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Indigenous Computer Industry

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INTRODUCTION

The computer has become a closely identified attribute of modern technological society. Apart from having made possible the great ascendancy of technology witnessed today in the advanced world, the computer has also the potential of aiding greatly the development of countries such as ours where use of technology is relatively less intensive. The subject matter of this survey of indigenous computer industry will cover, apart from a review of what has been achieved in India so far in terms of installations, usage and capabilities established, the importance of indigenous development as a major strategy, the efforts to be made to advance many requirements including the major one of trained manpower, the formulation of a cohesive wide ranging national computer plan and a few recommendations on general policy. We shall also analyse some of the problems such as organising for innovation and the dominant role an R & D culture with its emphasis on achievement and creativity will play in such a highly innovative field as the indigenous development of computers.

CURRENT STATUS

INSTALLATIONS

There are about 260 computer installations in the country today and of these about 50 – one fifth of the total are the result of efforts in the country to develop and productionise computers on an indigenous basis. During the six years beginning from 1969, the computer population in India has grown by 157 to a total of about 260. It may be noted that one third of the computers added in this period are systems developed and produced entirely on indigenous know-how and technology – a measure of the national efforts put in and impetus given by the Government to promote self-sufficiency in this vital field. There are quite a few large systems installed or planned for installation in the Country as national computer centres, such as the large computer centre at IIT, Madras and the National Centre for Software Development and Computing Techniques (NCSDCT) set up by the Government at TIFR, Bombay. One of the most far reaching developments in the computer field is the advent of minicomputers. Their low price, flexibility, small size and reliability have opened up wide range of new applications hitherto not considered suitable for computerization. Thirty out of fifty computers installed by ECIL so far, catering to the small to medium class of applications, more or less, belong to this class – third generation technology, small size, low price, 12-bit and 16-bit word length, wide range of applicability, etc.

COMPUTER USAGE

It is more important to know how to use computers than to know how to make them, since the former stimulates the development of the entire economy while the latter concerns the growth of only one industry. There have been four studies on the pattern of computer use in the country so far. It is interesting to see the near unanimity of their conclusion – except in a few cases, computers have not been used in any significant way, either in decision-making or in complicated industrial process control or project management. The Maharashtra Government Study concluded that "except inventory control, and to a certain extent, linear programming, rest of the purely decision-oriented computer applications do not as yet play any prominent role." The Administrative Staff College of India (ASCI) study says that accounting function is the major computer operation in most commercial organisations. "By and large, commercial computers are used for conventional data processing applications. Advanced processing systems like inventory models, linear programming for optimum product mix and optimum transportation pattern, project management reporting, etc. are still in the nascent stages of application." In Research and Development institutes, computers have so far been used mainly for numerical computations, study of design parameters and related problems. The Structural Engineering Research Institute at Roorkee, claims to have achieved substantial savings in design time and cost in optimising designs for transmission towers, multistorey frames, etc. with the aid of computers.

Only about 18 out of the 260 computers we have today are used for on-line/real time data processing, i.e., for computer based data logging and control oriented applications. The TDC series of machines have found usage in a variety of fields. So far, ECIL has handled fourteen on-line computer projects. The computer systems cover a wide range of applications such as nuclear reactor control, industrial process control, space, communications, scientific and engineering reasearch. In the field of scientific and engineering research, these machines are used for applications such as seismic data acquisition and analysis, crystal structure studies, stellar spectrum analysis, engine performance studies etc. The first on-line computer project was executed by ECIL in March, 1972 at the Seismic Array Station, Gauribidanur. The availability of the on-line computer has made the detection of seismic events and preparation of event files simpler and less time consuming. The largest computer based control system in the country designed and built for monitoring and control of the Fast Breeder Test Reactor at Kalpakkam, Madras is being supplied by ECIL. The computer system functions include reactor parameter data acquisition, analysis, alarm limit checking and calling for operator attention for remedial actions whenever necessary. An on-line computer system with telemetry interface is operational at Sriharikota for data acquisition and analysis. The 'quick-look' analysis available from the computer aids the ground control station to monitor the position of the space vehicle. Another on-line computer system built around the TDC-316 is being commissioned at Sriharikota. This system is meant for real-time monitoring of the trajectory of the rockets and impact point prediction. The Experimental Satellite Communications Earth Station, Ahmedabad, is employing a TDC-312 based computer system for automatic tracking of satellites. A TDC-312 based data logging and control system in the Gujarat State Fertilizer Company, Baroda is the first attempt at computerised process control with indigenous know-how.

