The gulf between the imported technology and local research effort is widening every day. The industrial firms have no control on imported technology and are in no position

to link foreign technology with local development effort. We are fast coming to a situation where we will have industry based on outmoded and borrowed technology: and this also completely divorced from local research effort. Conditions point to a situation of growing technological colonialism.

Whatever may have been the wisdom and necessity for building up the industrial base of the country predominantly on imported technology, it is the duty of the government to introduce suitable compulsions in industrial development policy to enforce a link up of the imported technology with indigenous research effort. Unless this is done, there can be no self-reliant economic growth, nor a solution to problems of frustration of scientists or brain-drain. Given a proper link-up, scientific effort will not only be more fruitful but it will grow manifold in dimension. The scientific infrastructure built up during the last 25 years is even

today inadequate to sustain a self-reliant industrial development. The research inputs needed to sustain industrial development are not mysterious figures but can be worked out for each industry through meetings and discussions between scientists, technologists, industrialists, economists and planners. On the lines of the Electronics Committee report, a plan should be built up for development of each one of the major industries and critical areas requiring research treatment identified. Research inputs and investment by way of laboratories/institutes and technical personnel by way of scientists, technologists, and engineers should be estimated for fulfilment of the technological plan in different industries. In this manner a scientific and technological plan for the country should be formulated as an instrument for a self-reliant industrial and economic growth. Only those who do not believe in planning or would like this country to be tied to the apron-strings of the power groups would deny the need for a Science Plan.

Structural Reorganisation of Indian Science*

N. P. GUPTA

1. The development of Indian Science Institutions has not taken place on the basis of any plan. Even the period of establishment of various agencies would indicate it. The Indian Council of Medical Research (ICMR) earlier known as (Indian Research Fund Association, was set up in 1911. The Indian Council of Agricultural Research (ICAR) came into being in 1929. Both these bodies were essentially grant giving agencies. The Council of Scientific and Industrial Research (CSIR) was established in 1942. The University Grants Commission was set up in 1953. The Atomic Energy Commission came into existence in 1956. The Defence Research and Development Organisation (DRDO) was set up in 1958.

Most of the scientific effort in this country is largely concentrated under the above agencies.

2. The extent and rate of development has not kept pace with each other in different areas of scientific research. The pay scales, service conditions and emoluments are different under various agencies which leads to movement of scientists from one organisation to another often for the sake of better emoluments.

The need for effective co-ordination between different agencies has been felt all round. In its absence, duplication of effort has to be avoided to prevent undue wastage of national resources.

The possibilities of higher science education and research through facilities available

*Presented at the 'Science Week' Celebrations organised by the ASWI on the occasion of its 20th anniversary.

at non-university science institutes are yet to be fully realised.

3. One may note the fact that agricultural research organisations have recently been regrouped and placed under a re-organised, autonomous, expanded Indian Council of Agricultural Research. This step when, fully realised, is bound to have an impact on Indian agricultural research and through it on agricultural production.

The Indian Council of Medical Research still continues to be largely a grant giving body on a very limited scale. It has the following institutions under its direct control.

- (i) Virus Research Centre, Poona
- (ii) Cholera Research Centre, Calcutta
- (iii) Tuberculosis Chemotherapy Centre, Madras
- (iv) Occupational Health Research Institute, Ahmedabad
- (v) Nutritional Research Laboratory, Hyderabad.

There are 'smaller units' working on Reproductive Physiology (Bombay), Contraceptives (Bombay) and Indian Registry of pathology, New Delhi.

The Ministry of Health continues to administer several large Research Institutes directly :

- (i) National Institute of Communicable Diseases, Delhi
- (ii) Central Research Institute, Kasauli
- (iii) National Tuberculosis Institute, Bangalore

- (iv) BCG Laboratory, Madras
- (v) All India Institute of Hygiene and public Health, Calcutta
- (vi) Central Family Planning Research Institute, New Delhi
- (vii) Demographic Research Institute, Bombay
- (viii) Chittaranjan National Cancer Research Centre, Calcutta
- (ix) Central Food Laboratory, Calcutta
- (x) Central Drug Laboratory, Calcutta
- (xi) Institutes dealing with Leprosy research, mental health etc.

The CSIR has many medical and biomedical research institutes :

- (i) Central Public Health Engineering Research Institute, Nagpur
- (ii) Industrial Toxicology Research Centre, Lucknow
- (iii) Central Food Technological Research Institute, Mysore
- (iv) Central Drug Research Institute, Lucknow
- (v) Central Indian Medicinal Plants Organisation, Lucknow
- (vi) Regional Research Laboratory, Jammu
- (vii) Indian Institute of Experimental Medicine, Calcutta.

The DRDO has its Institute of High Altitude Physiology and Institute of Radiation Medicine, Delhi and Defence Food Research Laboratory, Mysore.

The Atomic Energy Commission controls Indian Cancer Research Centre and its associated Tata Memorial Hospital, Bombay.

Other institutions of national importance like the Haffkine Institute, Bombay and Pas-

teur Institute, Coonoor, could be placed under ICMR.

The medical, biomedical and related research institutions lie scattered under various agencies. Most of these institutions should be placed under an expanded, reorganised and autonomous Indian Council of Medical Research. New regional medical research institutions to cover special areas may be necessary. Recent reports indicate that there has been a set back in disease control and eradication programmes. Malaria has reappeared in most places. Small pox eradication programme has to be redone all over again. Tuberculosis continues undiminished. An intensive programme of medical research to provide answers to problems of control of epidemic diseases is the need of the hour.

The third Reveiwing Committee of the CSIR had suggested that the CSIR being one of the premier research organisations should take initiative to move into new areas. But at the same time it should always examine the possibilities of transferring some of its established laboratories to other agencies.

Suggestions have been mooted in this country for reorganising the CSIR. According to some the Council could be divided into two or three autonomous bodies dealing with Industrial Research, Scientific Research, each having groups of national laboratories under their jurisdiction.

One of the study teams of the Administrative Reforms Commission has suggested that CSIR should transfer its institutions as follows :

CSIR Institution	Number	Transfer to
Medical & Biomedical	4	ICMR
Argriculture	1	ICAR
Oceanography and Geophysical Research	2	Proposed Board of Geosciences.

It further suggests that the following Institutes now working under various Ministries be transferred to CSIR :

Ministry

Irrigation & Power	—Central Hydraulic Research Laboratory Poona
-do-	—Central Soil Mecha- nics Research Labo- ratory
-do-	—Power Research Insti- tute, Bangalore
Works & Housing	—National Buildings Organisation, New Delhi
Industrial Develop- ment & Company Affairs	—Central Machine Tools Research Insti- tute, Bangalore

This study group has also suggested the establishment of a Board of Geosciences, coordinating of all Survey Organisations, meteorology, oceanography, geology, mineral surveys and water resources.

The remaining and the new CSIR laboratories could then be grouped under the following disciplines :

- (i) Civil Engineering
- (ii) Mechanical & aeronautical engineering
- (iii) Electrical and Electronics Engineering
- (iv) Development of natural resources
- (v) Chemistry
- (vi) Physics
- (vii) Cooperative Reserch Laboratories.

There are yet other suggestions for CSIR. These relate to transfer of some of the CSIR laboratories to user industries. But so far these industries have contributed little to development of these laboratories.

5. The need for a coordinating set up has been felt for some time. The Association of Scientific Workers of India has proposed the establishment of a National Science Council to integrate, plan and evaluate, the work done under all the major six or seven agencies concerned with scientific research and higher education.

The National Science Council should be a statutory body working directly under the Prime Minister or the Cabinet. The National Science Council will take over most of the functions of the science division of the Planning Commission.

It has been suggested that the National Science Council should recognise all professional scientific societies and assist them by providing funds etc. for their scientific activity. The scientific societies which are organised on a basis of voluntary membership should be utilised to act as Consultants to the National Science Council in their respective spheres. Secondly the National Science Council should also utilise the Staff Associations and scientists and scientific workers trade unions for discussions and opinions. The triple channel communication system is essential for Indian social set up with its parliamentary democracy. The single channel administrative system is ideally suited to rule over a people. The scientific workers and scientists will get a full chance of participating in the entire work of the National Science Council if all the three channels are utilised for communication both upwards and downwards for thoughts, comments, suggestions, proposals and their implementation. Absence of proper communication deprives those in authority of the aspirations and viewpoints of the younger scientists. On the other hand such an absence produces tensions, frustration and inhibits the creation of free atmosphere so essential for any creative work.

It is suggested that the National Science

Council should have representatives of the science establishments and concerned ministries. But in addition they should have active representations from scientific societies and staff associations and trade unions of scientific workers. A similar set up should be tried at all levels. The Executive Boards of establishments of individual research laboratories should also have representatives of the three groups to convert them into active and vigorous organisations in which the scientists share responsibility.

