Distr.
RESTRICTED

LC/R.471/Rev.1
30 May 1986

ENGLISH
ORIGINAL: SPANISH

E C L A C

Economic Commission for Latin America and the Caribbean

INFORMATION SCIENCES AND A DIFFERENT TYPE OF DEVELOPMENT FOR THE REGION */

*/ This document was prepared by the Joint ECLAC/CTC Unit on Transnational Corporations.

86-5-775

CONTENTS

Summary

In view of the severity of the social and economic needs faced by the countries of the region (which include a long list of interrelated problems and phenomena such as the extreme poverty in which large segments of the population are living, the decrease in real per capita income, rising unemployment, and economic and social heterogeneity), it might well be asked whether or not information sciences are a priority issue for the region. Given these characteristics of the countries of the region, food supplies, education, health, and social and economic articulation appear to be much more urgent questions. Nevertheless, the potential and flexibility offered by information technology gives us reason to think that an appropriate orientation of its technological uses would provide the means for satisfying the region's most pressing needs.

This hypothesis, together with the argument that the prevailing concepts and forms of development in the region need to be changed, has given this study its title and forms the central idea which will be developed here.

The starting point for this line of thinking is a deeply critical view of the existing forms of development of industrial civilization which are based on the uncontrolled degradation of matter and energy; this is what has given rise to the present crisis, as manifested in the increasing difficulty encountered in gaining access to scarce natural resources and in the runaway increase in environmental pollution. Hence the need to seek other forms of development which will be less dependent on the matter/energy matrix and more closely linked to non-material elements: the development of certain elements of culture and knowledge, such as the intelligent processing and classification of information. This is where information sciences come into the picture as a technology capable of augmenting information and of making it feasible to pursue a different type of development which would be more in keeping with a materially-finite world. This is what leads the countries of the region to seek a non-imitative style of development in which information sciences, rather than being used the same way as they are in the countries of the centre, will be used to more directly resolve the countries' most pressing needs.

Along with the development of this line of thinking, the basic purpose of this study is to help foster a discussion of this subject, which is of vital importance to an understanding of the sweeping changes which are buffeting our society.

/Finally, it

Finally, it should be clarified that in this study, the terms "information technology" or "information/electronics complex" are understood as referring to a group of related technologies primarily consisting of computer sciences, automatic control systems, digital control, robotics and all the technologies associated with telecommunications.

I. THE STRUCTURAL CRISIS OF DEVELOPMENT AND INFORMATION

There is general agreement about the fact that a technological revolution is now underway which will affect virtually all human activities. It is also agreed that the information/electronics complex and bioengineering constitute the main driving forces behind these changes.

The aim of this chapter is to demonstrate that this revolution is a consequence of the structural crisis now being experienced by world economic development and that, in accordance with the ideas propounded here, even its most fundamental concepts are being affected.

The crisis of matter and energy currently being experienced on our planet is manifested in the depletion of natural resources or the increasing difficulty encountered in gaining access to them, as well as in the steady rise in pollution and in all manner of disorders, ranging from the material problem posed by the accumulation of wastes to the social problem posed by the increasing ingovernability of our institutions.

Because of the material constraints which exist, new concepts of development must stress non-material factors (i.e., information, knowledge and culture) in order to counter the consumption or degradation of matter and energy which has thus far characterized present forms of development.

To the extent that new technologies carry with them the potential for making a qualitative leap forward in the management and expansion of information and knowledge, they open up the possibility of devising new development styles in keeping with a materially-finite world and with mankind's vast cultural potential.

1. Matter, energy and the economic process

In an attempt to gain some idea of why society is headed so resolutely and rapidly towards the intensification and mass use of new technologies, a few energy-related concepts must be borrowed from the field of physics for use in our analysis.

The law of the conservation of matter/energy (the first law of thermodynamics) states that it can be neither created nor destroyed, only transformed. The law of entropy amends the latter part of this definition to read: "only degraded".

Because it is so far-reaching, the law of entropy (the second law of thermodynamics) has been defined in many ways. Briefly, it can be stated that: in a

/closed system,

closed system, matter/energy is constantly changing (degrading) from a usable or low-entropy state (a state of order and/or concentration) to an unusable or high-entropy state (a state of disorder and/or dissipation). This process can only be reversed by incorporating low entropy (usable matter/energy) from outside the system into it, thereby producing a greater increase in entropy outside the system than the decrease achieved within it.1/

In the course of his ruminations as to which of the laws of science merited description as the "supreme law", Albert Einstein expressed the opinion that the greater the simplicity of a theory's premises, the more diverse the categories of things among which the theory established a relationship, and the greater its range of applicability, the more impressive a theory was. In that sense, classic thermodynamics was the theory which had made the greatest impression on him. It was the only physical theory of universal content which Einstein felt certain would always be valid within the range of applicability of its basic concepts.2/

In respect of its range of applicability, in the field of biology for example, the phenomenon of life can be said to consist of the compensation of continuous entropic degradation through the absorption of low entropy and the expulsion of high entropy. Any living organism, in order to remain in that state, must absorb low entropy from the environment (usable energy, food) and expel high entropy into the environment (wastes, residual heat).

In like manner, the economic process of production (whose fundamental objective is to keep a society alive) interacts with the environment by absorbing low-entropy matter/energy (natural resources) and expelling high-entropy matter/energy (residual heat, wastes, pollution).

Today's industrial societies are based on the utilization of power, which can be defined as the speed with which useful work is obtained from low-entropy energy. This is a way of replacing and amplifying the work done by human and animal muscle-power, which was the only source of usable mechanical power in earlier societies.

Non-industrial (hunting or farming) societies lived by making use of the flow of solar energy captured by vegetation and converting the energy stored in grass into meat, the energy stored in wood into heat. With the patterns of consumption and growth prevailing in the economies of industrial societies, however, they are only able to maintain themselves by using the stock of solar energy which has been stored up during the past 600 million years in fossil fuels (coal, bituminous shale, petroleum and natural gas).

/The constraints

The constraints resulting from the depletion of this stock create a need for research and development of a new energy system based on the flow of the sun's power, which, besides being renewable, has the added advantage of being clean. This is highly important because the limitations imposed by the environment as regards the accumulation of wastes or pollution are even more overwhelming than the depletion of the stock of resources: the present flow of matter/energy in industrial societies produces wastes and acid-laden water as a result of mining; oil spills from wells and during transport; radioactive wastes from nuclear plants; and all these processes produce residual heat. In the medium term, the main restriction on the consumption of energy will be the thermodynamic impossibility of getting rid of residual heat.

One fact which should be clarified at this point is that the entropic nature of the economic process is such that the perpetual recycling of the process' wastes is not a possibility, inasmuch as, according to the law of entropy, an amount of low-entropy matter/energy which is greater than the decrease obtained in the entropy of the recycled matter/energy must be injected into the system in order to carry out recycling.

An indefinite increase in consumption (or, more precisely, degradation) of matter/energy is physically impossible. Even without reference to its thermodynamic basis, the truth of this statement is becoming increasingly evident, as is the impossibility of an indefinite continuation of the growth of the human population.

2. Towards new styles of development

Although the development style of the central countries (unsatisfactorily imitated by some peripheral countries) has made it possible to satisfy the basic needs of a portion of the world's people, it should be made clear that this has been achieved at the cost of the exploitation of the planet's stocks of matter/energy on a massive scale which has resulted in their rapid depletion and irreversible ecological damage.

The imitation of this style of development by the countries of the periphery therefore constitutes a thermodynamics impossibility and is tantamount to ecological suicide, inasmuch as a large part of the planet's resources have already been used up in attaining the central countries' present level of development, and the resulting global entropic burden in many sectors does not allow for any further increases.

/This makes

This makes it necessary for us to re-think current development concepts, especially those which equate development with a per capita increase in material consumption. So long as society has no technology which would allow it to live on the flow of energy, the law of entropy will prevent a steady growth of consumption, and its manifestations will become increasingly apparent. The ecological manifestations which have begun to appear, such as the extermination of thousands of species in the depths of the North Sea, the Mediterranean and the Great Lakes of North America, are not just apparent but dramatic.

A review of the concepts associated with the present development style give reason to think that it is not only the style of the peripheral countries which should be revised. The paradigm of the prevailing development style is to be found in the countries of the centre. This model has ignored the laws of matter and energy based on the idea that the power of technological progress is unlimited and will always provide a substitute for a depleted resource and a way of increasing the yield obtained from any type of matter/energy. This idea, as well as other similar notions, is borne of a type of metaphysics prevalent in the modern world which is based on a profound conviction that mankind is immortal and capable of overcoming any limitation if faces. Thus, in an act of faith, today's civilization has jeopardized the future of coming generations by overconsuming the stock of resources before its technology has demonstrated that the above idea is correct.