TECHNOLOGY

Already considerable expertise is available in the country in certain areas of computer hardware development. The potential exists mainly in the area of main frame and interface development and manufacture. Work has been in progress at ECIL from 1969, in these two areas. Full range of system software and library routines are available with ECIL's TDC-12 computer. ECIL is also engaged in the development of software for real-time process control applications. ECIL has developed the basic system software for the TDC-12 system installed at Seismic Array Station, Gauribidanur. Various other organisations have developed a large number of application packages for the computer installations. Some of them have even developed additional system programs not provided by the manufacturers for their computer systems. Consultancy services are also available within the country which indicates the competence-base existing in the country. Regarding the peripheral equipment, a beginning has been made in the country. Public Sector Undertakings like HTL, Madras and BEL, Bangalore have manufactured prototypes of peripherals like Paper Tape Readers and Punches, Mosaic Printers and Console Typewriters. ECIL, on its part has developed a Display Unit.

FUTURE TRENDS

DEMAND FORECAST

Various agencies have conducted studies to estimate the demand of computers during the fifth plan period. The demand is of a high magnitude, in the range of 900 to 1300 computer systems in the 5 year period, 1974-79. About 75% of these are of the small computer class, 23% are of medium computer, and 2% large computer classes. A local production of the order of Rs. 90 crores and a consumption level of about Rs. 140 crores are estimated for the five year period.

TYPES OF MACHINES, COMPLEXITY

In terms of hardware complexity, the projected computer requirements span from simple systems in which a teletypewriter is the input-output device to large systems involving many peripheral equipments and mass storage devices and several special purpose subsystems for handling hundreds of analog and digital input-output channels. From the view point of applications, the systems can be considered as belonging to the classes, like OEM (Original Equipment Manufacturers) small on-line, large on-line and stand alone systems. Thus, hardware, software and system engineering required to integrate the computer with the application environment varies over a broad spectrum in terms of engineering, programming, manufacturing, marketing specialities besides the enormous range of peripheral equipment needs that go into these systems.

FUTURE USAGE PATTERN

The country, setting aside the efficiency aspects, has had an exposure in the usage of general purpose computers for business, scientific and on-line applications. For a variety of reasons, in the near future, computer usage in the country will take to the presently predominant patterns of usage abroad classified as "Time Sharing,' 'Computer Networks, 'Distributed Processing' and 'Remote Processing,' etc. Efforts are underway to equip ourselves to take up these forms of usage of computer systems. The DEC system 10 at TIFR is a time sharing system, for simultaneous use by 128 users. The system will not only expose the country widely to the problems and advantages of time sharing systems but also gives scope to develop sufficient expertise for managing such systems. Work is in progress to build systems around indigenous computers for time shared operations for upto 12 to 16 users. Development of Multiterminal 'BASIC' by Indian Institute of Management, Ahmedabad and ECIL, and development of hardware optional subsystems enabling usage of TDC-316 computers in the time-sharing mode are underway. The importance of computer networking is progressively being recognised as a means of providing economic computer services to a large community of users located at different parts of the country. A computer network is technically defined as an inter-connected set of dependent or independent computer systems which communicate with each other in order to share certain resources such as programs, data or hardware. Users who do not have large scale computers on site can access them via the network and those who have, can access off-site computers for specialized work. In short, the network offers wide access to a wide range of capabilities without expensive duplication of facilities. By aggregating specialized user requirements around a large geographic area into fewer centres the services can be provided at lower costs than would result from provision of equivalent services by means of large number of machines. The computer network usage will include remote job entry, remote batch processing, interactivity, terminals, dynamic file access, transfer and load sharing. The minicomputers will appear in a computer network as front-ends, remote access stations, concentrators or bus managers. Messages are normally handled by non-dedicated communication circuits. With the establishment of regional computer centres in different parts of the country, it is conceivable that the next logical step would be to interconnect these centres by means of high speed data links allowing access to data bases and computer facilities scattered around the country. As a viable alternative to a large computer, a number of minicomputers could be connected as a 'close coupled' network sharing expensive memories and peripherals. This concept of local network is attractive because of the decreasing CPU costs. These multiprocessor systems, though are comparable in throughput to a large computer. they cannot be an alternative in scientific applications where raw number crunching power is needed. In this direction, NCSDCT is developing a close coupled network of TDC-316 computers. The system software is currently under development at NCSDCT and the various interconnecting hardware blocks are under development at ECIL. It is expected that a commercially viable TDC-316 dual processor system will be a spin-off of this effort. Also work is under way to connect a TDC-316 as a remote access station to be located at Victoria Jubilee Technical Institute (VJTI), Bombay to the DEC 1077 system at NCSDCT. Another area which calls for our attention is distributed processing, where a set of computers handle distinct functions in a system. The independent tasks are decentralized but the common processing jobs are integrated via the interprocessor communication channels. The work load is distributed throughout the network reducing the burden on the main computer. The complexity and diversity of disciplines involved in the development of computer networks call for a national effort.