6. The Scientific Advisory Committee to the Cabinet should be appointed by the Prime Minister for advising the Prime Minister on any matter especially concerning science and technology. The appointees should enjoy the confidence of the Prime Minister. Their term of office should also be co-terminus with that of the Prime Minister or earlier if the Prime Minister so desires. No attempt should be made to make SACC to acquire a permanent status. Recently SACC has been under criticism for not functioning effectively. Suggestions have been made to 'activate' SACC by providing a secretariat and giving it powers to convert it into a Super-National Science Council. Suggestions include SACC functioning through a number of ad hoc panels. But then SACC and the National Science Council would be covering the same area. The work of the National Science Council would be subject to public scrutiny. The SACC should only be utilised for providing advice to the Prime Minister and the Cabinet.

7. The question of single Academy of Sciences has been mooted. The Prime Minister's Science Round Table suggested that the Government should take initiative in merging the four Academies which are now functioning, each claiming a national status. It is

debatable if a merger alone could solve the problem. Other groups of scientists have also moved into the field of 'Academies' and new professional societies are being formed and named as Academies. Perhaps the stage is not yet ready for such an action. In the first instance the setting up of a National Science Council with numerous professional societies acting as consultants may be tried. The academies may be left at this stage to evolve themselves free from formation of partisan group.

8. The formation of a Ministry of Science and Technology has been suggested. The Prime Minister's Science Round Table recommended that the new Ministry should provide leadership and guidance to all other ministries with regard to identification of areas for scientific research and development; (ii) Coordinate scientific research in different fields, survey national resources and measures for effective utilisation of results of research; and (iii) Advise the government on effective implementation of Science Policy.

The area of activity of this Ministry has to be carefully planned. Sometime it is thought that Ministry of Science and Technology would be nothing more than the Scientific Research wing of the Ministry of Education. Thus the Ministry of Science and Technology would in effect be the Ministry incharge of the existing CSIR.

The precise relationship between the Ministry of Science and Technology, the proposed National Science Council, the SACC and the Planning Commission should be defined before setting up such a Ministry. In view of the importance of science and technology for country's development this portfolio should be held by the Prime Minister.

PROTESTS ABOUT CZECHOSLOVAKIA

In the past few days there has been news from several quarters of protests against recent event in Czechoslovakia. The first of the documents which follows was signed by a group of scientists meeting at the XIVth International Conference on High-Energy Physics in Vienna on September 5, 1968. The second document is a letter from the president of the Czechoslovakia Academy of Sciences to the President of the Academy of Sciences of the USSR.

High energy Physicists :

Vienna, September 5, 1968 :

To the scientific academies :

The recent dramatic world event gives rise to a deep feeling of alarm within the international community of scientists. We witness today, as we have witnessed before, that overwhelming military might has been used to impose a political order on the populations of small countries against the will of their peoples.

The community of scientists has always striven for a better understanding between different nations and ideologies. The common interest in the discovery of fundamental laws of nature constitutes a strong bond between the scientists of the entire world, a bond which has brought people together across political barriers and which often has initiated a better understanding and collaboration, even in non-scientific fields.

The recent abuses of power constitute an affront to human values and human dignity. In particular these abuses threaten to break the bonds which have kept scientists together. We urge all scientific bodies to do their utmost to counteract this trend and to use their influence towards a resolution of conflicts by mutual help and understanding.

A. PAIS, New York (United States); E.L. GOLDWASSER, Chicago (United States); P.H. MEYER, Orsay (France); J.M. CASSELS, Liverpool (United Kingdom); M. NIKOLIC, Belgrade (Yugoslavia); V.F. WEISSKOPF, Cambridge (United States); N. ZOVKO, Zagreb (Yugoslavia); Y. GOLDSCHMIDT-CLERMONT, Brussels (Belgium); G. KALLEN, Lund (Sweden); J. PRENTKI, Paris (France); P.T. MATHEWS, London (United Kingdom); E. AMALDI, Rome (Italy); P. LEHMANN, Orsay (France); R. WILSON, Chicago (United States); Y. NE'EMAN, Tel-Aviv (Israel); T.G. PICKAVANCE, Chilton (United Kingdom); W. JENTSCHEKE, Hamburg (Federal Republic of Germany); S. WOUTHUYSEN, Amsterdam (The Netherlands); F. GURSEY, Ankara (Turkey); M.L. GOLDBERGER, Princeton (United States); W. PAUL, Bonn (Federal Republic of Germany); W. THIRRING, Vienna (Austria); G. SALVINI, Rome (Italy); D.H. PERKINS, Oxford (United Kingdom); A. LAGARRIGUE, Paris (France); A. SALAM, London (United Kingdom); C. N. YANG, Stony Brook (United States); G. F. CHEW, Berkeley (United States); G. EKSPONG, Stockholm (Sweden); M. G. K. MENON, Bombay (India).

Sorm to Keldysh.

Dear Comrade Keldysh.

Our people have received the occupation

with shock and indignation and reject this violent act, which perhaps has no historical precedent. Our people do not grasp how it is possible that a sovereign independent socialist state becomes without warning, and contrary to the will of all its people, the subject of military occupation by those whom until then it considers its true friends.

The brother feelings which the Czech and Slovak people have always maintained for the peoples of the Soviet Union and which sprung from centuries of tradition have caused sharp feelings of injustice and hatred which may persist for decades. With a deep feeling of sadness we see Soviet soldiers, young boys who do not understand what is going on, who do not understand the expressions of indifference and repulsion with which they are received by all citizens of our country, acquire a sense of disgrace which will influence relations between our nations for years to come.

I should like you, Comrade President Keldysh, to realize that the reports about the state of affairs in our country and about the attitudes of both our nations which are being furnished to the Soviet public are quite erroneous and at variance with truth. The military occupation has cemented together all our people without regard for political persuasions.

One expression of this unity is the fact that the plenum of the national assembly, which was legally elected in 1964, has been in session since the beginning of the occupation in unbelievably difficult condition. In spite of these difficult conditions, there are present at the meeting two thirds of depu-

ties who have unanimously condemned the occupation as violence and demand an immediate withdrawal of the occupational units and release of interned officers of our country in whom our people have full confidence.

The occupation has gravely lamed our science. The building of the Czechoslovak Academy of Sciences, in which you were a guest of honour, has been groundlessly occupied by Soviet personnel. Members of the academy and staff present were expelled out of it under points of guns.

Dear Comrade President Keldysh, with full responsibility as a public figure as scientist, I solemnly declare that our country has not been threatened by counter-revolution and that we have always had sufficient power to prevent any excesses which could occur in our country. In the name of my country for whose advancement I have always striven and in the name of a foreign member of the Soviet Academy of Sciences and of other academies of countries belonging to the Warsaw Pact, I urge you to use your influence so that our country will be free from occupation and that it can independently build socialism in our country in the interests of socialist ideas in the world.

ACADEMICIAN F. SORM

President of the Czechoslovak
Academy of Sciences,

Foreign Member of the Academies
in Poland, Hungary, Bulgaria,
German Democratic Republic
and Soviet Union.

August 25, 1968.

TECHNOLOGICAL FORECASTING

DR. ALAN MACKAY*

I must first explain, what will be obvious by the end, that in contra-distinction to your other speakers, I have only an ivory tower knowledge of the business world. However, the central heating in this ivory tower is beginning to fail and this encourages the inhabitants to make forays outside. If you want to know in detail about the techniques of technological forecasting, you should really consult a practitioner—I am only an observer of the scene who has been concerned with trying to unravel some of the complex web of relationships connecting science, technology and society.

Technological forecasting was admirably defined by Shakespeare in *Macbeth*. With some scepticism, Banquo asked the three weird sisters: "If you can look into the seeds of time, and say which grain will grow and which will not, speak then to me...." I presume that you want to hear about technological forecasting because, if it is a useful technique which delivers results, then you cannot afford not to know about it. Like the New morality, other people have it, so why should not we? But are we missing something or have we had it all along?

For example, here we have a fine industry—plantations growing indigo to produce indigo dye for clothing. Custom dictates that indigo is the traditional colour for clothes. Everything seems set for a quiet lifetime producing indigo as our forefathers have done for generations. We have a good product and a guaranteed market but then some chemist makes indigo synthetically and in a short time synthetic indigo can be made in quantity at a cost below that of the natural product.

Moreover it can be made in a cold country, unsuitable for growing indigo plants, but having a chemical industry. This is the kind of situation of which we would like advance warning so that we can make our dispositions. But to be on the lookout for such a situation is hardly a new idea.

Technological forecasting is essentially the estimation of what devices, techniques, materials, institutions, etc. are likely to move from the world of pure science into the world of practical politics, business, production and consumption. Attempts are made to attach numbers, that is, dates, probabilities, quantities to the forecasts. However, forecasts are also made in response to the question; we are going to try to do so and so, what are the chances of our attempts being successful?

Technological forecasting, in this sense of rational planning, has been known for a long time. P. C. Mahalanobis' studies of the data on which to base the Indian 5-year plans; the TVA Scheme in the United States and some of the planning in the USSR are examples of normative forecasting.

