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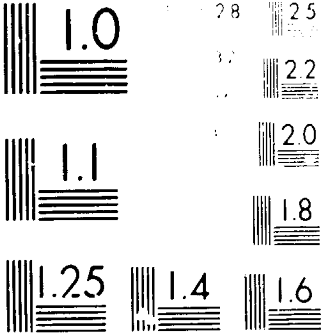
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IMPLICATIONS OF MICRO-ELECTRONICS FOR DEVELOPING COUNTRIES: A PRELIMINARY OVERVIEW OF ISSUES*

prepared by
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CONTENTS

Abbreviations

CAD	computer aided design
CAM	computer aided manufacture
DNA	deoxyribonucleic acid
EDP	electronic data processing
ESCAP	Economic and Social Commission for Asia and the Pacific, Bangkok
IDRC	International Development Research Centre, Ottawa
IFIP	International Federation for Information Processing, Geneva
OECD	Organisation for Economic Co-operation and Development, Paris
R+D	research and development

INTRODUCTION

1. A framework for the consideration of issues relating to the implications of micro-electronics for developing countries, should have at least three essential interrelated dimensions.

2. In sectoral terms we could, for convenience, consider

(i) micro-electronics as an industry;
(ii) micro-electronics as a tool for information activities;
(iii) micro-electronics applications in industry sectors;
(iv) other micro-electronics applications.

3. In terms of implications we could consider aspects such as growth of national income, effect on employment, capital, urbanization, environment and comparative advantage.

4. The issues to be identified may include policy action by developing countries, technological capabilities to be developed, change in production patterns and industry structures and actions at the international level.

5. This paper attempts a preliminary overview of these three dimensions. A discussion on these lines may, however, tend to be a superimposition of the trends and conditions in developed countries over the situation in the developing countries The basi question to ask could be different, namely how the developments in micro-electronics technology could be harnessed for application in developing countries to essentially developing country problems. Issues in this respect will also be raised in chapter IV.

6. It is not proposed to dwell on the nature and magnitude of the micro-electronics revolution taking place in the developed countries. These are covered by the growing literature and need only to be summarized very briefly.

7. The micro-electronics revolution, rightly so called, is not simply a series of technological innovations characterized by dramatic cost reductions and capacity improvements; not only a technology that has made possible technological achievements in other spheres; its impact has begun to be felt in almost every aspect of industrialized societies. The potential of micro-electronics and its dominance in the coming decades (which are also likely to witness dramatic possibilities in bio-technology as well) can be attributed inter alia to the following:

(a) It improves and substitutes a wide range of intellectual and intuitive skills;
(b) It can replace a wide range of electrical, mechanical, pneumatic and hydraulic control devices;
(c) Consequently it can replace a variety of existing products and services or extend their capabilities and create altogether new products and services;
(d) It is reliable, cost-effective and energy-saving.

8. These are a sufficient package of characteristics that have the capacity to affect almost all economic activities and thereby give rise to a series of economic and social consequences. In addition the impact of micro-electronics influences and is influenced by other technological developments such as lasers, optical fibres, printing and display technologies, software, automation, telecommunications etc. Thus there is a pervading atmosphere of excitement and apprehension. Many governments of industrialized countries have started investigating the effects, re-examining their policies and formulating and pursuing a micro-electronics policy. Irrespective of such examination it is clear that almost all industrialized countries will be manufacturing micro-electronics components or micro-electronics products and applying them in a variety of ways.

9. In an interdependent world economy with a technology-dependent third world, the foregoing developments cannot but have wide-ranging implications for developing countries. The following pages seek to bring out that it is important for the developing countries to recognize that

the technological advances in micro-electronics hold out potentials, beneficial and adverse, of a wide-ranging nature and that no time should be lost in perceiving and assessing those potentials and initiating the required steps to maximize the benefits of the impact. The more conscious and organized the response the better may be the results. Chapter V deals with some of the relevant questions in this regard in some detail. At this stage it will suffice to draw attention to a historical parallel viz. the advent of the internal combustion engine which profoundly affected economies and societies. A proper response to its advent would not have been found in limited evaluations based on short or medium-range economic considerations alone.[1/] The same parallel would apply in the case of micro-electronics. The quickness and perception with which the developed countries respond to the situation may well be a major factor in determining their industrial, economic and social development in the coming decades.

1/ "Report on Exchange of Views with Experts on the Implications of Technological Advances in Micro-Electronics for Developing Countries", Vienna, 10-12 June 1981 (UNIDO/IS.242/Rev.1).