IMPLICATIONS OF THE DEMAND

As indicated earlier, the large turnover, about Rs. 90 crores, expected to result because of indigenous production, though quite alluring, is very difficult to realise in the face of many hurdles as one sees today. One encounters typical problem areas such as :

* Inadequate trained manpower.
* Coherent and balanced development of all disciplines that is necessary to make the computer industry viable indigenously.
* The balancing and absorption of the forces and the impact that computerisation is likely to cause on economy and society at large, etc.

The acute inadequacy of manpower, trained specially to man the different disciplines involved such as design, development, production, maintenance of hardware, design and development of system as well as application programs and the very important area of system intergration and system engineering could possibly slow down the pace of progress in this field unless immediate steps are initiated for filling the gap in respect of manpower. Besides the manpower needs for development and production, as much, if not more would be required on the utilisation of the computers. The need, will be about 20,000 trained personnel within the 5th plan period. The minicomputer panel has estimated a raw need for about 7500 engineers alone ! Another area of importance relevant to Indian conditions is furthering computer awareness among the users and making them conscious of potentialities of the computer. This itself could be a massive and complex programme which calls for in-depth study and extensive effort on the educational programmes in the country at various levels.

SHORTFALLS AND MAJOR PROBLEMS

HARDWARE

We find that significant indigenous capability exists in the country to build up a self-sufficient computer industry. Considering the computer manufacturing aspect, ECIL has already started marketing TDC-312 systems which are faster third generation versions of TDC-12 and also 316 systems. TDC-332 is well underway and will be taken up for production in the near future. However, continued dependence on imported integrated circuits and peripheral equipment can have a very crippling effect on the Indian computer industry. Availability of these items from indigenous sources in required numbers will help establishing a sound base for the industry.

SOFTWARE

With the indigenous computer industry getting off the ground and with a variety of medium and large computers coming up in the country, the need for indigenous software development becomes urgent. Most of the flexibility of modern computers derives from well conceived and reliable software and the success of indigenously made computers depends on the availability of programmes relevant to the country. All out attempts to train software designers and to utilise large-scale software development techniques should be made. The plan for software development should become a plan to meet the requirements of software for carefully selected applications. These applications can be indentified long before the need for a computer becomes critical and indigenous industry will then be able to provide the software and learn from the experience. There should also be a programme to train software designers and to develop software tools that facilitate the building of large programmes. These tools would include special programming languages designed for building large system programmes, routines for checking and testing them etc.

USER AWARENESS

Certain aspects regarding computer usage were highlighted in a recent issue of Science Today. We have, it is pointed out, cases of computer systems being procured merely as status symbols with utilisation being sub-optimal. The computer is still not being efficiently used as an adjunct to a well designed management information system even where the computer was introduced to obtain some specific advantages. Even more important, in the Indian context of a developing economy, utilisation of data processing aids as catalysts for growth has not assumed significant proportions. Except in a few cases computers have not been used in any significant way, either in decision making or in complex industrial process control or project management. Thus we see that there are glaring gaps in the user awareness of the full potential of computers and their utilisation and in the promotional efforts required to plant the computer systems in required areas in a prescriptive way. These gaps have to be filled on priority, specially in the present context when the country is equipping itself with computer systems for such applications as in the Time Sharing, Computer Networks, etc.

MANPOWER

The manpower required as indicated in some of the projections calls for massive training effort. As a case in study, if we consider the manufacturing operations of ECIL, almost all people have to be specially trained irrespective of their background to suit the specific needs of the plans. We, at ECIL, have a full-fledged training cell for meeting the training requirements to support the computer activities. The training is a one year programme entailing considerable intensive effort. The situation can easily be extrapolated for size and complexity, and the national requirements visualised. No single curriculum can produce people who can design sophisticated hardware and software and at the same time are experts in all areas of computer application. To take up computer applications in any discipline, expertise in the discipline should be coupled with the training in computer science. It is easier to teach an expert about computers than teach a computer-man all subjects in depth. It is not the knowledge that counts but the confidence, maturity, intellectual potential and the aptitude for learning new things. No amount of class room teaching can give a student the insight and confidence needed in programming. A programmer has to find and resolve on his own, mental blocks in communicating with a machine and this needs a lot of time and access to a computer. The training programmes, academic, institutional and industrial, have to cater to these needs.

A CASE FOR INDIGENOUS INDUSTRY

Having surveyed the development capabilities and possibilities in the hardware and software fields and outlined some of the problems such as manpower training, computer usage etc., let us see the case for an indigenous computer industry. The need for having a strong indigenous infrastructure in the country for the development and production of computers is a thoroughly discussed topic. The late Dr. Sarabhai had very firm views regarding this issue. To quote his own words, "I think that this field is far more fundamental, of wider significance than almost any other field of electronics, even if I want to make such a comparison, because it is not a field, it is much more than that, it is an all pervasive way of thinking, looking at and analysing, and it is of particular relevance to our developing country where resources are scarce........... Can we, therefore allow such a major national capability to be in other than national hands ? .... Like France, Germany, UK, Japan and USSR, this country has to take a very definite position here. By all means, we should use the inputs from outside, but this cannot be a substitute for a country as large as India with the states we have. It cannot be a substitute for at least one major effort that is truly national. This effort calls for the types of initiatives which require to be pursued with great determination against great efforts of seduction, I might say, because there are many short term gains which might pre-empt our long term position in this matter........."