To anticipate my conclusion; you may have come across the New Mathematics which is now taught in schools and been surprised to find that it was just what we used to know in the old days as "thinking what you are doing." The new technological forecasting is basically just that, but with the recognition that we now have some powerful tools with which to help out our rather limited minds. We try to work out what is likely to happen in a specified situation. Technological forecasting is just the best

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kind of constructive thought, where ideas are tested by measurement and experiment, and where measurement and experiment lead to new ideas. This view has been well expressed: "Where do correct ideas come from? Do they drop from the skies? No. They come from social practice, and from it alone; they come from the three kinds of social practice, from the struggle for production, from the class struggle and from scientific experiment." I do not offer a prize for guessing who said that, but in fact it was the Chairman of the largest corporation in the world—Chairman Mao and is reproduced in his 'Little Red Book.'

We should first clear away one misconception, which is that as to the role of the computer. The computer has really nothing to do with technological forecasting its function is to carry out large and tedious calculations with great speed, and no name is worse for it than the "electronic brain". One of the principal roles of the computer is simply to force the clarification of human thought. If you can explain to a computer how to do your problem, then you really understand the problem yourself. You may even understand the problem so well that the computation then becomes unnecessary—in which case a notional cardboard computer is as good as a real one and obviously much cheaper. As a character-forming discipline learning Latin is a soft option compared with programming a computer. I have had a bad Latin prose sent back with the note "do again", but it never happened ten times in a row as is some times the case with a computer programme. Discussion of the computer is thus rather a diversion; the computer can indeed do marvellous things, but only if you yourself completely understand what you are doing, and that is the real difficulty. In forecasting, understanding the problem is the difficulty and handling the data is only incidental. However, if you really have to compute in an

exploratory way, then I would recommend that you first try using an on-line computer, preferably time-sharing the services of a large machine, in the dialogue mode. You have a personal teleprinter link and converse directly with the computer. It is really astonishing how much more work one can get through when mistakes are instantly pointed out and corrected, than when you have to wait for the return of the output the next day. In such a mode the complementary capabilities of the computer and the brain are much better matched. There are also various kinds of graphic input and output which are even more suitable for allowing the computer to aid in creative thinking, but these facilities are still rather rare.

The main requisite for technological forecasting is brains, backed by an organisation for ascertaining the facts in specified fields. It is not just a mechanical technique.

As early as 1902, H. G. Wells wrote:

"I must confess that I believe quite firmly that an inductive knowledge of a great number of things in the future is becoming a human possibility. So far nothing has been attempted, so far no first-class mind has ever focussed itself upon these issues. But suppose the laws of social and political development, for example, were given as many brains, were given as much attention, criticism and discussion as we have given the laws of chemical composition during the last fifty years—what might we not expect?" (Nature, 1902).

I suspect that H. G. Wells himself was quite clear about the difference between technological forecasting and science fiction, social speculation or day-dreaming. Wells persisted with the delineation of the social consequences of some invention, in spite of the fact that calculation would show it to be in contravention to well-established facts. Jules Verne was very scornful of this. Indeed

I remember that when I was at school, I was asked to produce an essay of literary criticism of the works of Dean Swift and responded with an analysis of why scale effects made the operation of Lilliput impossible. However, Wells is, I think, an under-rated figure and we are still in his debt for making us think about the social consequences of science and technology.

Richard Feynman, a Nobel-prize winner in physics, has defined the restrictions on the scientific imagination :

"The whole question of imagination in science is often misunderstood by people in other disciplines. They try to test our imagination in the following way. They say, "Here is a picture of some people in a situation. What do you imagine will happen next?" When we say, "I can't imagine", they may think we have a weak imagination. They overlook the fact that whatever we are *allowed* to imagine in science must be *consistent with everything else we know* ; that the electric fields and the waves we talk about are not just some happy thoughts which we are free to make as we wish, but ideas which must be consistent with all the laws of physics we know. We can't allow ourselves to seriously imagine things which are obviously in contradiction to the known laws of nature. And so our kind of imagination is quite a difficult game. One has to have the imagination to think of something that has never been seen before, never been heard of before. At the same time the thoughts are restricted in a straitjacket, so to speak, limited by the conditions that come from our knowledge of the way nature really is. The problem of creating something which is new, but which is consistent with everything which has been seen before, is one of extreme difficulty.

(‘The Feynman Lectures on Physics’, Vol. 2, 20-11, 1963)

This corresponds to the difference between speculation and technological forecasting.

It will not have escaped you that there is a serious philosophical difficulty involved in a forecast. The existence of a forecast is itself a fact of the present and may ‘change’ the future. Forecasts may be self-fulfilling or self-negating. The value of a forecast of the future is that one can affect the future and make it happen or not. You can forecast the winner of the Derby and deposit a sealed letter in a bank, but if you act upon your forecast and bet a lot of money on the outcome the odds may change or the horse may be pulled. The best attitude to take is not to regard technological forecasting as research into the future but more as an analysis of the possibilities latent in the present ; which seeds may grow and which may not. What we want to know is : where can we get to from here ?

What must we do to reach one goal rather than another ?

Where can we not get to from here ?

What are the limits of what can happen ?

What are the probabilities of a particular outcome ?

There are two sorts of forecasting : *Defensive*, so that we can prepare for it and *aggressive*, what Dennis Gabor has termed *inventing the future*. The latter, normative forecasting, implies the use of technology to reach certain social goals. Discussion of these goals is outside our present brief and involves the whole value system of our society. In the USA 16 National goals have been formulated (the 16th being to put a man, I beg your pardon, an American on the Moon by 1970). The USSR has similar goals set out in the last party programme.

We have talked all the time about fore-

casting technology. Why not forecasting science and scientific discoveries? It is important to understand that science and technology are different kinds of thing and grow by different processes. Technology certainly implies choice, but it is by no means clear that there is much choice in the development of science. I should refer you to the studies of Derek Price on such questions, but must make some brief comments. At present I may change my mind, later I believe that science has strong internal logic and structure like a tangled ball of string, and that it can only be unwrapped in a definite order. Some parts must be unravelled before others. If we try to concentrate on a particular piece we may never get it out because the thread we are following goes off into a completely unexplored part of the bundle which we have decided not to look at.

Basically we are trying to deal with four interlocking systems, *science*, which produces information cumulatively, new information being built upon old; *technology*, which produces artifacts—things, which are from time to time destroyed and replaced by new improved things (engineers never write); *economics*, which is a very complex subject using money as the main measure; and *society* which is composed of people who are replaced and re-educated every generation. In Price's metaphor, science is not just the fruit of the tree of knowledge, it is the tree itself (the whole system in fact). We can extend this by regarding technology as an animal, symbiotically related to the tree, which is periodically replaced as it wears out. The bits of the tree made by Euclid are still in use, although they do not grow very much nowadays, but Archimedes' machines have been replaced many times. Further, both tree and animal live in a climate which can be attributed to society. Some societies are good for science and technology and some are not.

The approach I have described is one of model making, system analysis and operational research and is one of the main techniques used in technological forecasting. We look on science, technology and society as a system, like a body, and try to sort out by observation and experiment how it all works, so that we can forecast what it is likely to do in various circumstances. I regard this approach as genuine science, and progress with it has been significant, if slow. I may say that I am associated with an organisation, the Science of Science Foundation, which seeks to promote the study of science, technology and society in a scientific way. We publish a newsletter which may be of some interest and hold conferences and seminars. Part of the trouble is that there is continual pressure from people like yourselves who want results and demand the production of laws and regularities before the formulation of such things is justified. The scientific standards of the subject thus tend to be compromised.

Let us look briefly at some of the techniques used in technological forecasting, besides the one of systems analysis just mentioned.

A major method is called the DELPHI TECHNIQUE after the well-known oracle. This is really just a fancy way of asking an expert. It compounds simple guesses in a very sophisticated way. If you have 50 experts you arrange that their estimates are fed round and round so that each expert revises his opinion in the light of the opinions of the others until some consensus, to which probability limits can be attached, is obtained. The problem, of course, is how to select the experts.

Sir Francis Galton, who was almost pathologically addicted to counting things, once visited a fair and noted down the 800 guesses which were made by Devon farmers as the

weight of a pig offered as a prize. He found that the true weight was within 1% of the mean of the guesses. The farmers clearly knew about pigs. On the other hand one could devise an experiment to measure the distance to alpha-Centauri, the nearest star, by asking 10,000 people—this might be expected to give an answer correct to 1%—but such a result would be obvious nonsense. It is claimed, however, as a minimum, that if you have to consult experts, there are better and worse ways of doing it.

Other techniques are concerned mainly with stimulating thought and with ensuring that nothing obvious is overlooked. For example, MORPHOLOGICAL ANALYSIS is really rather similar to the kind of children's book which has its pages divided into three separate parts with heads on the top sections, bodies on the middle section and legs on the bottom section. If you want to be sure that you have thought of all the possible kinds of aeroplanes you put the engines on the top, the bodies on the middle and the wings on the bottom section and examine all the resulting combinations systematically.

RELEVANCE TREES or MATRICES are systems for ensuring that you have considered all possible influences specifically before discarding them.