I. MICRO-ELECTRONICS AS AN INDUSTRY

10. In considering micro-electronics as an industry, there are at least three separate parts to be considered viz. assembling and packaging (the labour-intensive part); manufacture of chips (the capital-intensive part); and design (the skill-intensive part). Since chips are tending to become a component of all electronics manufacture, the overall range of electronics manufacture has to be considered.

11. The entire electronics industry was estimated to be worth over $135 billion in 1979 and is expected to expand to some three times that figure in constant prices in the 1980s. The industry is basically dependent on chips, even though they accounted for less than 5 per cent of the value of the finished products in 1979. The integrated circuits, or chip market amounted to $5.8 billion of which the fastest growing sectors were memories and microprocessors, which together accounted for over one third of the sales. The integrated circuits market is expected to grow by something like 12 per cent annually in the next few years. In the use of the chips, computer and entertainment products accounted for roughly 30 per cent each but the fastest growing sector - for integrated circuits in general and microprocessors in particular - is reported to be industrial control and instrumentation.2/

12. Based on production figures for some of the more industrially advanced of the developing countries, it is safe to say that the share of the developing countries is not likely to be more than 5 per cent of the world production. However, certain features of the situation are important. A few developing countries have taken up electronics production essentially in the entertainment field, partly on an export-oriented basis, involving offshore assembly by transnational firms. A few others have started production for a substantial internal market, often by way of assembly, while the majority are importing their requirements, which are generally substantial. What is more, the percentage share hardly conveys the qualitative difference in capacities.

2/ "Chips in the 1980s. The Application of Microelectronic Technology in Products for Consumer and Business Markets". The Economist Intelligence Unit Ltd., EIU Special Report No. 67 (June 1979).

13. Given the dynamic nature of the industry and its pervasive impact, the question is not whether developing countries should enter the field of manufacture of electronics but to what extent and how.

14. Barring a few exceptions, or unless regional production arrangements are made, many developing countries may find that the production of chips cannot be a near term objective, given the high research and development (R+D) and capital costs, the infrastructure and skill requirements, the ongoing technological advances and the significant cost reductions that have already taken place. The production of other components, peripherals etc. may be possible for more developing countries. Assembly operations, which have hitherto been of a labour-intensive nature, may be feasible for a large number of developing countries. It may be ventured that every developing country should start some electronics assembly, however small and rudimentary, not only as a measure of import substitution but also to gain familiarity with the growing technology and develop an insight for local applications. The point of entry should be decided by each country, keeping in mind the feasibilities in terms of investments, skills, and infrastructure requirements and striking a balance between manufacturing and application. However, the range of developing countries and the conditions are such that there are countries whose manufacturing efforts could extend to the production of chips, instruments and related equipment and yet others whose efforts may have to be limited to assembly-type activities and/or manufacture of peripherals.[3/]

15. Developing countries which have already established an electronics industry will need to review their products and manufacturing technologies in the light of the fundamental changes taking place. The choice of products and technology whether for establishing new industries or expanding existing ones will have to guard against product and technological obsolescence which is taking place at a rapid pace.

3/ "Report on Exchange of Views with Experts on the Implications of Technological Advances in Micro-Electronics for Developing Countries", Vienna, 10-12 June 1981 (UNIDO/IS.242/Rev. 1).

This is particularly so in regard to ongoing or planned export-oriented efforts of developing countries.4/

10. The last consideration leads to the question of comparative advantage in electronics manufacture. It has been found that in the period 1965-1967, the OECD export/import ratio in electronics-based trade vis-à-vis developing countries declined from 1.36 to 1.16. This was, however, based on exports from a small number of developing countries involving considerable specialization and following the pattern of direct foreign investment.5/ Moreover there are trends which operate against the comparative advantage of the developing countries. It is observed that rapid advancement of industrial technology is eliminating labour-intensive portions of the electronic industry. Those products which remained labour-intensive in their assembly have been divested of an important part of their value added due to changes in components. For example, the number of parts in a colour television set has been halved since 1970. It has been suggested that while a massive repatriation of offshore assembly is unlikely in the medium-term for various reasons, there is a rapid erosion of the comparative advantage of the developing countries in the electronic field in a structural sense.6/

4/ "It is important not to fall into the errors committed by some countries .... which provide a large number of manufacturers with very cheap manpower without benefiting from know-how in exchange." Microinformatics in 1980, Intergovernmental Bureau for Informatics, Rome, June 1980 (STAR/8002), p. 62.