The dubiousness of this conviction is illustrated by the confidence with which it was believed, until recently, that fossil fuels would be replaced by nuclear energy. Even before the series of accidents of the type seen at Three Mile Island or Chernobyl, it had become clear that, because of its high production costs as well as its serious implications for health and safety, it would not be possible to put nuclear fission into use on a massive scale. In view of the fact that the wastes produced by nuclear fission must remain buried and well-sealed for 25 000 years before they are rendered harmless, this technology is inhumane, as well as unviable. Disillusionment with nuclear fission gave way to hope in the promise of nuclear fusion. Fusion involves even greater technical problems, inasmuch as this nuclear reaction requires a temperature of 100 million degrees centigrade, and no known material exists with which a receptacle could be made to contain the reaction. This has made it necessary to direct research towards the construction of a "receptacle" in the form of a magnetic trap. This subject, which belongs to the field of plasma

/physics, is

physics, is certainly an exciting one, but it is to be feared that, in so far as its practical use is concerned, nuclear fusion may well suffer the same fate as nuclear fission.3/ This type of reaction can probably only take place in a form which is safe for mankind in outer space, as has been occurring in the sun for millions of years, even though no major scientific and technological effort has been made to concentrate the energy freely intercepted by our planet and hence render it usable.

Those who are called upon to stop the progressive destruction of the planet's resources or to improve environmental conditions also betray some confusion about thermodynamic concepts, inasmuch as it is impossible to turn back time or to reverse the increase of entropy. The truth of the matter is that, in the best of cases, all that mankind can do is to prevent any unnecessary degradation of matter and energy, with "necessary" degradation being understood as that which is required to sustain a decent quality of life. It must be borne in mind that any excessive degradation is not only an extravagance but also shortens the time during which the continued existence of mankind will be viable, and is thus an ethical problem in so far as it affects the lives of future generations. At this level of abstraction, it may therefore be said that the first problem to be dealt with in defining a style of development is a metaphysical and especially an ethical one, since it is necessary to determine what level of degradation of matter/energy will provide present generations with a decent quality of life while having the least effect possible on the quality of life of future generations as well as on the length of time during which mankind will be able to exist on earth.

3. The role of information in new development styles

Today's changing society will have to devise major scientific and technological innovations in order to reduce pollution, increase the yield of the system, control wastes and mitigate the effects of the constraints imposed by the depletion of the resources in stock.

These innovations, on whose success the existence of a new society will have to be based, will only be feasible if new scientific and technological know-how can be obtained by means of an intelligent processing of information on a massive scale. This appears to be the vital role which the information/electronics complex has already begun to play in the transformation of society.

/The possibility

The possibility that information sciences can ease the entropic burden of society may be reinforced at a higher level of abstraction by using probabilistic concepts to show that an association exists between information and low entropy.

Independently of any thermodynamic consideration, information theory has devised a mathematical definition of an entropic function, as a measurement of uncertainty, which has the same functional representation as the entropic function of thermodynamics. The same point could have been arrived at by using thermodynamics and the concept of mixed entropy as a starting point, with information being defined as the number of decisions necessary to reorder a mix, since both entities --that of information sciences and that of thermodynamics-- are really the same concept.

The closeness of the relationship between energy and information has prompted the observation that "the increase of entropy is nothing more than a decrease in information".4/ It also gives rise to the illusion that an intensified use of information could alleviate the entropic burden of society.

Everything seems to indicate that the difficulties created by a decrease in the consumption of energy would be attenuated by an increase in the amount of available information. One example would be the replacement of a large proportion of passenger transport (an activity involving a large amount of energy consumption or degradation) by an increase in the quality and quantity of communications systems (an activity involving a low level of energy consumption).

In industry, rather than substituting information for energy, energy could be saved by increasing yields through the introduction of information/electronic innovations in production systems.

In both the areas (transport and industry) cited as examples, the increase in the supply of information would result in reduced energy consumption and in improved yields from the transformation of energy, along with the resulting decrease in the generation of wastes. This would not, however, free society from its dependence on the dwindling stock of energy resources or the mounting accumulation of high entropy or pollution.

The imperative need to find an energy source which would not increase the planet's heat burden translates into a need to discover a technology which will allow the flow of solar energy to be transformed directly into usable mechanical power. By serving as an important aid to scientific and technological research, information sciences can speed progress towards such a breakthrough.

/The countries

The countries of the region, which face this structural transformation of society at a stage of incomplete industrialization, with disarticulated economies and enormous social needs, will have a much more arduous task before them than the central countries will, and must therefore make a major imaginative effort in order to establish realistic and viable goals within the proper context.

A first step in this direction is probably to rid themselves of the concept of a "technology gap", which is a reflection of a certain lack of imagination. In essence, the technology gap has been defined as the distance separating two states of technological development based on a comparison between a low level of technology in a peripheral country and a high level of technology in a central country. Logically speaking, the concept of a gap, which denotes distance, can only exist if the peripheral country wishes or is striving to reach the technological level of the central country. However, if the peripheral country aspires to different goals, the gap vanishes.

Technology's raison d'être is necessarily the satisfaction of needs; the technology developed or adopted by a peripheral country will therefore be entirely up-to-date if it is capable of meeting that country's needs, even if it is far removed from the technological level of a given central country. Certainly, this concept eliminates the idea of a gap and therefore permits a peripheral country to set its own course or, in other words, to employ a dynamic process in defining social objectives which will respond equitably to the needs of the entire population.

Thus, both the introduction of external technology into the countries of the region and the development of their own technology will have to be oriented towards communication and articulation among the branches of their economies and towards the satisfaction of their most pressing social needs.

II. TECHNOLOGY

It has been argued for quite some time now that technology may be the cause of the social problems of the countries in the region because the technology which has been introduced into the periphery has been designed for, and is appropriate to, the conditions of the central countries. Nonetheless, it must be borne in mind that the problems which have arisen (such as the regressive distribution of income, or

/consumption patterns

consumption patterns oriented towards a minority group within the population) are not an intrinsic part of any given technology, but are rather the result of inequitable social relations arising out of unequal access to political power. Technology's essential objective is to satisfy needs with a minimum of effort; the ways in which its benefits are appropriated is a question which lies outside its domain.

Nonetheless, it is important to realize that although a technology may be socially neutral, its application may result in major social changes. The direction taken by these changes, however, depends upon the political action taken to decide the use to which such innovations will be put.

Modern technology has also been accused of causing alienation or dehumanization. Nevertheless, a technology may be intrinsically good, yet people may be alienated by the way in which it is adapted or used by a society. The same technology may be used for war or for peaceful purposes. Television, for example, is a highly useful technology in the field of information, but is constantly being used to foster precocious or superfluous consumption that serve as a major driving force for the dynamization of the present social and economic system within the context of prevailing concepts of development. Using methods which in some cases involve subliminal messages, television advertising creates fictitious needs within society in order to generate types of demand that will serve the interests of the production system. This appears to be the reason why our society, while having a totally programmed and controlled education system, permits virtually hypnotic types of education in the form of uncontrolled advertising. The alienating factor is thus the compulsion to consume which is induced by advertising, rather than a technology whose objective is to transmit information via a shower of cathode rays projected onto a screen.

The example of television is no more than a faint reflection of a much more thorough-going phenomenon which consists of the submission of metaphysical principles to the paradigms generated by the natural sciences and technology. This is because the natural sciences have overtaken metaphysics and the social sciences, thereby leading to an uncontrolled use of technology, which in many cases has harmed society more than it has benefited it. Just because something can be made does not mean that it should be made. Technology has come to be the "how" and the "what" of production, whereas the "what" properly corresponds to the realm of policy, backed up by the social sciences.

/The new

The new technologies, and particularly information sciences and electronics, hold out great possibilities and hopes: a substantial increase in productivity, the freeing of human beings from uncreative activities, the possibility of a new concept *of development whose style would involve a more equitable distribution of surpluses*, and above all, the possibility of prolonging and sustaining the life of society through the generation of additional knowledge.

The factor which will determine whether these hopes are to become a reality or whether they will remain unrealized is not the potential of technology, but rather mankind's wisdom as it is reflected in the social, economic and political system adopted by society.