The situation like ours was also faced by UK, France and other countries vis-a-vis tremendous American domination in the field. The economic consequences of allowing free imports, operating European-owned firms under licence from American firms and local manufacture by subsidiaries of American firms were very carefully gone into. The damages to the home industry because of the pursuance of any of the above methods in terms of balance of payments, vacuum in research and development, strategic dependence on another nation in very critical fields have prompted most of the European countries to develop strong indigenous computer industries of their own. A great emphasis has been put on the manufacturing of computers, the general philosophy being that the computer industry, because of its high technological sophistication and its deep impact upon all other advanced industries is of key importance in the development of the whole economy. In the Indian context, the computer industry set up on a firm footing will have a very fruitful role to play as we have fairly large-scale and advanced programmes in defence, aerospace and atomic energy fields. As all the fields are research intensive fields, they have mutually supporting roles.

A computer industry is a major factor in the development of a modern economy for the simple reason that it combines three very important characteristics not often seen together.

- a mass production industry;
- an industry of advanced technology;
- a key industry.

A country which fails to master its data processing technology gives away to a considerable degree, the future of the electronic components industry and even of the electronics industry itself. One can easily appreciate the anxiety of European Governments to protect their domestic computer industries for above reasons. We have seen for ourselves, that association with internationally renowned companies has resulted in little transfer of technology and expertise in other industrial fields like Steel and Petro-chemicals etc. On the other hand, research institutions like TIFR, BARC, ISI, Jadavpur University and IIT Kanpur have done commendable service to the development of computer know-how in the country with the limited resources available. For a balanced industrial growth that will help national development in a substantive manner it is necessary that we allow the greatest possible participation of indigenous resources both material and intellectual. One has to be especially cautious about the deficiency of foreign collaboration especially where the sophistication involved in the technology proposed to be imported is high.

The fruits of indigenous efforts may not be immediately competitive, but produce a lot of first hand local expertise in research, design, and development areas. Taking a typical case, India's experience in the steel industry is of much longer duration than its experience in the nuclear engineering field. Nevertheless, as far as steel technology is concerned, we have no special innovational achievements. In the case of nuclear technology, however, because of the active control we have had, considerably greater progress has been made in a very short time and there has been a great deal of fall-out benefits in terms of technological know-how in allied areas. Today we have a name in the world of nuclear technology and nuclear power, a standing of respect while our achievements in steel making have been below par for the large foreign exchange and time that have gone into steel technology.

In any case, we have to note that the total or partial foreign dependence will not be desirable from the point of national security at least in those industries which have vital and strategic significance to the nation and which form broad based nuclei for defence operations. Thus there is an intrinsic compulsion for indigenous development and this relates to the infrastructure required to build up self-sustaining and self-supporting development.

PROMOTING THE INDIGENOUS INDUSTRY

How should the indigenous computer industry be developed ? It is known to people in the field that the complex and extensive sophistication of computer technology does not permit redundancy or multiplicity of parallel efforts because of the high costs, time delays and interface compatibility problems. In fact for a computer development programme to be viable there should be a minimum size of organised effort, a kind of critical mass below which progress will be very little and the cost excessive. The merger together of advanced companies such as CII, Honeywell, General Electric and Gamma-Bull can be viewed as a step to achieve critical size. The closure of RCA after attaining a high state of development was in all probability forced by the same factor of adequate size. The trend towards pooling is global as may be seen in the formation of groups such as Nixdorf-ADG-Telefunken in West Germany, Siemens-CII-Philips in Western Europe and ICT-English Electric-Ferranti in UK. The RJAD series of data processing systems is the result of a multinational effort among the East European countries in cooperation with USSR. It is a general feature of all gigantic and sophisticated industries, as exemplified in the Concord Supersonic Project, jointly handled by the British and the French. Another case is the Air-bus Project, which is a multinational venture involving UK, France, West Germany and Italy. When such is the situation in advanced countries with thir relative freedom to allow high costs, a nation like India can ill afford to ignore the critical size concept. There is little scope for parallel effort and it is necessary that we bring together all inputs into one well-planned, well-supported and well-executed computer effort. This does not in any way imply that a monopoly holding is advocated.