5/ Organisation for Economic Co-operation and Development, "Information Activities, Electronics and Telecommunications Technologies - Impacts on Employment, Growth and Trade" (DSTI/ICCP/80.10, 2nd revision) Vol. I, pp. 112-114.

6/ Juan F. Rada, "Comparative Advantages in Micro-electronics". Paper prepared for the International Conference on Informatics and Industrial Development, Dublin, March 1981.

17. Another important consideration in electronics manufacture is the manufacture of new products and applications.[7/] While a number of new products and applications will no doubt be taken up by developing countries, starting from watches and calculators, they may suffer from limitation of the size of the market, whereas others may not be taken up at all as not particularly relevant in a developing country context. New products for exports may be possible if there is a right combination of entrepreneurship, trade information and capacity to design new products. A more important question is the development of applications suitable to developing countries, which brings up a separate and larger issue which is discussed in chapter IV. In addition to bringing about economic and developmental benefits, when carefully and imaginatively applied, the applications will provide the demand for local manufacture.

18. The software side of electronics manufacture including systems integration, interfacing, installation, commissioning, maintenance, software development, training etc. cannot be neglected. It is a theme which will recur in the paper and will be discussed in chapter V as one composite requirement. It should, however, be mentioned at this stage that hard and software are often sold together and while hardware costs have come down, software costs have gone up significantly in developed countries. The combination of a firm's software and hardware, known as "firmware", has made it necessary that local capacities in developing countries should cover both. Also, it is not so much the chip by itself but what is done with it and the capacity to do it that has given rise to various applications and implications. Software and application capacity will help, and will be helped by local assembly/ production.

7/ It is estimated that by 1982 as much as 50 per cent of all manufactured products in the electronics industry of the Federal Republic of Germany will be new and not have been manufactured in 1977.

II. MICRO-ELECTRONICS FOR INFORMATION ACTIVITIES

19. A wide variety of information goods and services have come into being as a result of cost reductions due to miniaturization in electronics and the combination of computers and telecommunication systems.[8/] In manufacturing, information technology leads to a higher degree of flexibility in automation, new design and construction capabilities and the computer-controlled handling of materials and machine tools. New devices for information handling have made an important impact on the office, while new services and products based on information technology have emerged in telecommunications as well as consumer durables.

20. Information occupations are mostly in the services sector and to a lesser extent in the industries sector. A progressive shift has occurred in OECD countries towards occupations primarily concerned with the creation and handling of information which now constitute more than one third of the labour force. It has, however, been found that although information activities play an important role in the production of goods and services in most OECD countries, there is no evidence that information goods and services may in the near future become an important growth factor in final demand.[9/]

21. Most of the information occupations of developed countries may be be found in developing countries too but in fewer numbers. The services sector in developing economies accounts on an average for less than 20 per cent of the work-force whereas the average for developed ones is of the order of 55 per cent. The growth of information occupations in developing countries is likely to be less significant in the short run in view of their less advanced telecommunications infrastructure,

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8/ Micro-electronics as an information technology has been comprehensively analysed in Juan F. Rada, "The Impact of Microelectronics; a Tentative Appraisal of Information Technology (International Labour Organisation, 1980). Its coverage is relevant to other chapters as well.

9/ Organisation for Economic Co-operation and Development, "Information Activities, Electronics and Telecommunications Technologies - Impacts on Employment, Growth and Trade" (DSTI/ICCP/80.10, 2nd revision) Vol. I, pp. 112-114.

significantly lower levels of information consciousness and lower development of the industries and services sector. There is, however, a need for promoting information technology in the developing countries through a process which may require to be selective, a point which has given rise to a call for "appropriate informatics".10/

22. The industrial applications of micro-electronics are discussed in chapter III. However, it may be stated here that information technology can be applied selectively in developing countries without significantly affecting employment but saving capital and operating costs including energy. Examples of such applications would be industrial process control; on-line control systems for production planning, inventories and raw materials; and off-line planning systems for manpower and maintenance. Such applications, particularly in large manufacturing units, will have obvious benefits for the operation of those units.

23. Office automation is assuming great importance in developed countries, since something like 40 per cent of office time is taken up by routine activities; "office productivity" has been growing significantly slower than manufacturing productivity, and office costs are becoming a progressively higher proportion of total overhead costs. A close study (not so far undertaken) may be needed of developing country conditions not only from the employment point of view but also from considerations such as capital and foreign exchange costs and problems of maintenance and repair. Wage levels are also lower in developing countries. There may nevertheless be specific areas in each country where the benefits may outweigh the costs. A similar selective approach may be required in regard to consumer durables, bearing in mind the consumption patterns, the total demand, social costs etc.