1. The development of technology

Before discussing information policies or any other policy on technology, it would be helpful to arrive at a clearly-defined concept of technology and a systematic picture of the development of technology.

Inasmuch as the word "technology" has been worn out by advertising, which has so stripped it of its meaning that it is now thought of as a product which can be bought and sold, we must first establish its true meaning. Technology is essentially knowledge and it must therefore be learned rather than purchased.

Thus, since a country's or any collectivity's body of knowledge forms part of its culture, technology is also an important part of that culture and in this sense is a collective quality.

This collective connotation is what allows a systemic concept of the development of technology to be formed by making a distinction among three categories of knowledge which, while distinct, are also inseparable in so far as they constitute a system. Firstly, there is creative technology, which is the type of knowledge that makes possible technological research and development and the planning and design of new equipment. Secondly, there is production technology, which is the type of knowledge that permits the economic manufacture of equipment based on the qualitative and quantitative fulfilment of plan specifications. Thirdly, there is user technology, which is the type of knowledge required for the efficient use of equipment in order to raise productivity and reduce the need for human labour.

/These three

These three categories of knowledge both feed and provide feedback to one another, thereby forming a system. The development of technology is made possible by the interaction of these three types of knowledge, as shown in figure 1.

In the schematic illustration of this system, it may be seen that creative technology receives input in the form of information about requirements for new products and functional specifications from user technology and about manufacturing restrictions from production technology; in turn, its output (the results of research and development) is provided in the form of plans and designs for production technology and in the form of data on existing technological constraints in the development of certain products for user technology. The inputs for production technology consist of the plans and designs provided by creative technology and the qualitative and economic restrictions imposed by users (user technology); its output is equipment for user technology and manufacturing restrictions for use by creative technology. The exterior circuit, which runs clockwise, is formed by functional specifications, plans and designs, and products (capital goods), and constitutes the driving force behind the development of technology. The interior circuit, which runs counter-clockwise, is formed by user, manufacturing and technological constraints, and slows down or regulates the speed of technological development since, in each case, these constraints essentially represent the frontier of knowledge as well as the limits of economic and industrial feasibility.

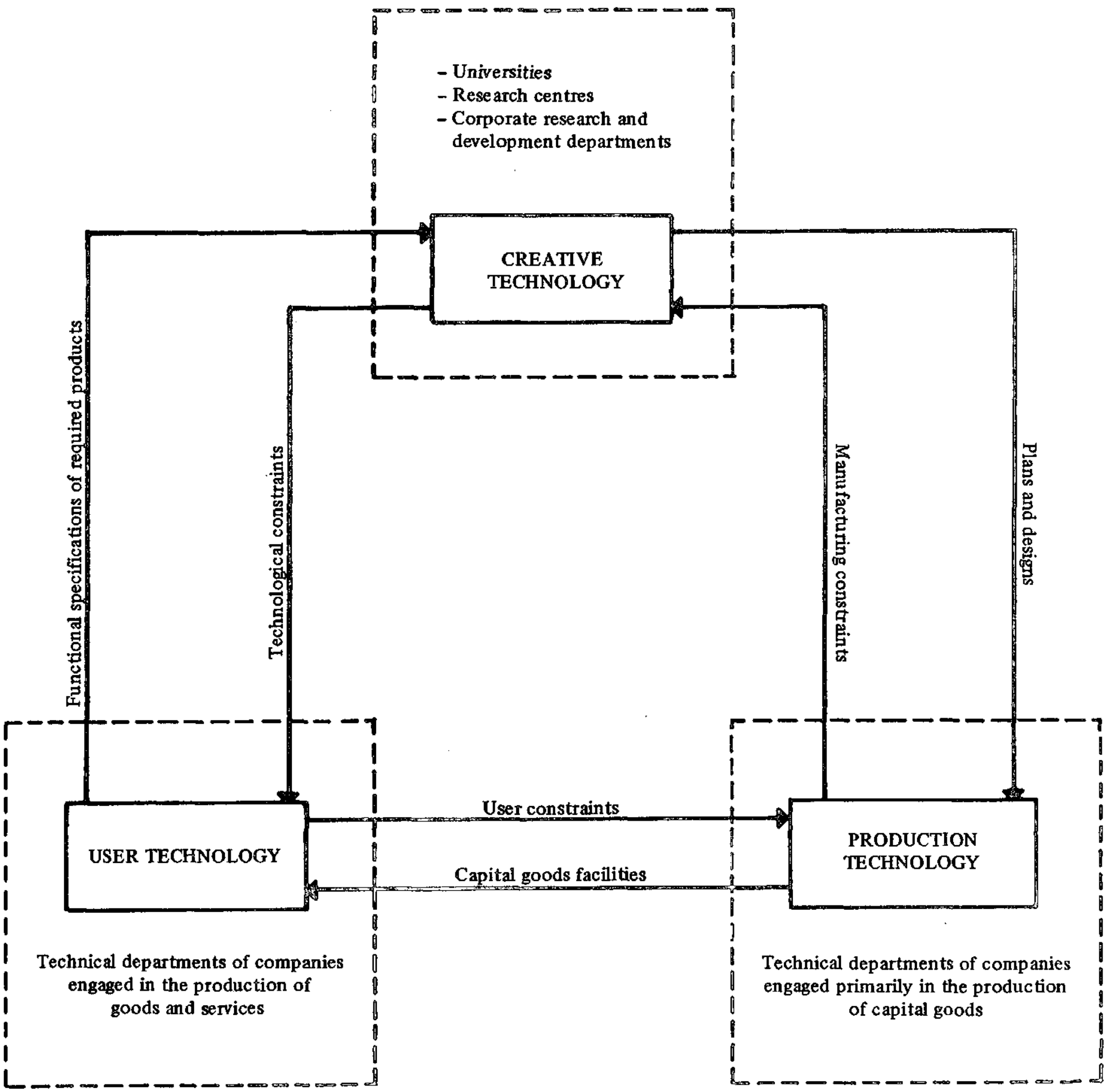
In systems theory, the word "system" is basically used to designate the "inter-connectivity" of the various elements. In other words, a system is, by definition, a system of relationships, which means that all systems involve a type of relationship or link connecting the different component elements. Information is transmitted by way of these relationships, and each component of the system will either do or cease to do something when the information reaches it. In summary, a system can be said to be a network of informational relationships which set its different components into operation.

The relationships which form the system of technological development basically involve information. In the case of the driving (exterior) circuit, these connections carry the information which activates the receptor component. Thus, creative technology is activated by requests for new goods and services required by the economic system; production technology is activated by new plans and designs; and user technology is activated by the improvements brought about as a result of

/Figure 1

Figure 1

A SISTEMIC PORTRAYAL OF TECHNOLOGICAL DEVELOPMENT



/the utilization

the utilization of more productive tools. This is obviously a self-feeding circuit, and it could accelerate indefinitely if it were not for the existence of the regulating (interior) circuit, whose connections provide feedback to the various elements in the form of information about the constraints associated with technological know-how, economic feasibility and the capacity of physical infrastructure.

In technologically-autonomous countries, these three categories of technology are present within the country and are closely linked to one another. In general terms, they are distributed roughly as follows: creative technology is generated in the universities, research centres and corporate research and development departments; production technology is situated and generated primarily in the technical departments of companies producing capital goods; user technology is to be found in the technical departments of companies producing consumer goods and services. It should be noted that in the case of information sciences, user technology is to be found in all three centres of knowledge, since information sciences are used in the universities and in all types of companies to manage and process information. This points up the interesting fact that information sciences is a technology which assists and augments all the others because it reinforces the network of informational relationships which set the components of any system into motion.

Generally speaking, technologically-dependent countries only have user technology, with the other two categories of knowledge remaining outside the country. This prevents the creation of information links which would form the driving force or circuit behind technological development. The absence of any one of these categories of knowledge means that the others must divert their activities to other spheres, to the detriment of their primary function. An example which is close at hand is provided by the countries of the region; their failure to incorporate the capital goods industry into their industrialization process has caused the technological circuit to remain incomplete in many areas due to the lack of production technology. As a result, the other categories of technology have had to stray from their objectives towards secondary goals which are lacking in dynamism. At this point, information technology can be used as an example: a number of countries in the region use information systems, especially computer systems, quite heavily in the production apparatus of various branches of their economies, and they

/thus have

thus have a certain degree of user technology. They also have good universities which could constitute centres of creative technology, but because they lack a computer industry, they are not able to close the circuit and the universities are therefore caught up in a vicious circle in which they only train professionals in user technology and teach technicians to use computers, providing instruction in computer languages rather than in computer architecture. In those few cases where professionals are trained in advanced technology, they often have to emigrate due to the lack of professional positions in which they can apply and expand their knowledge.