NATIONAL COMPUTER PLAN

Making the country self-reliant in this crucial area of computer manufacture and utilisation is an enormous task. This calls for a truly national plan which is thoroughly integrated and comprehensive. The plan should cover development of hardware, components and peripherals, software and application, manufacture and services, manpower development and training. Careful assessment of the "real needs" should be made from the view point of optimal usage pattern envisaged. Time bound plans relevant to the Indian conditions must be drawn up.

The initiative taken by France will be of relevance in this context. The French Government has set up a special institution 'la Delegation a' l 'Informatique' with the target 'To have an efficient and coherent policy' on the use of computers towards the growth of the country. This institution was expected "to promote the French 'Plan Calcul' in every of its aspects namely industrial development as well as governmental equipment and utilisation policy, research, education and training policy." This Central Coordinating agency was aimed to be not an agency which directs other agencies by imposing its own point of view but which calls important points and coordination needs to their attention, assists and advises them in the solution of their problems and proposes to the government the necessary decisions or general policy. "The objective which has been sought by 'la Delegation a' l 'Informatique' is for each agency responsible for a computer policy to establish.

- Forecasts about computer application and systems for the next 3, 5, 10 years.
- Control of global coherence by use of standardised formulation applied to all government agencies and allowing for comparisons, adjustments and evaluation.

This policy is being gradually implemented and will eventually lead to a national programme which will be a true national computer use development plan." A similar approach can be taken in India also.

One of the chief characteristics of the industry is the multiple disciplines involved starting from the development and production to the ultimate utilisation. For the whole programme to have a significant impact on the national economy, serious efforts should be made, as in France, to strike correct balances between the efforts going on and to be taken up at different institutions in the country engaged in computer activity. Duplication of efforts should be avoided and a cohesion obtained in the overall programme. Already, we have several "islands of excellence" operating in the country in this field and the present task should be one of properly linking all these islands or segments with adequate support. New agencies can be created to cover the gaps as and when required.

The importance of a well formulated, coordinated and executed national policy in this area cannot be over-stressed. To be meaningful, this policy has to embrace production, promotion and utilisation of these machines. The emphasis on adequate pre-planning arises due to the large (3 to 7 years) time constants between the initiation of any manufacturing activity and its total implementation. This estimate takes into account the delays in obtaining permits, sanctions and finance, the time taken to procure equipment and materials, the magnitude of the developmental effort and, above all, the time taken to train technical staff.

Coordination in this field has three goals; on an immediate basis, to initiate steps to cater urgently to the pressing needs; as an intermediate objective, to institute positive promotional efforts, to close the gaps that exist in production technology, material availability, and process knowhow; and from the long term point of view, to start and follow through R & D work in appropriate areas concerned with computer equipment, techniques and systems. There will, in addition, be need to have continued review and evolution of policy in all these aspects.

Therefore, the best policy as far as the development of the computer industry is concerned is to rely entirely on indigenous technological innovation so that our development will be relevant to Indian conditions and will keep pace at all times with the Indian needs without over emphasising technological sophistication that is unnecessary and expensive. Towards this we need to establish and bring up a totality of infrastructure spanning semiconductor and other component development, circuit development, hardware, peripherals, software, systems engineering, etc. In order that we do not waste our time and resources, we must pool our efforts initially into a single unified project of sufficient size, what has been referred to as critical size, that will support self-sustained growth. The nation has abundant potential for computer usage as well as adequate rich talent for developing the industry entirely in a self reliant way. We must rely on it.

MANAGING TECHNOLOGICAL INNOVATION - SOME ASPECTS

A major challenge we face in the development of the computer industry is the management of technological innovation. The computer industry is characterised for its high technological innovation content and for its employment of large number of highly intellectual personnel especially in the Research and Development. In this context "innovation" means that process by which a new idea is successfully translated into economic impact within our society. Only after an invention is put into sufficient use to have an economic effect, can it be termed as an innovation. It is necessary to stress that technological innovation is more than Research and Development. The management of technological innovations is much more than the maintenance of a R & D Laboratory.

Research and Development and Technological innovation raise some difficult problems for management. This is because they are relatively young corporate activities, and have certain characteristics which differentiate them from other corporate functions. Research management is not only the critical difference between a good oraganization and an average one, but research is the most difficult to manage of all functional activities. There are three main reasons for this special difficulty. The first is the degree of uncertainty, second is that you are managing a new kind of employee who views himself as a professional person. Scientists and Engineers differ from other employees in their expectations, values, attitudes, and motivations. The third source of difficulty is measuring results of research projects when each task is unique and never repeated. Even if one could measure the results, the delay in the feedback loop is so great that it is hard to use the knowledge of results as a basis for planning in future.