A *decision tree* is a systematic way of exploring the ramifications resulting from the existence of a variety of choices. In one's career there have been various decisions which appear like branch points. If other choices had been made, how would one's life have been different? Suppose all the consequences of all the various decisions were explored, then a kind of tree diagram would be obtained representing the potentialities of a situation. This is like taking a couple and tracing all their descendants.

A *relevance tree* branches in the opposite

direction, that is towards the past. If a certain outcome is desired, various immediately preceding contingencies are identified. Each of these has pre-requisites and so on. This is like taking a person living now and asking who all his ancestors were.

SCENARIO-WRITING is an important activity, especially in normative forecasting. It is just the writing up of a story of what might happen in the future, incorporating local colour to give verisimilitude. The technique is important for decision-making, because it spells out possible futures. It is like taking a string of possible moves in chess, too long for exhaustive enumeration, but not excluded by the rules, to show the kind of things that might happen. The obviously unlikely is excluded, as is the impossible. Possible scenarios can be re-cycled round a group of experts who will in turn revise them according to their specialised knowledge. Scenarios help people unclear as to their long-term social aims to formulate them more clearly. For example, the reaction to a scenario might be, "No, I would not like that to happen" in which case analysis might show how the unpleasant consequences developed and at what stage in the decision tree something might be done to avert them.

The use of scenarios is one way of eliciting ideas from experts when direct questioning might leave them dumb. Erich Jansch's opus "Technological forecasting in perspective", published in 1967 by OECD, gives considerable information on such techniques, and references to very many more, all presented with a teutonic seriousness.

Technological forecasting is now practised on a very large scale. It is often conducted by a relatively new kind of institution, somewhat unhappily called a "think-tank, which is in fact a generalised consulting agency. Examples of the biggest are Rand, Stanford,

the Hudson Institute and Arthur D. Little-all, you will note, in the United States. One of the biggest customers is NASA, the US National Astronautics and Space Administration. NASA is the best example because its activities are right up against the borders of the future, so that, in planning some space expedition for 5 years ahead, not only are the most modern materials used, but the present trends in the development of materials are extrapolated 5 years into the future, and the design is made on the basis of the extrapolations, hoping that the efforts of those developing the materials come up to expectations.

The think-tank I consider to be a useful idea, since it permits people experienced in generalised problem-solving to be called in to deal with a particular question. In doing this they can bring in a wider range of techniques and information than the questioner could muster on his own.

Again, there are built in dangers. Most of the main think-tanks are in the United States and their views tend to be unduly Americo-centric. Even apart from this symposium I would advise you to read the book "The year 2000" by Hermann Kahn and Anthony Wiener of the Hudson Institute. You will see two things, first, as is only too clear, our future depends on the military balance of power. Any forecast of the future demand for soap-powder might be vitiated if someone mis-calculates and presses the wrong button in Omaha or Moscow. Indeed the major function of the think-tank business is military and is concerned with decisions such as whether to construct an ABM system or not.

Secondly, Kahn and Wiener in particular have apparently not seen a backward country and apply the pre-conceptions of their own, excessively mobile society, too freely. Abdus

Salam was asked what Pakistan would look like in the year 2000 and replied that it would probably be substantially indistinguishable from Pakistan today.

In short, inasmuch as technological forecasting is genuine science with proper standards, it should stand, but if it is not genuine science, then it may prove to be just a fashion and fade out. If a group of people concur in their opinions it may be because they share the same prejudices and have considered the same unrepresentative bits of evidence, rather than because they are objectively correct. Just because everyone believes something it does not follow that it is a fact. However, a generally held misconception is itself a fact of the present, influencing the future as much as a well-based belief.

Even Herbert Marcuse, the prophet of student revolt, in "One dimensional man" his analysis of industrial society, says that he vacillates between the possibilities (a) that industrial society will contain qualitative change or (b) that internal pressure will explode it or (c) that there will be some catastrophe. Nobody can tell at present.

If global predictions are unreliable and predictions of smaller scale effects depend on them, how much more unreliable are the latter ?

Clearly we can only hope, at best, for limited and short range success in forecasting. Jantsch says that small industry is neglected. This may be for substantial reasons. If the military and industrial complex of the USA experiences unpredictable fluctuations it may be that these become so acute when looked at on a small scale that prediction is unprofitable.

It is clear that to try to analyse to any depth involves ones complete world outlook.

The Russians, for example, talk about Marxist-Leninist technological forecasting. However, certain limited problems can be solved fairly satisfactorily. For example, one SSF Seminar was addressed by a representative of TEMPO who described an analysis of the developments likely in the oil-tanker world. They were able to recommend to their clients fairly definitely what directions to follow as regards tanker size, propulsion, speed, operation etc.

The study gave certain estimates which could be checked. For example computer simulation showed that the big Greek tankers were run within 1/2 a knot of their optimum speeds and that the Japanese 300,000 ton tankers were built for maximum profit and not just for the sake of being the biggest. This kind of study, however, could be better classed as operational research, which is a more respectable science than forecasting.

What can we say about products in the consumer goods range, in view of the underlying uncertainty? Since there are trends and fashions, is it not sufficient to identify the trend setters and to follow some distance behind leaving the leaders to make the big mistakes and to do the expensive development work?

There is a lot to be said for such a point of view but it still leaves you with the necessity of doing the research to identify the trends and its leaders-

A young man received his calling-up paper and wrote back to the War Office: "Dear Sir, I have read your literature carefully but have decided not to participate in your scheme".

- like that, contracting out of research just will not work. Circumstances will catch up with you.

My own present views on consumer

goods, which may be long ago discredited, are that we are only likely to do much forecasting by going rather deeply into sociological research.

I see considerable truth in the advertising slogan "We do not sell face-cream; we sell beauty". After all, who would buy a car if they could buy transport. (Actually, recalling the sight of people tenderly washing their cars on Sunday mornings, I have doubts as to the truth of that aphorism).

Anyway, I think what people are really willing to pay for, are not goods, apart from staple foods, but *situations, sensations and services*. They pay for football pools, betting shops and holidays, and when they buy commodities the most successful are those with sociological consequences built in-like opium, motor cars, transistor radios and Xerox machines.

I think that needs to be directed away from the piece of hardware to the situation. Situations can be sold directly. In the UK we have only a limited range of institutions, such as the pub, discoteque, strip club, Cafe Royale, etc. In Japan they have a wider range including *mood saloons*, where you have a cafe with music, decor and food to suit your feelings. In Germany there are cowboy clubs for grown ups for grown up horseplay out of doors. In the USA, when a man is really rich, he can afford to hunt for his food and cook it out of doors over an open fire.

In considering the adage 'build a better mousetrap than your neighbour and the world will make a beaten path to your door' is wrong in that it stresses the material object itself. This might not apply in traditional Hindu society where people are supposed not to catch mice. One should look at the object more as the locus of a large number of social connections. Individual water

taps may be better than one tap at the end of the road if you want to wash up, but if you want to meet people whom you might marry, then the old system is better. We now have to introduce a computer dating service along with the piped water.

In conclusion, then, what should we do about technological forecasting?

The easy answer is, look at Jantsch's report, and then consider whether:

- (1) To do it yourself, on a large or small scale,
- (2) To call in a consulting organisation specialising in the field,
- (3) To use published service and forecasts,
- (4) To subscribe to a report service shared with others, or, of course, to do nothing.

As a test, suppose that one of these organisations produces the forecast that by 1970 your produce A will be superseded by a new product B, the real problem is, how you are going to evaluate the report. What evidence would you require before you would believe it? Can you spend time on evaluating the report? Does the executive side know enough not to be deceived by pretentious talk about techniques of forecasting? If not, then it is clearly a waste of money buying such forecasting services. The point is that even if you have a forecast produced outside, and even if it is tailor-made for your own organisation, it has to be evaluated and this requires efforts so that in almost every case it would be worthwhile to set up a small group to deal with long-range thinking, not only as a look-out for the approach of technological change, but as a look-out to follow the success or otherwise of techniques of forecasting. This clearly needs people inside the

*("Science and the modern world", Penguin, p. 118).

company and also people outside with good connections.

I think that in a medium sized company you should not worry too much about technological forecasting but should concentrate on having an intelligence department who can stand back a bit from immediate problems, be in touch with many aspects of the outside world and who can filter in new ideas to the right places. They should, of course, be in close touch with the planning department, and with any research department, either operational or physical.

I do not think that there is any alternative to this step. You find people whose job is to think scientifically and who are not so close to today's problems that their horizons are filled with them.

Alfred North Whitehead, who died in 1947, but who continues to rise in my estimation, wrote in 1926:

"The possibilities of modern technology were first in practice realised in England by the energy of a prosperous middle class. Accordingly, the industrial revolution started there. But the Germans explicitly realised the methods by which the deeper veins in the mine of science could be reached. In their technological schools and universities progress did not have to wait for the occasional genius or the occasional lucky thought. Their feats of scholarship during the nineteenth century were the admiration of the world. This discipline of knowledge applies beyond technology to pure science, and beyond science to general scholarship. It represents the change from amateurs to professionals.*

Technological forecasting essentially marks the change from amateur to professional thinkers and analysts in business, and is part of the general advance of science into all kinds of fields, including now that of

management. I leave you with the final question. Should you look for scientists outside and bring them into business or produce scientists of those already in business?