All of the above points to the need for technological policy to be coupled with an education policy, a policy on research and development and an industrial policy covering both users and capital goods.

2. Technology, national security and autonomy

The expansion of the information/electronics complex into all sectors of modern economies and the vulnerability of technologically-dependent countries create a need to look at technological progress in another light, and this involves taking a different approach to national security. Up until now, the idea of national security has essentially had a military connotation in the countries of the region, but the time appears to have arrived when it is necessary to extend this idea to include other fields.

In this study, the term "national security" is used to refer to the degree of autonomy characterizing a country's production process. Thus, from this standpoint, the highest level of national security would be reached when a country is not only capable of providing essential goods and services to its population, but is also autonomous with respect to natural resources and its own technology. Using this absolute, certainly utopian, level of security as a starting point, various degrees of national security can be defined, as well as different levels of dependence, which is its counterpart.

Thus, a country can sustain its production process while being autonomous in terms of natural resources but dependent on others for the technology it needs. On the other side of the coin, it may have technological autonomy and be dependent on others for natural resources (matter/energy) which it does not possess. The consequences of these two types of dependence are not the same, however.

/It is

It is interesting to note in this regard that dependence on an external supply of matter/energy is basically a much more critical state of affairs than is dependence on external technology because the continued existence of society is at stake as regards the flow of matter/energy, whereas in the use of one technology or another, the only thing at stake is a difference in productivity. It thus seems paradoxical that the most developed nations are those which have technological autonomy, even though they lack natural resources. An example is provided by the case of most of the countries of the region, which are rich in matter/energy but not highly developed, while most of the European countries and Japan, which are relatively poorer in matter/energy, are developed nations.

The only explanation for this paradox is the geographic concentration characterizing the generation of specialized knowledge. Because of the power conferred by a mastery of technology (knowledge), the geographic distribution of the consumption of matter/energy bears little relation to the geographic distribution of natural resources. There is obviously a close correlation between a nation's degree of technological autonomy and its level of development; indeed, it may be said that technological autonomy is virtually a prerequisite for development.

Judging from the amount being invested in the information/electronics complex, the countries of the centre seem to be quite aware of the fact that knowledge is a major source of power. Their desire to maintain their hegemony in international relations prompts even the most liberal economies to act as planned economies in creating preferential conditions for investment in research and development in the field of information technology. Japan is an extreme case due to its lack of natural resources, as is illustrated by a statement made by an official of the Ministry of International Commerce and Industry:

> "Our resources are limited and we need to take a technological stride forward so that we can earn the money we must have in order to eat and to buy petroleum and coal. Until not long ago, we were lagging behind foreign technology, but now we are going to pioneer a second revolution in information sciences. If we do not do so, we will not survive."5/

In all events, the fact should be borne in mind that a technology capable of producing a substantial increase in intellectual capacity could give rise to a new balance of world power. As things stand now, the power imbalance between the developed and the underdeveloped worlds will tend to increase with the introduction of new information technology. The application of intelligent policies on information sciences by the countries of the region hold out the only hope of lessening this trend.

Another important consideration for the countries of the region is the concept of technological autonomy in basic economic sectors. Most of the economies in the region have very few, if any, sectors which are technologically autonomous from a nationwide or regional standpoint. The vast majority of the basic sectors in these economies are technologically dependent on countries outside the region.

Experience has shown that a lack of technological autonomy in an economy's basic production sectors makes it more vulnerable to any type of outside aggression than any lack in the country's military defence does. An embargo placed by a central country on inputs or replacement parts for capital goods in a basic sector of a peripheral economy has proved to be a much more harmful and more politically-usable weapon and form of pressure than the force of arms. It would appear that power relations among nations are now much more closely linked to technological autonomy in basic sectors than to traditional military might.

Thus, in considering guidelines for the formulation of policies on information sciences, the foregoing factors must be taken into account not only in order to understand what is occurring in the centres, but, much more importantly, in order to put the prospects for progress of the countries of the region into proper focus.

3. Technology transfer

Since technology, because it is actually knowledge, must be learned rather than bought, the phenomenon of technology transfer is a difficult one and requires certain conditions which are not always in evidence; as a result, attempts to transfer technology often meet with failure.

Technology transfer is the transmission of knowledge from one group to another which makes the receiving group capable of performing certain functions. In order for such a transfer to be useful (in the sense of enabling the receptor to adapt the technology it obtains to its own situation) and stable (in the sense of allowing the receptor to offset the rapid obsolescence of technology at a later date), the transfer of knowledge must be complete, both in terms of the transfer of creative, production and user technology, and in terms of transferring technology which covers the entire spectrum of information involved, ranging from the frontier

/of knowledge

of knowledge to the most basic details. Otherwise, technology transfer is no more than an illusion which rapidly vanishes in the face of obsolescence and non-adaptiveness. In order for technology transfer to have the above characteristics, the transmitter must have the intention of carrying out a complete transfer, while the receptor must have the professional and collective capabilities required in order to acquire the entire range of knowledge involved in the technology that is being transferred.

So-called technology transfer carried out by means of the emplacement of transnational corporations in the countries of the region has been incomplete, to say the least. For the most part, transnational corporations are the vehicle for a specific form of the international division of labour which runs counter to adaptable and stable technology transfer. Most of the subsidiaries set up in peripheral countries carry out activities involving low-level technology, such as the production of consumer goods and of trivial parts for capital goods and the assembly of parts produced in other countries. The technology involved thus remains under the control of the parent company and a complete transfer of technical know-how to the periphery does not take place. In the best of cases, a partial technology transfer occurs, usually of user technology which rapidly becomes obsolete or inapplicable due to a lack of adaptation.

Modern companies' production methods make it virtually impossible to carry out a complete technology transfer such as that described above. The production methods currently used by corporations involve a planned division of production based on a fixed compartmentalization of the production line whereby those working in one compartment do so in accordance with a programmed routine which does not require them to master the technology of their own compartment or even to know what is being done in neighbouring compartments on the production line. This means that operators' knowledge is confined to a pre-established manual concerning routine operations, and the operator's intelligence and decision-making abilities therefore play no part in the process. If, in addition, the complementary compartments of a single production line are located in different countries, then the technology in question undergoes total dismemberment. Under these conditions, any technology transfer is clearly impossible.

/These are

These are the types of production methods used by high-technology transnational corporations: their operations are divided up among subsidiaries which assemble the various parts, while the technology as such is concentrated in the parent company, which distributes operating manuals to its subsidiaries that contain technical instructions for assembling parts, that, while they contain the technology, represent no more than a "black box" to the subsidiaries.

If the object is to carry out technology transfer, it is unlikely to be achieved through the emplacement of a transnational corporation. In the region's experience, these subsidiaries usually employ professionals of the country in question as personnel managers, technicians whose job it is to adapt assembly manuals, or as technical salesmen. Given this situation and in view of the fact that many companies' power is based on their ownership of technology, it would be utopian to hope that any sort of useful technological knowledge is going to be transferred by this means.

III. INFORMATION SCIENCES

The importance of information sciences in modern societies is a subject which has been widely discussed and publicized. Even at the risk of being repetitive, however, it is useful to address the subject from the standpoint of the increasingly close link between information sciences and virtually all branches of production and services in modern economies.

Information systems for monitoring and controlling production and management have spread so widely throughout industry that, today, a large proportion of industry executives believe that computer monitoring systems have become a true corporate necessity and that the absence of such systems would seriously harm production. In the services sector, finance in general and banking in particular are not only using information sciences in their management systems, but offer a wide variety of new services which are only possible because of the progress that has been made as regards the information/electronics complex. With industry being invaded by digital control systems in machine-tools and by robotics on production lines, it is clear that the information/electronics complex, whose presence is felt not only in control and management systems but also on the production line itself, is becoming the nervous system of society's production apparatus.

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All this may be very well, especially in view of the fact that the formation of this new nervous system has given rise to striking improvements in the productivity of most sectors of those economies that are making full use of information sciences. Yet this phenomenon has involved relations of dependence which have not been sufficiently assessed. Never before has the world seen such an increase in subordinate relations as that now occurring in those linking the vast majority of the branches of production with the single branch represented by the information/electronics complex. Realizing this, an increasing number of large companies in other branches of activity are buying or investing in companies which form part of the electronics complex; they do this not only for profit, but also --and basically-- because they realize that the productivity of their own branch of industry is increasingly contingent upon the incorporation of the latest information/ electronic innovations into their line of production. The direct objective of such investment is thus to gain technological autonomy.