Dr. Sarabhai, expresses his views on this problem thus :

"The type of administration required for the growth of science and technology is quite different from the type of administration required for the operation of industrial enterprises, and both of these are again quite different from the type of administration required for such matters as the preservation of law and order, administration of justice, finance, and so on. The general absence of the proper administrative set–up for science is a bigger obstacle to the rapid growth of science and technology than the paucity of scientists and technologists, because a majority of the scientists and technologists we have are less effective through the lack of the right type of administrative support. The administration of scientific research and development is an even more subtle matter than the adiministation of industrial enterprises." The administration or management of such innovational and developmental activities thus raises a relevant question as to how this has to be tackled, both at intra-organisational level and inter-institutional/national level.

There are various approaches or thoughts expressed by various management scientists on this aspect of managing innovative organisations. It is established by these scientists that a different type of structure is required to organise for innovative tasks. After a study of organisation structures in over hundred electronic and other innovation based companies in Scotland, Burns has argued that innovation is more likely to flourish in a framework which is "Entrepreneur Centred" rather than "Management Centred." "In management-centred organizations," says Burns, "the problems and tasks facing the concern as a whole are broken down into specialisms. Management, often visualized as the complex hierarchy familiar in organization charts, operates a simple control system, with information flowing up through a succession of filters, and decisions and instructions flowing downwards through a succession of amplifiers. Entrepreneur-centred systems are adapted to unstable conditions, when problems and requirements for action arise which cannot be broken down and distributed among specialist roles within a closely defined hierarchy. Communication between people of different ranks tends to resemble lateral conclutation rather than vertical command. The entrepreneur-oriented organization, while it does not stress hierarchical structure, is none-the-less structured. Structure is on the basis of expertise in handling the problem faced at the moment. Who is 'best authority,' is settled not by hierarchical directive but by consensus. In this organization the individual's commitment to the organization is far more extensive than in the management-centred one. In the latter organization the task and the length of the work day are explicitly defined. In the entrepreneur centred organization commitment is to 'what has to be done.' If things are required outside what might be a normal set of task, one is still expected to do them."

"This general concept," Burns continues, "is confirmed by at least one other study which showed that almost all the inventive and innovative events in the development of six complex weapons systems in the USA took place in an "adaptive" environment in contrast to an "authoritarian" environment. Of course, the description of "management/authoritarian" systems and "entrepreneur/adaptive" systems is to some extent caricatural, and the distinction between them artificial. Some functions may best be performed within the framework of a "management" system, whilst others may require a mixture of both. But the evidence suggests that, whilst new science-based firms tend to be strong on entrepreneurship and weak on management, the reverse danger exists in large establishment firms."

Charles Handy, Professor of Management Development at the London Business School approaches the problem, by viewing "culture" as an organisational characteristic. According to him, in the 'role' culture or bureaucracy, the work of and between functions is controlled, by procedures for roles, procedures for communications, and rules for settlement of disputes. Rules and Procedures are the major methods of influences. The efficiency of this culture depends on the rationality of the allocation of work and responsibility rather than on the individual personalities. The role organisation will succeed as long as it can operate in a stable environment. Role cultures are slow to perceive the need for change and slow to change even if the need is seen. The task culture is job or project oriented. This culture is extremely adaptable. Groups, project teams, or task forces, are formed for a specific purpose and can be reformed, abandoned or continued.

This organisation works quickly since each group ideally contains within it all the decision making powers required. Individuals find in this culture a high degree of control over their work, judgement by results, easy working relationships within the group with mutual respect based upon capacity rather than age or status. Control in the task culture organisation is difficult. Essentially control is retained by the top management by means of project allocation and people and resource allocation. Top management feels able to relax day to day control and concentrate on resource allocation decisions.

Dr. Sarabhai also states that the conditions under which scientists and professional workers are motivated are somewhat different from those prevailing in bureaucratic or industrial enterprises. Money, hierarchical status, and power are important needs for most, but to scientists and professional groups need for autonomy of working conditions and self-development are also important factors. Most of us are familiar with the hierarchical organization structures involving vertical controls which continue to dominate governments whose principal role until recently was one of preserving a social order. They carry an administrative service, characterised by anonymity coupled with security of tenure, insulating individuals from outside pressures. The system has built-in controls which act negatively, attempting to stop a wrong thing from happening. To realize how distant this culture is from one wherein innovators are involved in developmental tasks, we can examine some of the factors which have been observed in the study of atomic energy. Among professional groups of scientists and engineers, motivation and control was largely inherent and contained in professional commitments. Control was exercised through discussion and judgement of peers, with administration performing largely the role of service. Autonomy of working conditions and self-development were important to the innovators. Horizontal control systems are effective when they involve mobility and interactions.