24. The application of information technology in the services sector of the developing countries may have a significant pay-off as it is the technology that underpins activities in the services sector.11/

10/ See papers prepared for the International Conference on Informatics and Industrial Development, Dublin, 1981.

11/ See R. Narasimhan, "The Socio-economic Significance of Information Technology to Developing Countries". Paper prepared for the International Conference on Informatics and Industrial Development, Dublin, March 1981.

Obvious but important possibilities exist in operations of electricity utilities, petroleum installations, port operations, railway wagon turnround, traffic control in large cities, monitoring food supplies and storage facilities, meteorology, flood warning etc. Not so obvious is the challenge posed by the need to provide education, health care and community services to the geographically dispersed small communities in developing countries. This challenge can be met only by innovative solutions using information technology. This aspect is referred to again in chapter IV.

25. But the application of information technologies to developing countries is beset with some basic problems which in fact span the whole area of the current discussion. The first of them is telecommunications and it is useful to briefly discuss its relevant aspects at this stage.

26. It is important to bear in mind that the benefits of micro-electronics applications cannot be reaped fully without an adequate telecommunications infrastructure - which does not exist in developing countries as a class. This is at a time when telecommunications technologies are advancing at a very rapid pace in the developed countries. For example, telephone density per 100 inhabitants is over 20 in developed market economy countries, between 10 and 20 in centrally planned economy countries and less than 5 in developing countries (with the exception of Argentina and Mexico). In five developing countries (Argentina, Brazil, India, Mexico and Pakistan) more than 75 per cent of telecommunication needs were met by local production; in four (Chile, Egypt, Iran and Turkey) local production was between 26 per cent and 75 per cent, while in all other developing countries it was less than 25 per cent.12/ A study of imports of 13 developing countries showed that the import of telecommunications equipment as a percentage of total electronics imports varied from less than 10 per cent in Argentina and the Republic of Korea to over 70 per cent in India.

12/ See United Nations Conference on Trade and Development, "Electronics in Developing Countries: Issues in Transfer and Development of Technology" (TD/B/C.6/34), pp. 12-18.

27. It is clear that the application of micro-electronics for development should include the substantial strengthening of the telecommunications infrastructure in developing countries. Without such strengthening, developing countries may find themselves severely handicapped in applying information technologies. At the same time, the provision and/or expansion of telecommunications facilities tends to be highly capital-intensive while their operation tends to be labour-saving. For example, the capital investment needed to increase telephone density from 2 per cent to 5 per cent in five years' time with a 3 per cent growth in population may require an annual investment of $50 million a year, of which one third will be spent on installation, operation and maintenance and two thirds on equipment procurement (generally imported). Seventeen countries in Asia alone planned to spend about $10 billion on such investments over the period 1972-1980. The telecommunications facilities markets of Brazil and Venezuela were expected to reach $1,700 million and $267 million respectively in 1980.

28. The foregoing raises some important issues. If information technologies are to be widely used in developing countries and innovative applications found in the services sector and in rural areas, a telecommunications strategy (integrated with a micro-electronics strategy) may have to be worked out and implemented involving methods like subscriber radio system,13/ satellites, etc. to cut capital costs. With rapid technological advancement/ obsolescence, there is also a need to guard against purchase of outmoded equipment. At the same time, with the introduction of electronic switching technology, the unit sizes of commercially manufactured exchanges are increasing rapidly, which is highly likely to make such systems cost-ineffective in most developing country networks because of the smaller capacity needed in any one location. 14/ There is

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13/ See Sang Joon Hahn, "Application of Micro-electronics for Development: Issues for Consideration" (ME.2). Paper prepared for Exchange of Views with Experts on the Implications of Technological Advances in Micro-electronics for Developing Countries, Vienna, 10-12 June 1981.

14/ This reinforces the case for wide use of information technologies which will contribute to greater demand for the capacity.

therefore need for a careful choice of telecommunications equipment as part of a telecommunications strategy.

29. A second basic problem in applying information technology in developing countries i raising the level of information consciousness - of information as a necessary part of any activity. This aspect does not appear to have received sufficient attention. It does, however, involve a complex web of considerations, involving decision-makers' attitudes, availability of basic information to be channelled, capacity to design systems and not least, the ability to perceive the requirements of a given situation in developing countries. Algeria is reported to have initiated an informatics policy. Generally, however, the problem is treated merely in terms of purchasing computer hardware. Here experience in developing countries may vary from limited effective use to mistrust of computers or keeping them merely as demonstration pieces or of not necessarily putting them to solve priority problems.