New information processing units, whose headlong advance and wide dissemination have been made possible by the invention of microprocessors, are invading all fields. Microchips have been introduced into automobile engines and dashboards; into offices through the introduction of wordprocessors, photocopiers and microcomputers; into the capital goods industries within machine-tool control mechanisms; into the consumer durables industry, housed in sewing and washing machines; in the consumer goods trade within cash registers and fuel pumps; in all sorts of instruments and mechanical tools in general; and, of course, in electronics. The list is extremely long, but it may suffice to say that today a large part of the world's people carry a microchip on their wrists.

The potential of this technology moved the OECD to describe the information electronics complex in its interfutures report as the main nucleus for the reorganization of advanced industrial societies' production structures.

1. Fifth-generation computers, artificial intelligence and the extensiveness of the changes now underway

The long-standing controversy concerning the feasibility of artificial intelligence or of building a "thinking machine" appears to have turned into a race among the developed countries to be the first to build fifth-generation computers.

In order to give an idea of what "fifth-generation" means, it might be pointed out that the advent of this generation will put an end to another controversy which

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has long raged among Spanish-speakers as to whether these units should be called "computadores" (computers) or "ordenadores" (ordinators, or organizers). In view of their new features, a consensus will surely be reached to call them "razonadores" (reasoners). They will be approximately one thousand times faster than any of today's units, will be able to understand written and spoken words, will be able to speak and, above all, to reason.

What will set fifth-generation computers apart from their forerunners will basically be a new concept in their basic design. Computer generations have generally been classified according to their main technologies:

- First generation (1951-1958): electronic vacuum valves;
- Second generation (1959-1965): transistors;
- Third generation (1965-1971): integrated circuits;
- Fourth generation (1972-19 ?): large-scale integrated circuits.

The design of these four generations has been based on the overall concept of John von Newmann, according to which they are composed of a central processing unit, an arithmetical unit, a memory, and input and output devices; their basic feature is that they operate sequentially, or in series (in other words, step by step). Fifth-generation computers, on the other hand, will represent an abandonment of von Newmann's scheme; they will work with parallel architectures and will be capable of dealing not only with numbers but also with symbols.6/

The fifth-generation concept is based on the obvious fact that most intellectual activity involves inference (i.e., reasoning) rather than calculation; hence the need for new units to be capable of dealing with symbols as well as numbers so that they can process symbolic logic programmes. Some precursors in this respect are already in operation under the name of expert or specialized systems; although still at a rather modest level, it has been demonstrated that a computer can be given the ability to reason, within certain limits, just as a doctor reasons when he makes a diagnosis, as a chessplayer does when he carries out a strategy or as a chemist does when he determines the atomic constituents and the structure of a molecule.

The new computers will (and "expert systems" are, at an incipient stage, already doing so) work not only with data bases but also with "knowledge bases"; they will not only operate by means of sequential calculations, but also by means of inference. This means that in addition to data processing, they will process facts,

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hypotheses, beliefs and experiences or empirical rules in order to reach correct (heuristic) conjectures. It also means that, in the course of such processing, the computer will form lines of reasoning such as syllogisms or use methods of back-chaining towards an objective. The concept of a "knowledge base" has a very profound meaning and far-reaching implications. Among other things, it involves the storage of information which is synthesized, condensed, classified, and in general, processed in such a way that it is no longer merely information but becomes knowledge. Furthermore, a "knowledge base" draws upon the information contained in specialized texts and which is taught in universities, but it also draws upon heuristic knowledge, i.e., the experiences and perceptions of the specialists working on the design of the programme in terms of empirical rules which lead to the formulation of correct assumptions. Heuristic knowledge cannot guarantee results in the way which mathematical algorithms do, but it normally provides the desired results. All of this points to an overwhelmingly important feature of artificial intelligence, which is its ability to enrich its knowledge base with the experiences obtained by the programme in each processing run. In other words, the computers will be able to improve their performance based on their past experience.

Knowledge-based systems are within the realm of applied knowledge, i.e., the application of knowledge to a specific, specialized task. Yet it is unlikely that any such system could be designed to develop general theories. It might almost be said that all artificial intelligence is applied, inasmuch as experimental results are required which will confirm the theoretical assumptions contained in the programme. If a programme does not produce experimental results which could be described as intelligent, then the theoretical bases contained within the programme should be discarded. The engineering of knowledge, as a branch of artificial intelligence, is not concerned with searching for general laws. Currently, it is primarily focusing on specialized systems and, within this category, on three priority subject-areas: firstly, the representation of knowledge, which involves studying ways to represent specific knowledge about a field or discipline as data structures within a computer's memory so that they will be accessible for use in problem-solving; secondly, the utilization of knowledge, which consists of studying the design of methods of symbolic inference in order to be able to use knowledge in problem-solving; thirdly, the acquisition of knowledge, which consists of studying

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methods of acquiring the academic and heuristic knowledge contained in textbooks, in the minds of specialists and in the experience gained by an intelligent programme in the course of its work.

Programmes already exist, albeit within narrow fields of application, which are exhibiting intelligent behaviour in the sense described above. Using these programmes, even in present-day computers, a certain degree of success has been achieved in certain branches of medicine in connection with the diagnosis and treatment of disease, as well as in chemistry as regards the determination of molecular structures and components, in geology with respect to mineral prospecting, in information sciences in relation to the diagnosis of system failings, in that sphere of biology concerned with genetic structures and in the field of "knowledge engineering" itself.

It should be noted, however, that specialized systems involve a type of artificial intelligence which has some serious limitations. The first is, precisely, its specialization, inasmuch as the narrowness of its field of inquiry (due to the unwieldy size of the knowledge bases required by each specialization) prevents the acquisition of the desired degree of general knowledge and multidisciplinary behaviour. Another limitation, which is more important from the conceptual standpoint, is that this type of artificial intelligence is basically dependent on a programme that, while it may contain a great deal of "intelligence" in respect of the methodology of reasoning, is --as a programme-- entirely lacking in creativity.

In response to this lack on the part of specialized systems, another line of research into artificial intelligence has arisen. This line of inquiry is more closely associated with cibernetics inasmuch as it is primarily based on research into how the human brain operates; its field is that of systems of thought rather than methods of reasoning. Those involved in this line of research maintained that thinking is not a regulated processing or manipulation of symbols, but rather the result of complex inter-neural connections which form circuits that feed one another and receive feedback from one another.

On this basis, research on artificial intelligence within the field of cibernetics involves the study of how densely-interconnected circuits produce output which is consistent with input signals but does not specify programmes that would govern this procedure; rather, the system will be allowed to find its own solutions by trying out different link-ups within the circuits. This approach is pointing the

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way to a processing system which would be closely associated with flexible hardware and whose architecture is based on a large number of parallel lines of processing; processing and memory units would be spread out along the circuits, there would be almost no central control, and the only software would be some general instructions, such that the circuit could, without programming, freely find solutions based on stable-state concepts drawn from statistical mechanisms or from probability theories, rather than on the logical sequence represented by algorithms.

This concept, which focuses on computer hardware and is based on the microelectronic imitation of neurophysiological discoveries, involves a central technology which is distinct from the one described in connection with fifth-generation computers, and might therefore be classified as sixth-generation.

The ramifications of the sweeping changes which these computers, whatever their generation, have begun to bring about within society are of enormous proportions; their true magnitude is not yet known or even suspected, but at the least it may be said that they are changing our ways of thinking. Today it is generally agreed that the mental processes of an educated person are very different and much more complex than those of an illiterate. Experience in working with a present-generation computer changes our ways of thinking to some degree; the use of a fifth-generation computer will surely open up an entire new world to us, and its impact on society will probably be as great as that of the introduction of the printing press.

2. The social impact of information technology

Before computers were introduced into the production process, the characteristic which all the machines used on production lines had in common was that they helped, replaced and amplified the physical work done by man by transforming some form of energy. Now, however, the characteristic shared by all computers and related units of the information electronics complex is that they help, replace and amplify the intellectual work done by man by transforming some form of information.

People who work with their minds have begun to experience what many other workers have been experiencing for decades: the replacement and amplification of their skills by machines. In effect, industrial society displaced manual skills by converting manufacturing into "machinofacturing" by transforming energy into useful work, but the intellectual activity involved in control and management remained the

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domain of human beings. The new "information society" has begun to displace productive intellectual work as well as by changing "machinofacturing" into "sistemofacturing" based on a more intensive application of information sciences in management (both within and between companies) and computer control of robots on production lines.