Thus, R & D and technological innovation create new and sometimes difficult problems for management. This is partly due to the relatively recent growth of R and D and innovation as important management functions, and partly due to certain unique characteristics which, – as we have seen with regard to organization – may require adaptation or rethinking of conventional management practices. The prime requirement for the successful management of innovation would appear to be entrepreneurship – not only in individuals but also in organizational forms capable of transmitting knowledge and information across functional and divisional boundaries, and of responding rapidly to change, and in evaluation methods which take account of technological and market uncertainties and of the nature of the various stages of the innovation process. These organizations need an appropriate mix of the management and enterprise orientation.

This analysis of the peculiar managerial demands in an organisation dominant in the innovation – R & D culture leads logically to the next managerial complication in the innovation chain : how effectively to transfer technology. Let us look at one important area viz., transfer of technology and inter-institutional mobility of scientific personnel, where government can consciously promote a policy. The transfer of technological knowledge is mainly "person embodied." In his study of 567 successful innovations in U.S. industry, Myers found that personal experience and personal contacts were responsible for three-quarters of the information inputs to these innovations. This means that the effective transfer of technological knowledge requires the encouragement of personal mobility and person-to-person contacts, both within and between institutions involved in various parts of the innovation process. According to Mayers' report, successful science-based firms "spun off" from quasi governmental laboratories at MIT are precisely those where the degree of knowledge transfer is the highest. A more liberal attitude by the governments towards knowledge transfer person-embodied or otherwise – could lead to a greater commercial return from existing technological capabilities. Person-to-person contacts are the essence of effective collaboration. This, government can encourage through a number of mechanisms, ranging from the financing of "concerted actions" – in other words, research programmes which university and industry undertake jointly, to the establishment of institutions or mechanisms through which scientists and engineers from the universities and industry can meet – and have an incentive to meet – continually and informally. This effectiveness of the latter method should not perhaps be under-estimated. The work of scientist depends crucially on the interaction with others. It is therefore of utmost importance for most scientists to keep in constant touch with their fellow scientists. Absence of such communications is the main contributor to the feeling of "scientific isolation," which is one of the primary enemies of scientific morale in the developing countries. Indeed, it is a disheartening thought to realize that compared to other colleagues, one is handicapped from the outset by a lack of information and contact. According to a report of U.S. National Academy of Sciences to the Committee on Science and Astronautics, the best way of technology transfer is through moving people with ideas all the way from development through production and the organisation should make this easy. It is very difficult to transplant new ideas from one organisation to another by any other means.

An illustration in point is the experience of ECIL, which is an industry with an innovation dominant organisational culture. The accepted motivational standards here spring from the need to achieve, to progress steadily to results targeted and towards this to overcome all bottlenecks and problems and to find satisfaction in a task done – in short, a task-centred culture, not rule bound but finding its discipline within the frame work of team spirit and commitment. It is interesting to note that ECIL's base of indigenous know-how which forms its exclusive fount for all manufacturing and management know-how, was transferred from the R & D laboratories of BARC to Hyderabad by transferring a group of 300 people who were working in the electronics R & D of BARC. Even today at ECIL transfer of a product from R & D to manufacturing is achieved by making the R & D team itself take up manufacturing – in other words, the mode of transfer of know-how is through transfer of people and not through transfer of notes and manuals alone. The principle operates all the way to marketing and has been result bearing in that it has made ECIL a quick economic success.

So far we have discussed the problems and various approaches suggested with regard to management of innovational activity at the intra-organisational level. Let us now consider some general aspects of policies and plans required at the national level in a developing country like India. It is all too evident that the less developed countries face serious problems in the form of shortages of qualified personnel and capital funds needed. Also, certain development policies (such as investment and industrialization strategies, protectionist policies, etc.) may have more effect on technological progress than science and technology policies per se.

Hans Heymann Jr. of RAND corporation discusses the problems with reference to Turkey and the same are very much relevant in a developing country like India. The more sophisticated techniques and approaches of advanced countries have little practical utility to developing countries. He illustrates the point by describing three "dubious solutions" adopted in advanced countries that have no significant transfer value. He views from the perspective of a developing country, that there are only two points that need to be made about the tools of "systems engineering" adopted in United States for R and D Management : (1) they were created to cope with a very special set of problems in a very special environment, and (2) more often than not, even within that special environment, they don't work.

He attributes the Soviet successes achieved in such fields like astronautics, space and nuclear, not for the system but for breaking out of it. In the field of aeronautics, the Soviet government resorts to extraordinary high-level intervention to overcome the indifference of the bureaucracy. It will, for example, endow certain carefully chosen design groups with a great deal of power, authority, and resources; it will assign a particular development task to several competitive design bureaux; it will reward success with sharply progressive bonuses and honorific awards; and it will vertically integrate the administration of the system to assure better interaction and information flows.