This is just like the question which some archaeologists had to face in examining a sunken ship. Should they take archaeologists and teach them to swim, or take swimmers and teach them archaeology? Their clear confusion was that it was better to make the archaeologists swim; but in your case, who is the archaeologist and who the swimmer?

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 D. J. de S. Price, "Little science, big science", Columbia U. P. (1963).
 Nigel Calder, "The environment game." "SSF Newsletter" (Bimonthly £2:2:0. p. a.)
 Science of Science Foundation, c/o Ciba Foundation, 41, Portland Place, London, W. I.

(Contd. from p. 18)

icipation and guidance given by Dr. W. H. Cleghorn, a British Scientist in the course is noteworthy.

10. A memorandum has been submitted to the Sircar Committee on behalf of the branch.

Dehradun Branch

Seminar on "Import Substitution in Petroleum Products, processes and other know-how"

The ASWI of Indian Institute of Petrole-

um, Dehra Dun is arranging the above Seminar during April/May 1969. Papers are invited for the Seminar. Those interested may contact Mr. T. C. Joshi, Secretary, ASWI (IIP), Application Division, Indian Institute of Petroleum, P.O. IIP,, Mokhampur, Dehra Dun (UP). Necessary facilities for stay will be provided.

ASWI Activities

Karaikudi Branch

1. The following is the list of new office bearers elected for the year 1969.

President :

Dr. P. B. Mathur

Vice President :

Mr. T. R. Venkatasubramanian

Mr. V. N. Ramachandra Sarma

Secretary :

Mr. V. Lakshminarasimhan

Joint-Secretary :

Mr. P. Subbiah (SSA)

Treasurer :

Mr. N. Karuppannan

Executive Committee Members :

Miss A. R. Yamuna

Mr. S. Chakrapani

Mr. G. Jothinathan

Mr. N. Muniyandi

Mr. C. Rajagopal

Mr. P. N. Narayanan Namboodiri

Mr. R. Sabapathy

Mr. K. V. Rangaswamy

Mr. S. Balagopalan

Mr. N. Radhakrishnan

Mr. R. Gangadharan

Mr. N. Krithivasan

Central Council Members :

Mr. C. Chakravarthy

Mr. S. Palahichamy

Highlights of Karaikudi Branch activities in 1968.

1. The facility of taking out Scientific Journals for overnight study and reference, from the library, has been extended to scientific assistants also. The practice of counter-signature by Scientists is given up.

2. Advertisement circulars were printed by the Branch to augment the resources of Vijnan Karmee and we secured one advertisement also.

3. A number of meetings were arranged. Many participated including Prof. N. R. Dhar, Dr. K.R. Bhattacharya, Shri S. Kasturi, Dr. Cleghorn, S. Mayyappan, Dr. K. Raghavan and Dr. H. V. K. Udupa.

4. A separate hostel quarters has been provided for Lady staff members.

5. The apprenticeship period of six graduate apprentices was extended by 6 months when they were about to be terminated. This is due to the personal representation of the Branch representatives to Director-General, CSIR. All have now been absorbed as SLAs.

6. The town bus transport facility has improved due to the memorandum submitted by the Branch to the local MLA. Some mofussil buses are now diverted through Institute main road, a proposal suggested by the Branch.

7. The twentieth anniversary celebration of ASWI was marked with a lively cultural programme. Two dramas were enacted. Thus ASWI undertook a cultural programme for the first time for the benefit of the CECRI Society.

8. A nucleus has been created for a library of ASWI with the purchase of books on Fundamental Rules & Supplementary Rules Conduct Rules.

9. The German language course was conducted and eight members have come out successful in the examination. The parti-

(Contd. on p. 17)

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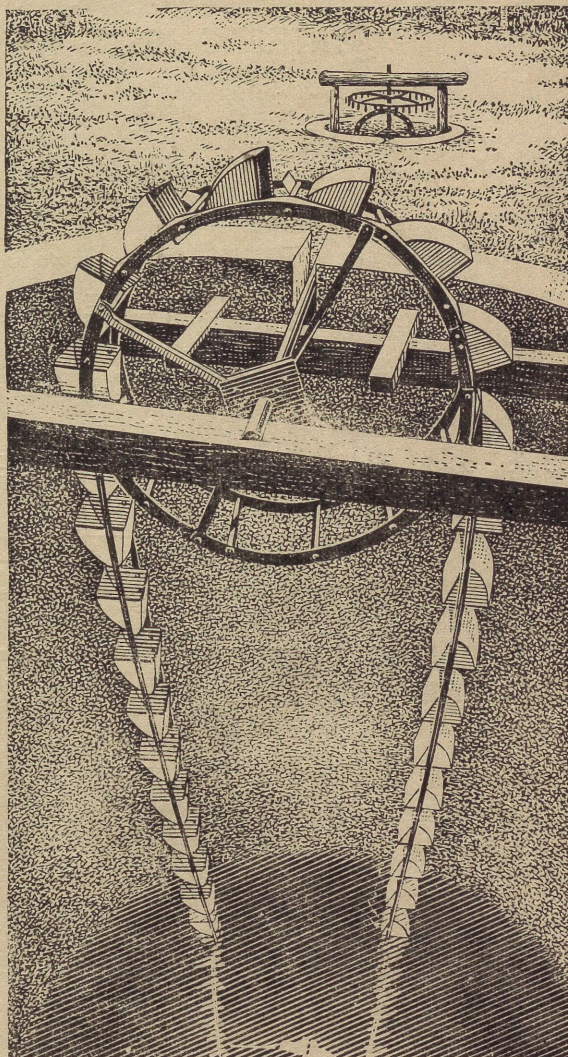
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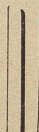
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TAKING SOME GOLD OUT OF THE GOLDEN JUBILEE OF CSIR

The last session (November 1991 issue of BASWI) of the Helmerian on value-alternatives for the development-oriented science and technology focussed on the strategies that would make international science and technology appropriate for developing countries. Quoting the views of *Thomas H Tietenberg*, former president of the Association of Environmental and Resource Economics, it was observed that the developing countries are caught in a downward spiral. "At the local level they have limited access to land or productive assets. At the national level they are held at bay by corruption and development policies that discriminate against the poor. Globally their situation is worsened by rising debt burdens, falling export prices for the product they sell, and the flight of capital that could be used to create jobs and income".

This situation has been created by science and technology as developed and practised by the advanced countries to keep themselves in a upward spiral. It is neither possible nor desirable to reverse or slow down the trend or the progress in the international science and technology. The only alternative is to create and

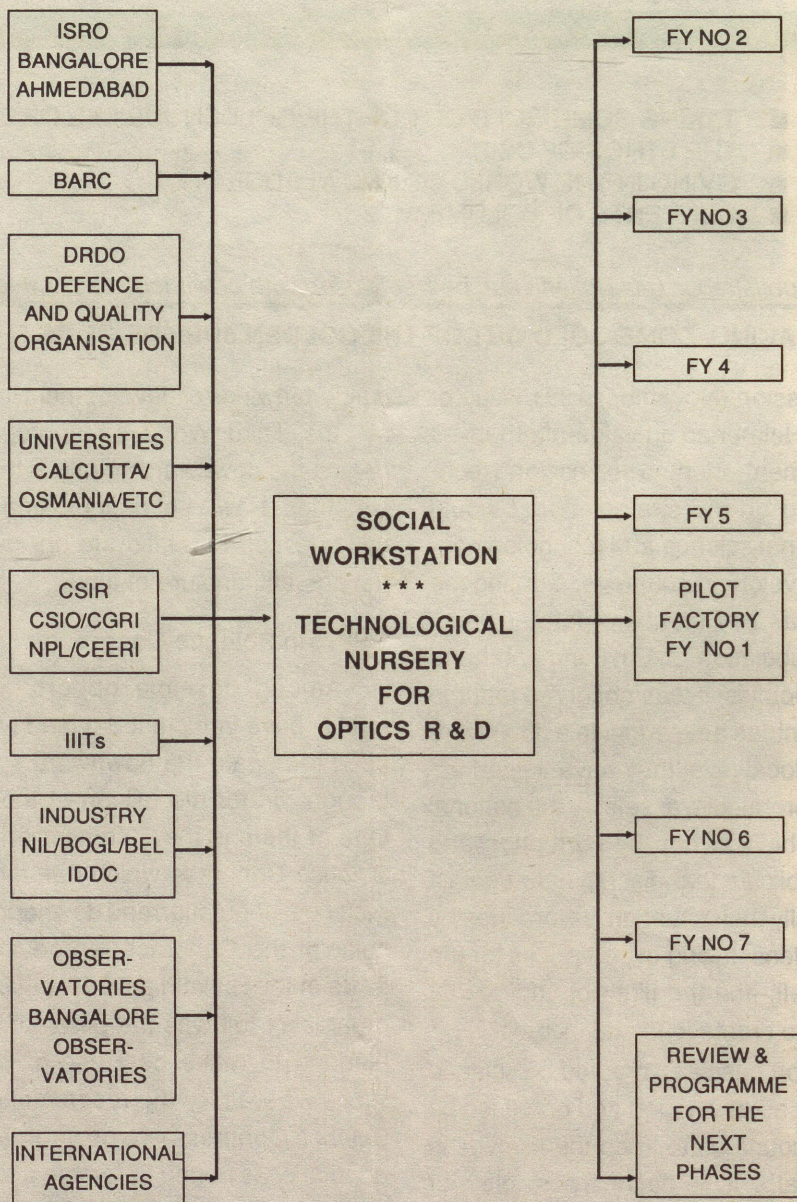
build whirlwinds of development in the countries of the Third World on appropriate lines to negate the downward spirals of their respective countries. How? Let us try to find an answer to this question in relation to our own country at the present juncture of time.