If the introduction of energy-based machines into the economic production process produced sweeping changes in social structures, then the incorporation of information-based machines will also give rise to a new, and no less important, restructuring of society.

To be sure, the process of change will not be free of social problems. Manual workers' opposition to the introduction of energy-based machines will probably be mirrored by non-manual workers' opposition to the introduction of information-based machines. Nonetheless, this new technology will result in increases in productivity which will free people from non-creative work.

It therefore does not seem logical to oppose the introduction of this new technology; a more suitable response would be to take care to channel the impact of its introduction towards the creation of a more viable and equitable society.

The displacement of human labour which is reflected in the steady rise in unemployment in the central countries has at least one positive aspect; income has come to be a right of citizens which is guaranteed by the State. In all countries of the centre, a person who is out of work receives unemployment insurance payments in an amount which comes quite close to the wages of an employed person, in addition to the health services and education which are guaranteed by the State, and this is equivalent to an increase in real wages. Even more importantly, it means that access to the goods and services which constitute society's product is ceasing to be wholly dependent upon remuneration for the work performed by an individual. In order to maintain and increase a social scheme of this type, real increases in productivity are obviously required. Fortunately, new technologies are making this possible. This trend stands out even more clearly if we take into account the fact that the introduction of information technology, and especially robotics, lowers the labour component in the cost of goods and services to less than 10%; if human productive labour, either physical or intellectual, is replaced and amplified by machines in the same way, then this means that the new social structure will provide the necessary conditions for changing the prevailing forms of inequitable appropriation

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of surpluses. Whether society will take advantage of these conditions or not will depend more on political variables and its social organization than on technology, inasmuch as the way in which technology develops and spreads is a consequence of social relations.

IV. GUIDELINES FOR POLICIES ON INFORMATION SCIENCES IN THE REGION

Thus far, we have examined information sciences' great potential for bringing about sweeping social and economic change. If, in addition, it is considered that these new technologies are reaching the region at a time when its industrialization is incomplete and its economies and societies are disarticulated and, furthermore, if the fact is borne in mind that the introduction of these innovations into the region's precarious social and economic systems is already beginning to take place on a disorganized and random basis, then it becomes clear that policies on information sciences need to be established which will provide a frame of reference for an appropriate incorporation of these technological advances into the countries of the region.

The necessity for such policies becomes an imperative one if new (non-imitative) forms of development are to be shaped, since the way in which this technology is introduced would then have to be consistent with a new development style that is more in keeping with the specific characteristics of the region.

The foregoing considerations, in addition to the great variety of types of knowledge involved in the technology of the information/electronics complex and the broad range of fields in which the new technologies can be applied, suggest that, at the least, the following three concepts should be regarded as general criteria in this connection: Firstly, the feasibility of introducing and developing these new technologies in the countries of the region is contingent upon a significant role being played by the State, just as the State has been the driving force behind the development of the information/electronics complex in the countries of the centre. Secondly, the development of this technology requires effective co-ordination among technological, educational, industrial and social security policies. Thirdly, and no less importantly, the degree to which the countries benefit from this new technology will be determined by the level of regional integration achieved in this sector.

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In other words, whatever future course of development the region embarks upon, if the characteristics of this new technology are to be successfully combined with the specific characteristics of the countries of the region, action on three different fronts will have to be taken simultaneously: the State will have to act as a dynamic motivating force, the social and economic context will have to undergo a process of adaptation, and regional integration of the sector will have to be carried forward.

1. The importance of the State in the development of information sciences 7/

In the central countries, it may be seen that microelectronics is developing more rapidly than other high technologies. This is undoubtedly due to the determined effort which the State has made in these countries to promote this branch of technology ever since the development of technologies related to information sciences, telecommunications and electronics began. From the time of the Second World War onwards, these technologies have been developed with State financial support in response to these countries' military requirements.

So it was that the first computers made their appearance early in the post-war period. The United States' technological leadership during this period may be attributed to the State demand which was channelled through the military/space-administration complex and other government institutions. The United States Government also engaged in open protectionism under the "Buy American Act" adopted by the Department of Defence, under which preference was given to the purchase of nationally-made equipment so long as its price was not more than 50% higher than that of similar foreign-made equipment. This is what permitted United States industry in this sector to get off to such a roaring start. Even today, the United States Government continues to earmark a great deal of resources for research and development, its stated objective being to remain at the forefront of technological progress with a view to becoming the first post-industrial society on earth.

In Japan, State involvement in the sector began in 1958 with the establishment of the "special measures for promoting the electronics industry" act of the Ministry of International Trade and Industry, which has financed research and co-ordinated the activities of large private Japanese companies ever since then. This process was stepped up in 1973 in response to the oil crisis and Japan's strategy was redefined so as to benefit high-technology sectors by promoting production which

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represented a high value added. Early in the 1980s, the Ministry of International Trade and Industry took the offensive as regards planning the development of information sciences by launching a 10-year plan to build fifth-generation computers; it created an institute of technology for this specific purpose and is providing special financing and co-ordination services to the research laboratories of the leading Japanese companies in the sector.

In the beginning, the European computer industry did not receive systematic State support; even though European universities and research centres introduced major technological innovations in this field, the initial lack of State demand was very probably what permitted the penetration of the United States industry, which dominated European markets and companies in this sector until the mid-1960s. From 1965 onwards, in response to this penetration (which was referred to in Europe as the "American challenge"), European governments began to promote national industries by fostering consortiums of companies dealing with related technologies and by establishing some policies to boost State demand in the sector. Nonetheless, due to the absence of more determined State action, United States industry still holds sway over most of the information sciences sector in Europe.

If State involvement has been a fundamental factor in the development of information technology in the countries of the centre, it can well be imagined that State participation is absolutely essential to the achievement of any objective in this field in the countries of the region.

It is highly unlikely that the challenge which international trade in information technology and electronics poses to the region can be dealt with by means of open-market policies and the free interplay of market forces. The countries of the centre apply carefully thought-out protectionist measures and plan their selection of fields in which they wish to develop high technology with the clearly-defined objective of increasing their hegemony over international trade. The countries of the region (which, as has been discussed, should modify their style of development in the medium and long terms) must, in the short term, apply policies which will link up over time with their strategy for achieving "a different type of development" but which, at this point in time, will lessen the impact of this new offensive launched by the centres.

The importance of the State's role in the development of information sciences in the region has already been demonstrated by Brazil. Brazil's present regional

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leadership in this field is primarily due to the role which the State has played in formulating policies which, based on a concept of national security and technological autonomy, provide for the State to take an active part in training the human resources required for this new technology and in the reservation of market shares in order to allow national industry to undergo the necessary learning process.

Brazil has won its present place at the forefront of regional information technology by virtue of the fact that its policies have provided for the systemic integration of the three types of knowledge discussed previously. From the very start, this policy has promoted creative technology in universities and research centres and today, in addition to the research being carried out in universities, there is a Technological Centre for Information Sciences (CTI) which serves as an independent agency of the Special Department for Information Sciences. Production technology is being developed by private and State computer and related industries with the help of legal provisions for reserving market shares with respect to certain areas of the information/electronics complex. As in other countries, user technology is the domain of private and State users in virtually all the other branches of the economy. With this basic infrastructure, i.e., a complete system, Brazil is in a position both to develop its own technology and to assimilate foreign technology effectively.

The size of Brazil's domestic market has certainly contributed to its present leadership role in the region as well; this only means, however, that smaller countries will have to compensate for the limited size of their markets by ensuring that the State exerts a relatively greater degree of influence, by improving the co-ordination of their social and economic adaptation and, above all, by means of a major integration effort in the region.

2. Technological, economic and social articulation

The development of a country's own technology or the effective assimilation of modern technology from without require the conditioning or simultaneous development of other spheres of society, particularly education, industrialization and social security, in order to adapt and augment the advantages of such technology and to minimize any harmful effects it may have.

New information technology presents the countries of the region with the possibility of linking up the different elements of their economies (or, more properly, of their societies) and so to make these currently disarticulated elements into a system.