He discusses the Japanese Solution what he calls "symbiosis" which means, that unique set of mutually-supporting relationships between the government, the financial system, and the private sector, that has made the Japanese economy probably the most efficient in the world in absorbing advanced technology and in generating growth. Japan's success can be attributed to the functioning of a very special system, all of whose parts interact to stimulate growth. The unique situation in which the national economy of Japan now finds itself, including its extraordinary ability to sustain a high rate of innovation, must be largely attributed to pre-conditions that existed, and policies that were adopted in the Meiji Era of Japanese industrial development. However much we may admire the effectiveness of their approach, it is surely not transplantable to a different set of circumstances and to an environment that is not as favourably endowed.

After analysing the success of developed countries, Heymann Jr. finally suggests a strategy based on Concentration and Selectivity for developing countries. The strategy, very simply, is to concentrate substantial effort on building a few islands of scientific and technological excellence, rather than to diffuse all efforts over the entire sea. The aim would be to bring about selective improvements in the effectiveness of research and technology by focussing high-quality talent and resources on a few priority areas. Essentially, it would involve the steps : (1) identifying a few critical problem areas of national importance and of high probable innovative response; (2) locating for each area the most qualified and respected talent or the most distinguished institution doing promising work in that area; (3) supporting such talent or institution with sufficient resources and authority to permit mounting a concerted, sustained attack on the sea. The process sounds deceptively easy. In fact, of course, it would almost certainly encounter some difficulties of implementation, but hopefully on a much more limited scale. One advantage of the "critical problem areas" approach is that it dramatizes particular problems and thus makes it easier to arouse enthusiasm and to mobilize energies toward their solution. Another is that novel precedent-breaking activities can be confined to a single problem area at a time, thus not disquieting the entire system. Also, by basing the effort on the best ongoing work and the most prestigious people and institutions in each area, the new activities would be built on strength, would be developed within existing structures, and would be assured of a significant element of support.

It is worth considering the relevance of this proposal to our country. After building up of such islands of excellence, the link-up of all such islands through a plan is the major task of the Government. However, this is not too complicated as we know by experience at ECIL. The evolution of ECIL has followed the pattern of first establishing islands of excellence in different fields such as process instrumentation, ultrasonics, servo controls, components, communications, computers, etc. in the form of technology groups working independently but subsequently integrated into one corporate organisation with a view to make the output of these groups economically viable.

This scheme has to be followed on a nation-wide scale to bring about the required technological development. It will, on the other hand, be an exercise in frustration and infructuous expenditure, if we try to copy the approach of advanced countries to establish technological projects where a large organisational scheme is first drawn up to suit the project conceived, then proceeding to fill up the organisation with people with the requisite specialist skills.

In conclusion, we see that there is wide scope for computer usage in a developing country like ours. The computer demand of the country is best met by relying on indigenous technological capabilities presently available in various fields. Care should be taken to see that the development effort is compatible to the Indian conditions. Nurturing the available islands of expertise in different areas of computer activity and creating new islands wherever required will result in the creation of a strong technological base in the country and will help accelerate the development of the country. The organisational atmosphere, to bring up these innovative activities, should be one, which encourages task culture and is free from stifling rules which curb the creativity and initiative of the personnel; it should be one which fosters team spirit and individual commitment to the organisational objectives. The structure of the organisation should help growth – growth of the men with their work. Transfer of technology is best effected through transfer of people with the product spanning development, manufacturing and marketing. Emergence from ECIL of fifty wholly indigenous computers, in the short span of four years is proof of the effectiveness of the above methodology. There is every reason to believe that the policy of self-reliance will be of maximum benefit to the country, in the long run, and the day is not far off where we can have large indigenous computer systems matching contemporary international standards.

LIST OF REFERENCES

1. "Gaps in Technology – Electronic Computers," Report presented for information at the third ministerial meeting on science of OECD countries, 11th & 12th March 1968.
2. Report of the Panel on Mini Computers, 1973, Department of Electronics, Government of India.
3. Special supplement on Computers – Science Today, March, 1975.
4. "Research & Development Plan for Electronics & Communications" – Preliminary Plan submitted to Planning Commission, by IPAG, Electronics Commission.
5. Proceedings of National Conference on Electronics, 24–28 March, 1970.
6. Speech by Monsieur Andre Danzin, Directeur de l' Institut de Recherche de' informatique et d' Automatique at the Indian Computer Society's Conference, New Delhi, February 26 – March 1, 1973.
7. "Conditions for Success in Technological Innovation," OECD Report, Paris, 1971.
8. "Management of Research and Development," papers presented at Seminar organised by the Scientific and Technical Research Council of Turkey, Istanbul, 4–8 May, 1970.
9. Handy, C. B. : "So You Want to Change Your Organisation – Then first identify its culture," paper presented at the Top Management seminar on Organisational Development at Indian Institute of Management, Bangalore, 25th-26th January, 1975.
10. Sarabhai V. A. : "Management for Development," Vikas Publishing House Pvt. Ltd., Delhi, 1974.