The 79th Science Congress

Among possible opportunities that we readily have in India today and which could be used to negate the downward spiral two were brought in for discussion at the last session. One of them is the 79th session of the Indian Science Congress which has the focal theme "science, population and development". The circular of the Congress reproduced in the last issue of the Bulletin gave an outline of what the organisers felt was the problem and how they planned to make best use of the Congress. While we wait for the recommendations of the Science Congress, we may remember that the population is bound to remain a formidable factor in our planning process for several generations to come and that there is no instantaneous

SCHEMATIC FLOW CHART OF THE TECHNOLOGICAL NURSERY FOR OPTICS R&D FORMULA

PRIMARY SOURCES OF OPTICS R&D (NATIONAL /INTERNATIONAL)	INTEGRATING CATALYTIC HARDWARE	PRODUCTION UNITS TO BE DESIGNED AND CREATED
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solution for the population. The Science Congress is, therefore, likely to reiterate the some of the known solutions for making the population more productive in terms material and moral resources and the focus on long term measures to control population. It is, thus, necessary to consider how to implement the known solutions and identify strategies for that purpose. Who can do this and how?

The Golden Opportunity

An answer to the above question was provided in the last issue of BASWI by making a reference to the golden jubilee celebrations of the Council of Scientific and Industrial Research (CSIR) and these celebrations offer us with the other opportunity that can be utilised to build a developmental whirlwind to negate the influence of the downward spiral. Founded in 1942 to promote the war efforts of the erstwhile British Government this Council was asked to establish a network of national laboratories and research institutes all over the country when the country became independent. For over the four decades since then the Council has been able to raise a sizeable infrastructure capable of handling R&D work in almost all disciplines. In the earlier stages this Council handled almost every thing in the field of science and technology but with the formation of specialised departments and agencies progressively, it is finding more scope for dedicating itself to its primary objective of fostering industrial development of the country.

But the presence of other departments dedicating themselves to specialised fields does not any way reduce CSIR's responsibility

nor does it reduce the responsibility of other departments towards the overall progress of the country in fostering industrial development. A recent announcement of the Defence Minister offering the availability of Defence R&D by the civilian industry is a pointer in this direction. There is no doubt, however, that the primary responsibility of fostering industrial development of the country rests with the CSIR alone. What can or what should CSIR do?

The Preceding Helmerian

The preceding Helmerian considered the above question in detail. The title of that Helmerian was "System of technological nurseries as an alternative strategy for the development of countryside". A detailed note on that Helmerian appeared in the February 1991 issue of BASWI and the January 1991 issue carried its backgrounder under the title "Nursing technologies for development. The case example of Optics Research and Development". The flow chart of the Technological Nursery for Optics Research and Development (TNORD) reproduced at the opposite page describes the formula.

TNORD has been registered as an All India Society for promotion of internationally marketable optical components. Its operational structure is patterned after the CSIR and its managerial structure is based on the Indian National Science Academy. Two successive national events - Symposium on Optics (1985) and Seminar-cum-Workshop on Technological Nursery for Optics Research and Development (1988) both supported by all concerned in optics research and development worked for building

a consensus for the organisation of the Nursery. It was registered on November 1, 1991 and started functioning with effect from January 1, 1991. With the formation of TNORD the erstwhile NPL activities on design and development of optical systems represent its historical past and the foundation stones of its future structure as NPL does not have future plans in the field of design and development of optical systems and the corresponding facilities are being transferred to TNORD on loan for five years.

Towards a Live CSIR

This live transfer of NPL/CSIR efforts to a new form of organisation for direct application is important as several efforts of CSIR and other organisations tend to die soon after the projects are over and facilities dismantled. The emphasis on the utilisation phase generated by this project is bound to correct some of the shortcomings and limitations of the existing R&D efforts.

A network of parallel technological nurseries around TNORD will look after other locality specific areas of socio-economic and social welfare activities. Thus, the basic purpose of planning and organising technological nurseries for raising industrial orchards in the countryside is to provide a living link between researches done in national laboratories and institutes and what we call development.

The last session carried a note entitled "Threat of technological colonisation : Scientists seek 'command' role" on a day-long seminar on "The Management of Change" organised by the Council of Scientific and Industrial Research. It

is obvious that some scientists atleast do still believe that scientists have a key role in managing the change and that inspite of its failure to deliver the expected results during the last fifty years, CSIR is the body to lead the nation towards development. The Helmerian made a reference to the **Karimnagar project**, an earlier seminar on "Research relevance rhythm" and the recommendations of this seminar vis-a-vis the Karimnagar project. These recommendations have been incorporated in the TNORD programme and in the **strategy of live transfer** just outlined. From the trends of the golden jubilee celebrations it seems that the programme should receive a favourable response from the CSIR authorities.

To know the official view of the CSIR on these issues we reproduce in this issue the fifth CSIR foundation day lecture delivered by *Dr A P Mitra*, CSIR Bhatnagar Fellow and a Former Director General of Council of Scientific and Industrial Research. From the views of *Dr Mitra* in this lecture as well as from the views of *Dr Atma Ram*, his counterpart a generation ago we find that the CSIR does want to establish excellence in the quality of its research efforts and the quality of their utilization in socio-economic and social welfare directions.

CSIR experts and expertise do have a 'commanding' role in a living developmental process but all concerned must recognise that we are "living in the age of knowledge" and experts and expertise do need some special consideration as the last note of this issue of BASWI suggests in the context of computers. Ignorance does not have a place in a real developmental process and let this be recog-

nised as a golden rule during the golden jubilee year of the CSIR.

THE ETHOS OF CSIR

[Fifth CSIR foundation day lecture delivered by Dr A R Mitra, CSIR Bhatnagar Fellow and a Former Director General of Council of Scientific and Industrial Research is reproduced below as a part of the Helmerian on development-oriented science and technology. The previous session (November 1991 issue of BASWI, carried views of Dr Atma Ram also a former Director General of the Council but he had retired twenty years ago. Dr Mitra is a fellow of the Royal Society and the current President of the National Academy of Sciences. His views also provide a picture of the current thinking at the academic level in India.]

I am honoured by your invitation to speak today here at NPL (my scientific home) and on a day that marks the beginning of the Golden Jubilee Year of CSIR. Some 37 years ago, in 1954, I joined NPL at the invitation of the late Sir K S Krishnan to build up the radio science group. Amongst the audience today, I am perhaps one of the oldest in the CSIR family. I would like to speak to you about the "Ethos of CSIR". One might ask: does CSIR have or can CSIR have an ethos? Can any organisation have a definite ethos in changing world?

A Dynamic Organization

I believe it is possible and CSIR has. It is an old organisation - but is a living one - dynamic, self correcting, responsive with a sense of belong. To outsiders, and even to me working within the system, it sometimes looks a non-homogenous, incoherent, and an unmanageably large body of conflicting interests and attitudes. This apparent Brownian motion has, however, not hindered, perhaps even helped, the tremendous elements of flexibility that the system has provided over the years.

Growing Family

CSIR is a growing family with an awareness that growth must be controlled. From its beginnings at the Alipore Test House in Calcutta as the Board of Scientific and Industrial Research, it has now a network of 39 laboratories and over 80 field stations with a staff of about 27 thousand and a scientific strength of over 6000. This is a large body, like a large joint family. The laboratories have different characters; some are truly national dealing with the broad spectra of science and technology, some were formed on response to regional requirements and others are commodity-oriented laboratories. This reflects a responsiveness to different types of requirements. The modes of formation of the laboratories were so often different: some were grown *ab initio*, some were transferred from other systems and some came into existence by splitting of existing laboratories. Sometimes we have gone too far in this process: we have ended up splitting a laboratory into too many pieces. We shall learn some lessons from this growth pattern: one lesson is that growth has to be restrained at some stage and perhaps we have reached that stage. In fact this unrestricted growth prompted the Review Committee to

recommend total elimination of our field stations. Although we should not go that far, the system must be given some boundary conditions. We could, for example, think of temporary multilaboratory centres, when a new initiative is to be taken. Indeed such an example is the Centre for Mathematical Modelling and Computer Simulation (C-MMACS) set up recently at Bangalore. And when such inter-laboratory centres are set up, we should give them working autonomy. The large family system would work only under a Federation-concept with working autonomy for individual members.