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Thus, whereas information/electronics technology tends to be focused on personal consumer goods in the countries of the centre, in the region this technology should be exclusively directed towards increasing productivity in general, achieving technological autonomy in basic branches of the production system and towards improving nutrition and basic services such as education and health. It should be stressed that information technology, because it "amplifies" information, carries with it an enormous potential for bringing about economic and social improvements and for generating and disseminating knowledge which can be used to produce material improvements in living conditions and to provide the mass of the population with access to cultural sources in the countries of the region.

a) Education policy

The headlong increase in knowledge which is occurring as a result of new scientific and technological breakthroughs is making some ideas about education obsolete. For example, the concept of an illiterate person, which used to be a cultural description of a person who was seriously hampered from being useful to himself or to society, has become outmoded. Today this category has shifted its position within the cultural context, and an illiterate person is beginning to be seen, not as someone who does not know how to read and write, but as someone who is incapable of transmitting or receiving new information; according to this new definition, an estimated 40% of the United States population would be classified as "illiterate". While it is certainly disputable, this concept is put forward here as a means of illustrating the dynamic character which some classic parameters for the measurement of education may have.

It is also important to realize that the concept which has gone by the name of "comparative advantages" is, from an international standpoint, increasingly dependent on the capabilities and knowledge of the population and less and less so on a people's geographic location or the natural resources they possess.

Clearly, in order to deal with changes of such enormous proportions as those currently taking place, the countries of the region require more and better education: "more" in the sense that society needs to devote more time and more resources to education; "better" in the sense that education must be oriented towards the specific characteristics of the region and towards raising efficiency through the use of this new technology.

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The problem of reorienting education may be addressed from a variety of different angles. One consideration is the problem of providing professional support for the development of information/electronics technology; this is a matter of quite some complexity inasmuch as it not only involves possessing advanced science and technology, but also entails ensuring that the majority of the people understand the new technology since, as already discussed, technology is collective in nature. Thus, the region needs professionals with a solid background in software (symbolic logic, Boolean algebra, relational algebra and information-storage structures, among other disciplines) and in hardware (especially in solid-state physics, semiconductor electronics and telecommunications systems). These professionals must also, however, have a solid humanistic background so that they are capable of undertaking the social management of the uses to which technological progress may be put and of orienting new lines of research.

The collective nature of technological knowledge means that, at differing levels of detail, it must be disseminated on a very large scale. In this respect, middle-level or technical training is even more important than advanced training. If technological development is to be achieved, it is essential to have the mid-level manpower capacity needed in order to carry out the delicate manual tasks required by these new technologies. Actually, this is a cultural problem which exists throughout the region whose origins are surely to be found in the inequitable gap that exists between manual and non-manual workers' incomes. Very probably, the greatest obstacle at present to the development of information/electronics technology in Brazil is precisely the shortage of manpower trained in mid-level technical skills, as evidenced by the fact that the equipment maintenance system constitutes a major bottleneck. In view of the fact that the greatest limitation on the further progress of virtually all areas of high technology is constituted by what is known as precision mechanics if the region is to achieve any type of substantive technological development, it will have to make a major effort to teach technical manual skills on a massive scale and to give recognition to the cultural worth of those who are capable of using their hands to produce useful goods and services for society.

Another consideration as regards education is that, in addition to an educational system for children, the rapid growth of knowledge creates a need for an ongoing system of adult re-education at all levels so that people may continually

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update their knowledge and thus avoid joining the ranks of the "new illiterates". Fortunately, such a re-education system is becoming increasingly feasible thanks to the new technology ("tele-education") and to the increasing amount of free time being made available as a result of the gradual displacement of human labour in the production process.

Everything seems to indicate that a new educational scheme will have to prepare society to phase out a large part of its consumption of matter/energy and to "consume" knowledge in its stead. This might perhaps be achieved by reorienting the present sort of consumerist "tele-education" carried out in the form of uncontrolled advertising towards an ongoing system of re-education by embuing advertising with an educational character which it currently lacks.

b) Industrial policy

No matter how well co-ordinated technological and educational policies may be, they will not achieve their objective if they are not coupled with an appropriate industrial policy. Technological innovations as well as scientific and technological experts need to interact with the industrial system. Technological advances must be adapted to industrial capabilities, and the professionals who are trained in accordance with educational and technological policy require jobs in industry where they can apply and improve their knowledge. In summary, technological development calls for close co-ordination among universities, research centres and industry, as occurs in Japan, for example.

Furthermore, if the object is for the region to have its own technology which is adapted to its needs and to be in a position of technological autonomy as regards the basic sectors of its production systems, then industrial policy in the region, whatever its nature, will have to place special emphasis on filling the existing gaps in the capital goods industry. Whatever style of development the region may adopt, the technology which will interpret that style will take the form of capital goods. In other words, a given technology corresponds to a given development style, and any technology takes the form of the capital goods it makes available to a society in order to give concrete expression to its form of development. In this sense, capital goods define a country's development style. The region needs capital goods which suit its specific characteristics, and information/electronics technology has a great deal of potential in this regard.

c) Social security policy

The object of linking technological policy with social security policy is both to orient technological potential towards social objectives and to minimize the harmful social effects of technology.

Thus, from the standpoint of social security, information technology in the countries of the region should be directed towards improving the population's access to health services by providing mass coverage; this, in turn, would be achieved by using hardware and software that are appropriate to a situation in which there is a shortage of high-level medical personnel.

Moreover, a large part of the educational needs described above could be met by using mass media and computers more intensively in the education system, even without increasing the number of schools or teachers.

Another --and no less important-- way of using this technology to further the articulation of regional society is to improve the supply of information and knowledge made available to the isolated agricultural sectors of the region in order to increase the efficiency of planting and harvesting and, thus, to produce a larger and higher-quality food supply.

If the use of information technology by the countries of the region can bring about improvements in the fields of education, health and nutrition, then more serious attention should be paid to its potential in this respect.

One of the harmful social effects which the region must guard against is the isolation or tendency towards individualism which is produced by a close relationship between men and machines. If this relationship is useful in the production system, then it will have to be put up with as a necessary evil, but when this same type of relationship takes the form of entertainment or sport, then it seems to be an aberration in at least two senses of the word: first, two or more people engaging in a form of sport or entertainment with a machine rather than with one another seems to be asocial by definition; secondly, technology is expensive, and its use for entertainment thus implies a confusion of priorities, an economic absurdity for a developing country, and a manifest example of social insensitivity.

The other important point to be brought out with respect to social security policy relates to the displacement of human labour caused by new technology. In view of the fact that, in general, the rate of manpower absorption is lower than the growth rate of the working-age population in the region, it is imperative from a

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social and political standpoint to begin to loosen the connection between work and personal income by establishing social security policies which are conducive to freer and more equitable access to education, health, and the basic goods and services that are society's product.

3. Regional integration in the information sciences sector

In keeping with the prevailing line of thinking in the central countries, it has been suggested that peripheral countries should orient their development of information technology towards software because it is an activity which makes intensive use of better-paid labour, its production is not very standardized, competition in terms of its prices is therefore less keen than it is in the case of hardware, and because software is intensive in intellectual labour whereas hardware is capital-intensive. This is an attractive suggestion to the countries of the region, given their present position as net capital exporters which do not have enough jobs to offer to their professionals, but before subscribing to such a strategy, we should consider the fact that the rapid progress being made in semiconducter technology is making it increasingly easy to put software of all types inside microchips. Software is therefore becoming hardware or, to put it more accurately, a sharp distinction between software and hardware no longer exists; in its place, there is a broad "grey" area referred to as "firmware", which contains both categories. In addition, the difficulties involved in protecting software are at least as great as those which exist in the field of publishing with respect to the protection of copyrights; if the countries of the region were to devote themselves to developing and marketing this type of product, they would therefore run a serious risk of having to deal with clandestine trade in software and, what is still worse, of suddenly finding that a development effort which has taken several years has been supplanted by the marketing of the same software housed within a microchip.

The rapid and fluctuating changes characterizing the progress being made in information technology make it necessary to undertake a balanced development of hardware and software, which are actually interrelated categories that feed one another and receive feedback from one another in accordance with market requirements.

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Furthermore, inasmuch as the development of information sciences in the region should be directed towards meeting its specific needs, joint development of hardware and software is imperative if the region is to follow its own path rather than following in the steps of the central countries.

Therefore, the requirements of a non-imitative and technologically complete type of development, the variety of disciplines involved in information technology, and the limited size of the markets of the individual countries in the region all indicate that regional integration in this sector is the only viable strategy for dealing with the challenge posed to the region by the development of these new technologies.