Response to Changing Perceptions

CSIR can pride itself that it has responded to new areas as these emerged in the international science. Two important examples are: Oceanography and Modern Biology. The International Indian Ocean Expedition saw the emergence of the National Institute of Oceanography. In the last one or two decades there has been an emergence of a multitude of CSIR laboratories involved with different aspects of modern biology. The initiation of **C-MMACS** in Bangalore is also a response to the recognition that mathematical modelling and computer simulation play a pivotal role in all areas of science and technology including the biological sciences in which inputs of mathematical systems were earlier restricted to preliminary aspects of statistics.

A Tradition of Distinction

CSIR has a tradition of a sustained level of distinctions and a stream of major achieve-

ments - the distinction of having a galaxy of world class experts and of an ambience of easy informality. It has several firsts. NPL played crucial role in the introduction of the metric system of Weights and Measures in 1956 through the Weights & Measures Act of 1956 jointly with the Bureau of Indian Standards (the Indian Standards Institution) and the Department of Weights and Measures. The first Time & Frequency transmission started from Kalkaji in 1959 under the call sign ATA: this was later to become part of an international system. The first technological development of electronic components from indigenous materials such as soft ferrites, silver, mica capacitors and a range of carbon products including cinema carbons came from NPL in the fifties. These early activities were forerunners of the establishment of the Central Electronics Ltd (**CEL**), the first industrial unit coming out of CSIR activities. A classic volume was *Col Chopra's 'Indigenous Drugs of India'* - the first pioneering attempt in using the indigenous-based system within the constraints of modern medicine. Then we had the Swaraj Tractor designed and built by **CMERI** which later went into production by Punjab Tractors Ltd, Chandigarh. A major milestone was crossed when Punjab Tractors Ltd delivered its 100,000th tractor recently.

'**AMUL**' came out of **CFTRI**. The Banthra Project started by the late *Prof Kaul* and nurtured by the NBRI scientists transformed the *usar* soil into productive biomass. **R V Gaveshni** commissioned on December 3, 1975 was an Indian built first multidisciplinary oceanographic research vessel: it has provided some of the most valuable oceanographic data

in this country for almost 25 years. This old research ship has now been reconditioned and is back for scientific work, hopefully for another two decades. The Antarctic Expeditions which have fired the imagination of scientists and the public at large have been primarily the responsibility of NIO. The first successful expedition in 1981 within a record time of three months is a landmark in Indian oceanography. In this the role of CSIR, which acted as the nodal agency, has been recognised. Amongst the firsts, I would like to include also the discovery and subsequent efforts of metallurgical processing of polymetallic nodules first collected from sea bed in January 1981. We have had one of the most successful examples of technology transfer in the area of agrochemicals. More recently, there have been several firsts in drug development. Both the chemical and the biological laboratories have contributed significantly in this area. The introduction of Centchroman, the oral contraceptive, is a recent significant achievement. So has been the development of Zeolite catalysts by NCL. The bamboo flowering activity of NCL has attracted worldwide attention. These are only a few examples - to show that excellence was always nurtured and appreciated. Then there have been attempts to build major facilities: an ethos of thinking big. The wind tunnels built at the National Aeronautical Laboratory, the tower testing facility in Madras by SERC, Madras, the MST Radar that has recently been commissioned near Tirupati on a ST mode and the launching of the SROSS-C Satellite, expected in early 1992 with NPL payloads, are examples of large tasks encouraged and successfully undertaken and successfully ac-

complished by CSIR. In this tradition of distinction one should also mention the longstanding role of CSIR in international linkage - both in collaborative programmes with similar bodies elsewhere through agreements and in taking a pioneering role in large international programmes. The International Geophysical Year (IGY) which was perhaps the first organised entry of Indian science into international arena was directed by the NPL. IGY was the beginning of space age. It also changed almost entirely our concept of the earth-atmosphere system. CSIR's contribution to this changing concept was large. The Thumba Rocket Range and the Hyderabad Balloon Facility were established as a result of these activities and Indian space research began in right earnest. So was the role of the CSIR laboratories in the SITE Programme that was taken up by India in the mid-70s. CSIR led the second aspect of the SITE Programme which involved the use of satellite radio beacons. Another such programme is the recently concluded IMAP - the Indian Middle Atmosphere Programme starting on January 1, 1982 and terminating on March 31, 1989. In this the thrust was on a relatively narrow part of the atmosphere from the ground to 90 km. It involved participation of some 200 scientists and 20 organisations. Facilities generated during this programme and data obtained provide now the base for global change studies and the International Geosphere-Biosphere Programme - IGBP. A by-product was the decision to set up the MST Radar referred to earlier. This tradition of distinction can also be gauged by looking at the people CSIR has generated. It produced a number of highly dis-

tinguished scientists of world class status and continues to do so.

The Changing Culture of CSIR

In any major organization, its culture, operational scenario, its attitudes continually change within a broad framework. This is part of its ethos. In CSIR such changes have been going on since its beginning: part of CSIR ethos is that such changes have occurred in recent years. These have been forced by external systems. I will call them "forcing functions". One forcing function is the changing expectations of the government. Governments everywhere are asking their national research systems to be selfsustaining, at least partly, and contribute to national wealth through pragmatic and competitive local technologies. They also expect the research systems to provide the technical inputs for policy options. This was clear in the first major meetings of the Heads of Research Organisations held about a year and half back in Australia. Surprisingly, the governmental attitudes were the same in all countries - developed or developing; 'science for science sake' was not accepted. In all countries represented in the Australian meeting, governments wanted a rethinking and restructuring of national research systems. The four issues raised in this meeting were: (a) the governmental investments on research, (b) generation of funds by research agencies from other sources, (c) dissemination of scientific results to the public and the press, and (d) international relations. The next important forcing function for CSIR was the recommendations of the Review Committee headed by *Abid Hussain* and the decisions of

the Society based on these recommendations. It was urged that: (a) we should generate 1/3rd of our budget from outside sources by 1992-93, (b) that we should go out and interact with the industries, and (c) that since no laboratories were to go out of CSIR, we should bring the outside agencies inside our decision-making system. The third forcing function was the undertaking by the Government of a number of societal missions in which CSIR was asked to provide major scientific and technical inputs. These included Missions on Drinking Water, Immunization, Oilseeds and Literacy. Our involvement in Drinking Water Mission, in particular, was very rewarding because it exposed us to a number of boundary conditions; strict time frame, tried technologies, standardisation, economy of efforts as also generating a culture of working together not only amongst scientists but also with administrators and managers. How did we respond to these forcing functions? We did so in a number of ways. First, instead of taking CSIR laboratories out we brought in the external government agencies, industrial concerns and universities by involving them in our Research Councils, our Advisory Board and the five Technology Advisory Committees. The change in attitude was immediate and remarkable. External members from other organisations and from the industries, considered the laboratories as their own and defended the laboratories even when I criticized some of their functions. This was a healthy sign. The 1/3rd cash flow concept required that we go out and work with the universities and accept and seek commissioned work for the Government Departments. Here again CSIR learnt to work

under constraints of time and economy and was exposed to a commercial, industrial and a totally different work culture. Another cultural change needed was partial decoupling of the Headquarters from normal operations of the laboratories at the same time keeping a watch on its expected outputs. For this purpose, the peer review concept was introduced in which once a year the peers coming from inside and outside CSIR (including RC) would review the programmes and plan for further work, and budgets were allotted. A three-year budget concept was introduced. The key parameter was our attempt to introduce autonomy down the line in each laboratory to at least group levels. Administrative and purchase procedures were changed: you will find an interesting account of these in *Omesh Saigal's* book "**Towards a New Administrative Culture in CSIR**". To encourage young scientists at an early stage, the Young Scientist Award system was introduced.

The Future Perspectives

What should be our direction in future? In this I would like to draw upon the recommendations and deliberations of two major get-togethers:

- (i) International Science and its Partners: the lessons from ICSU's Visegrad meeting.
- (ii) *Abdus Salam's* Blue Print for science development in the South. The first defined three kinds of partners: Intergovernmental organisations (IGO's), Governments and Industry. It set up three Panels to cover these three areas, the first chaired by *Prof Mayor*,

Director General of Unesco, the second by *Dr H Leussink*, former Minister of Education and Science of Germany and the third by *Dr M Lavalou*, President of the Technological University of Compiègne of France. The deliberations are important since these show the way by which CSIR may also forge its link with its partners. The partners are similar. Before outlining the major recommendations, I would like to quote a few of the comments made during this meeting by some of the distinguished people:

- (i) "Although most scientific advances could be traced back to a single scientist, it is not the best way to make an impact on society and scientists need to respond to outside concerns". (We would consider this vis-a-vis the "*Gharana*" approach prevalent here).
- (ii) "The increasing importance of science and technology driven by economic aspects whether in developed or developing countries and global environment deterioration" has to be noted. (Note the words "driven by economic aspects").
- (iii) "The role of social sciences in global change and environmental questions: 80% of environmental phenomena had as their source human activity and 100% of the solutions to these phenomena had to do with actions of people". (Hence the need to involve people in such programmes).