Talk about integration in the region seems to bring on a general mood of pessimism, since most integration efforts have achieved only a very small part of their objectives, when they have not ended in complete failure or in statements which do no more than enrich the rhetoric of the field, if that. One of the factors which has played a large part in this situation is probably the lack of executive authority characterizing the bodies that have been created to promote integration, inasmuch as they usually have performed a co-ordinating function but have not had executive power. In view of the vital importance of the information sciences sector and the speed of its development, any integration body in the region must, from now on, have an executive as well as a co-ordinating function within the sector.

The foregoing considerations, combined with the fact that companies are the type of organization which are in the best position to perform an executive function, suggest the possibility of creating a multinational (as opposed to a transnational) company whose owners would be those countries in the region which wish to take part. The objectives of such a company may be summarized as follows:

i) To orient the development of information/electronics technology towards the satisfaction of the region's most pressing needs (education, health, social and economic articulation, and technological autonomy in basic production sectors);

ii) To disseminate these new technologies so that they may be assimilated by the population of the partner countries by setting up a number of production subsidiaries and research and development centres within these countries;

iii) To boost other sectors of the countries' economies by reaching joint research agreements with local universities and agreements for the supply of inputs with national companies;

iv) Since the development or orientation referred to in point i) above is either lacking or at a very preliminary stage in the central countries, a regional company of this type could attempt to fill this technological niche, covering potential markets in this sector in less developed countries of Africa and Asia;

v) To create jobs in the region for national professionals and technicians specializing in technologies related to information sciences/electronics.

In order to put such a company on a sound footing, the partner States would, as a minimum, have to provide strong support in connection with the following basic aspects:

i) The provision of an initial capital outlay to permit the company to be established and initial operating capital, which could later be recovered in the form of profits;

ii) The protection of the company's market and the provision of assistance in the form of State purchases of equipment along the lines of the "Buy American Act" (worth imitating) by the partner countries;

iii) The concession of tax and tariff advantages for inputs manufactured by subsidiaries of the company located in other partner countries.

The creation of such a company would not be free of problems. Nonetheless, the efficient introduction into the countries of the region of this new technology is a very complex task no matter how one goes about it, and the formation of a multinational company seems to be the most direct way of achieving the objectives that have been discussed. Any measure of success achieved in this regard would have the added advantage of serving as a paradigm for other sectors of the economy as regards regional integration.

4. Possible short-term measures

Thus far, this chapter on policy guidelines in the field of information sciences has primarily taken a medium- and long-term view. Nonetheless, the current impact of the technological offensive launched by the centres requires that decisions be taken rapidly in order to lessen the harmful effects of the indiscriminate and imitative application of such technology in the countries of the region without its prior adaptation. With this in mind, a series of suggestions which might prove useful in connection with short-term decision-making are made below:

a) Each country of the region needs to generate a small group of high-level professionals whose training has prepared them to understand the wide variety of new technologies and their applications so that they are able to identify obsolescent technologies and to recognize possibilities for adapting a given technology to a country's actual needs and its specific social and cultural patterns. Such a group of professionals would have to be capable of fully understanding the latest scientific and technological advances and would also have to have a solid cultural and social background so that they would have a clear idea of what a country's real needs are.

b) The purchasing of equipment by the State or by autonomous State enterprises should be such as to promote the standardization of hardware so that State computer facilities would be compatible, could provide back-up for one another during maintenance and so that the development and use of software could be shared by the various State institutions. The current proliferation of incompatible brands and systems in the public sector belies a lack of co-ordination, to say the least. Ideally, this type of standardization with a view to compatibility should not be confined to the institutional level of a single State, but should be carried out throughout the region at the State level in order to avoid a duplication of effort and to expand the market of software for State use in the region.

c) The present balance-of-payments constraints affecting most of the countries of the region would seem to point to the advisability of concentrating imports of information technology/electronics in those product lines which could be considered as capital goods for use in the production and basic services sectors while discouraging the expenditure of foreign exchange on imports of electronics designed for consumer use or entertainment. This would have the added advantage of safeguarding national sociocultural values.

d) Although, as has already been discussed, in the medium and long terms it would be best to undertake a balanced development of hardware and software, in the short term it seems advisable for the countries of the region to start by giving priority to software technology because, apart from the fact that this step could

/be taken

be taken immediately, it would save capital and foreign exchange and, above all, would help to generate high-level professional skills in the region. It should be stressed that a policy emphasizing software would only be advantageous in the short run, during which time the region can gear up for a major hardware development effort involving, for example, the creation of a multinational informatics enterprise such as that outlined above.

Notes

1/ In everyday language, the second law of thermodynamics states that, when things are left to themselves, they tend to get mixed up and do not return to an orderly state by themselves (see Bertrand Russel, The Scientific Outlook).

2/ G. Tyler Miller, Jr., Energetics, Kinetics and Life, Belmont, California, Wadsworth, 1971, p. 46.

3/ Fission: the division of an atom into its component protons and neutrons.
Fusion: the union of two nuclei of one element by which another element is formed.

4/ G.N. Lewis (1930).

5/ Sozeburo Okamatsu in La quinta Generación, Feigenbaum and McCorduck.

6/ A precursor of such a computer has just been put into operation at the Lawrence Livermore Laboratory. It is a Cray-2 computer which incorporates parallel processing techniques using four processors and memories which operate simultaneously; it has 2 000 megabytes of central memory, can carry out 1.2 billion arithmetical operations per second and has 240 000 chips packaged into a very small space which can be refrigerated by means of a synthetic liquid.

7/ An excellent analysis of this subject is given in Clélia Piragibe, Industria da Informática, Desenvolvimento Brasileiro e Mundial, Editora Campus, Rio de Janeiro, 1985.

/Annex I

Annex I

ENTROPY AND INFORMATION

The close relationship between entropy and information may be illustrated by referring to some mathematical formulas of thermodynamics and of the theory of knowledge.

Probability concepts play a fundamental role in both thermodynamics and the theory of knowledge. The theory of information quantifies the knowledge possessed about a given subject by assigning a given probability ("p") to the various possible answers to a given question. Full knowledge is equivalent to the possibility of assigning a probability of zero ($p = 0$) to all conceivable answers except one, to which a unitary probability is assigned ($p = 1$). Assigning a value of $p = 0$ to any given answer is equivalent to saying "this answer is impossible". Assigning a value of $p = 1$ to an answer is equivalent to saying "this answer is certain". If our level of uncertainty is such that we are obliged to assign an equal probability to all conceivable answers, then we are in a state of maximum uncertainty, or in other words, possess no information whatsoever.

The mathematical definition of entropy is such that if a value of $p = 1$ is assigned to one answer and, therefore, the value of $p = 0$ is assigned to all other answers, then entropy equals zero. If all probabilities are equal, then entropy is at a maximum.

The mathematical function of entropy is symbolized as follows:

$S(Q, X) = -k \Sigma P_i \text{ Log } (P_i)$, in which "S" stands for entropy and "Q" represents a well-defined question; "X" represents our knowledge about "Q", which leads us to assign probabilities (P_i) to the various possible answers; "k" represents a random factor of scale, and "Log" is a natural logarithm.1/

In this way, the information (I) contained in a given message is measured by the difference between the entropy which defines the amount of knowledge possessed (X_1) prior to receipt of the message and the entropy which defines the amount of knowledge (X_2) possessed after receipt of the message:

$$I = S(Q, X_1) - S(Q, X_2)$$

As may be seen, the informational content of the message is a measurement of the degree of change which has occurred in the amount of knowledge possessed by the receptor. A message which communicates only what is already known produces no change in the amount of knowledge (X) and therefore no change in the assignment of probabilities (p_i) and, hence, no information has been transmitted.2/

A simpler thermodynamic system which, moreover, bears a direct relationship to computer architecture is an elemental magnet which has an equal probability of being in either of two states. This means that $p_1 = p_2 = 1/2$ and therefore: $S = K \text{ Log } 2$. Since the random constant "k" is thus equal to 1/Log 2, in order to arrive at a unitary value for entropy, it is said that the elimination of the most elemental unit of uncertainty corresponds to one bit of information. In other words, if $k = 1/\text{Log } 2$, then entropy is measured in terms of bits of information.

By means of a simple operation interpreting the value of the constant "k", it can be demonstrated that the relationship between informational entropy and thermodynamics entropy has even taken on a quantitative dimension: 1 bit = 10^{-23} Joule per degree Kelvin.

Annex I, Notes

1/ This mathematical expression was formulated by Claude E. Shannon in 1948 in The Mathematical Theory of Communication.

2/ This concept of information has been used successfully in the field of engineering in the design of communications-channel transmission systems.

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