- (iv) "How difficult it is in countries undergoing economic crisis and/or rapid political changes for lasting links to be established between scientific communities and members of Government". (India fortunately, is an exception).
- (v) "With inter-governmental organisations, one should identify a number of major issues which represent urgent problems the solution of which requires partnership based on concrete well-defined scientific projects between the scientific community and the intergovernmental organisations. These include environmental protection, food systems, energy supply, education and training, human health and safety, reduction of natural hazards, population and employment, development and resolution of social conflict". (CSIR may have to involve social scientists in planning its activities in these areas).
- (vi) "There is a natural need in all societies for a close tie between science (not only the natural sciences but human and social sciences) and government".
- (vii) "On industry, three parameters were identified: matter, energy and information".
- (viii) "In relationship with industries there is always an 'acceptance' phase. This must be tidied over". The major conclusions and recommendations that

we might use as guidelines in CSIR include the following:

- (i) "The need for sound reliable scientific information to be made increasingly available to governments and other partners and to be brought to their attention when necessary. (ii) Science community to conduct and issue independent assessments on scientific issues, of which the environment is one frequently mentioned example: This would enhance the role of scientists in governmental policy issues. (iii) Media are considered to be key players in the question of information and communication. Scientific community had not always drawn enough benefit from the valuable light which the media could help to shed on the needs of society in relation to science and its actions to scientific issues."

Salam's Blue Print

Professor *Abdus Salam* has given a 5-point blue print for development of science and technology in the South. These five points need to be noted by CSIR. These are:

1. A substantial increase of human and financial resources for science and technology:
 - * at least tripling the number of scientists and engineers;
 - * doubling R&D expenditure to at least 1 per cent of GNP; and
 - * a 10 per cent cut in defence budgets in all states of the South to obtain the requisite funds.
2. Integration of science and technology programmes into national development plans, supported by adequate financial, in-

stitutional and legal framework; raising the status of scientists in society and improving their conditions of work, with scientists assuming reciprocal responsibility towards society.

3. Exemption of scientific books and journals from copy-right regulations and establishment of technological information centres; ideas on NEST (New and Emerging Sciences and Technologies) to be borrowed from the North.
4. Emphasis to be placed on higher and secondary technological and scientific education as well as on scientific literacy. Encouragement to be given to technologists to become scientists, and scientists to become technologists.
5. Strengthening the institutional basis for science and technology by:
 - * giving first priority to the creation of 20 Centres for Science, High Technology, and Environment, with equal emphasis to be given to training and research;
 - * strengthening the organization and work of TWAS and TWNSO; and
 - * continuing to strengthen existing international centres such as the International Centre for Theoretical Physics in Trieste.

The Greying of CSIR

Since we are talking about the future of CSIR, we should be concerned with what I would call "the greying of CSIR". *Abid Hussain* Committee already pointed out the unacceptably high average age of the scientists in the CSIR laboratories. We have in the last few years tried

to bring in young scientists in different modes through the usual systems of research fellows and research associates and the Pool Officers and also by introducing a quick hire system. Nevertheless the percentage of competent young scientists in the laboratories continues to be low. On top of it, there is now the increasing emphasis on austerity. I am afraid this will end up in an administrative injunction of stopping recruitment in the scientific cadres. That, in my view, will be unfortunate. While we should make all efforts to induct only people of quality and motivation, the process of entry of young scientists in our establishments would have to be continuous. A break, even a temporary, not only adds to the braindrain but gives the wrong signals. But, growing of young scientists into quality experts need not be limited to young recruits, we should also include people who are already in the laboratories. A significant portion of the time of the senior scientists should be spent on these young scientists. In fact a comment that I used to make was that a senior scientist should be judged not merely by the way he runs the Division or a Group or a Project but also by the number of young talents he has grown up. It is important that this role of a senior person is not underemphasized or overlooked. Ladies and Gentlemen, I hope I have given you a sufficiently clear picture of CSIR and its ethos; of a living, continuously changing organization with excellence as a goal, but also one in which its should always try to keep itself young in spirit.

LIVING IN THE WORLD OF KNOWLEDGE

[The leading note in this issue discusses CSIR as a manager of change. What are the requirements for CSIR as an organization to be able to manage change? We are living in a world of knowledge today and are surrounded by experts and their expertise. If a change is a goal then we can refer to some expert advice on goal management. Let us get educated from the experience and expertise of computers.]

In a conventional computer based information system, such as a data base manager, the knowledge contained within the system resides within two distinct domains: first, there is the knowledge inherent in the system's data and within the data structures used to represent the data, and second, there is the knowledge represented within the control algorithm employed to acquire and manipulate the system's data.

Control Structure

Where does the knowledge content of these systems come from? In these types of systems the control algorithms are either provided for the user as a 'black box' or, more rarely, are developed by the user. In either case, any inherent knowledge the system may have about its given application domain is embedded within, and often obscured by, the syntax of the programming language used to encode the control structure. Thus the conventional information system, while being very flexible in adapting to varying data volumes and contents, is inherently inflexible when changes must be made affecting what decisions and choices are made and what conclusions and results will be provided.

The problem of imparting knowledge to a computer system is further complicated by the fact that those persons who have the knowledge of how the system should behave and what results should be produced traditionally lack the skills necessary to translate that knowledge into program algorithms and data structures. Thus it becomes clear that the source of the knowledge transference problem is the linkage of application knowledge with the control structure of the system.

The solution provided by production rule expert systems is to separate the application specific knowledge from the algorithmic control structure. A production rule expert system contains a generic control structure. This generic control structure eliminates the need for the developer of an information system to design heuristics depicting the "how to" and "what happens next" of the problem. Obviously, by providing such a control structure, there are some limitations imposed on the types of problems that can be handled with such a system. But these limitations are offset when one sees the ease with which problems that previously were considered large and hard to manage when

tackled using conventional programming methods can be solved in a compact and manageable way using expert systems. The difference between conventional programming and knowledge engineering is that one is no longer occupied with the chore of describing to the computer what is supposed to do, but rather, the system developer now must describe to the computer the relationships between the facts, events, things, and qualities that comprise the domain of the application. These relationships embody the 'conceptual rules' specific to the application domain and collective are referred to as a "knowledge Base" for the domain. The usefulness of such a method in solving real-world problems and applications still must reside in the case with which knowledge can be represented. Thus, the usefulness of expert systems depends upon the developing a convenient and natural means of representing knowledge.

Goal Selection

We now begin to see a picture of a knowledge base as a collection of rules with each rule defining some cause and effect relationship found within the application domain. In order to complete this picture of a knowledge base two essential elements remain to be explained : how are paths formed with the collection of rules, and how does the expert system's control structure choose a goal? Traditionally goal selection has been the cause of one of the major obstacles to the user of an expert system. In the course of an analysis session the expert system must obtain situation dependent information from the user. In an in-

teractive expert system this information is obtained by a direct query. Thus, in a knowledge base with a large number of achievable goals, the user may be required to respond to a large number of questions which have no bearing on the particular situation at hand. In any situation where the time-to-solution is critical, the large amount of time required for a user to respond to the many unnecessary questions would detract greatly from the real-world practicality of an expert system. The beginnings of an ironic trend can be seen here : as knowledge bases become larger and cover more extensive domains, and thus are more "intelligent", they will also become more and more unusable. It becomes apparent that some means of increasing the efficiency of goal selection is necessary. In typical expert systems the functional responsibility for goal section can be found in three places: (1) the knowledge engineer - who, as part of creating the knowledge base, specifies the entire set of conclusions that can be reached, (2) the expert system's control structure - which provides an interactive means by which the user is assisted in narrowing down the number of goals that may be applicable to the current problem, (3) the user of the expert system - who, by making gross estimates to the nature of the problem, helps select the goals that best fit the problem. Unfortunately, deficiencies in the knowledge representation or in the expert system's control structure must be made up by the user.

In order, for the expert system, to be able to prove a goal the knowledge base must contain some knowledge about that goal. Knowledge for an expert system is of course contained

within the rules. Thus, for the expert system to be able to prove or verify a goal, the goal must be a conclusion of at least one rule in the knowledge base. When the expert system's control structure attempts to verify a given goal,

it finds those rules which contain supporting statements that conclude the goal. For a given goal only a subset of the rules of a knowledge base will have any knowledge that would be of use in validating that rule.

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ROLE OF WOMEN IN AGRO-INDUSTRIAL PERSPECTIVE FOR ENVIRONMENT RECONSTRUCTION

[Proceedings of the topic seminar, New Delhi, December 9-10, 1986]

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