30. The effective use of computers, the designing of systems appropriate to developing country situations and the application of information technology in general lead to the third basic problem, viz. the technological manpower capabilities. The spread of information occupations requires that those engaged in them should be trained to handle the equipment and process and apply the information. While the issues arising therefrom will be discussed in chapter V, it is relevant to note at this stage that such capabilities are deficient in most developing countries.

31. The foregoing shows that the spread of information technology in developing countries has to encounter structural deficiencies, thus calling for greater application of thought to the basic problems involved and a selective and imaginative approach in general.

III. MICRO-ELECTRONICS FOR INDUSTRIAL APPLICATIONS

32. Micro-electronics can create new products, make existing products "smart" and improve manufacturing (including testing) processes. Their applications can be presented as follows: 15/

	Function	Illustrative applications in
1.	To take the place of wired logic	Electrical and control equipment
2.	To take the place of mechanical engineering	Machine tools, pumps, compressors and typewriters
3.	To transform the very conception of a product	Clocks, watches, audio-visual equipment
4.	To increase the functions of an industrial product	Scientific instruments, electronic weighing machines
5.	To create new products	Entertainment products

33. A wide variety of products and product modifications have begun to appear, particularly in the fields of entertainment and consumer durables. The versatility of micro-electronics in manufacturing arises from the fact that a number of basic tasks can be undertaken by micro-electronics in conjunction with other devices. Among such tasks are:

(a) The controlled movement of materials, components and products;

(b) The control of process variables such as temperature, pressure and humidity;

(c) The shaping, cutting, mixing and moulding of materials;

(d) The assembly of components from sub-assemblies and finished products;

(e) The control of the quality of products at all stages of manufacture by inspection, testing or analysis;

(f) The organization of the manufacturing process, including design, stock-keeping, dispatch, machine maintenance, invoicing and the allocation of tasks. 16/

15/ Constructed from the information in Xavier Dalloz "Microelectronics and Conventional Industrial Products". In Microelectronics, Productivity and Employment (Paris, Organisation for Economic Co-operation and Development, 1981).

16/ J. Bessant, E. Braun and R. Moseley "Microelectronics in Manufacturing Industry: the Rate of Diffusion". In The Microelectronics Revolution, Tom Forrester ed. (Oxford, Basil Blackwell, 1930).

34. Apart from process control in the process industries, and testing and quality control in a wide variety of industries, it is clear that the foregoing tasks imply that substantial applications are possible in industries such as manufacture of farm machinery, machine tools, production of industrial equipment, handling equipment, arms industry, electrical equipment, household appliances, automobile industry, ship-building, aircraft construction, precision instruments and equipment education aid, food production and processing and retail and distribution. The techniques which are being applied in several of these industries incorporating application of micro-electronics technology include numerically controlled machine tools, computer-aided designs, computer-aided manufacture and robotics.[17/]

35. Though the situation is dynamic and replete with new applications, thus making it difficult to assess their impact, initial studies have already been made in a number of industrialized countries. It will be useful to mention some of these assessments illustratively.

36. In France the industrial micro-electronics market is expected to increase at least tenfold between 1978 and 1985.[18/] Some 10 per cent of the French labour force is currently in electronics. Almost half the total of electronics specialists are already in other branches of the economy like automobile shipbuilding and engineering. It is expected that the bulk of the additions to the electronics specialists will be working on the application of micro-electronics to industrial products. It is estimated that the sectors affected by micro-electronics in France employ 33 per cent of the work force in French industry, produce 30 per cent of the value and account for 40 per cent of all French industrial exports.

17/ For some typical applications of microprocessors see also Table 2.1, pp. 22-23, in The Impact of Microelectronics, a Review of the Literature, J.R. Bessant, J.A.E. Bowen, K.E. Dickson and J. Marsh (London, Frances Pinter (Publishers) Ltd., 1981). See also Juan F. Rada "The Impact of Micro-electronics; a Tentative Appraisal of Information Technology" (International Labour Organisation, 1980), pp. 45-47.

18/ Xavier Dalloz, op. cit.

37. In Canada an assessment of the sectors which should be most affected by computer-aided design and computer-aided manufacturing revealed that the sectors and activities where the impact of the technology will be the greatest within manufacturing are transportation equipment industries (16 per cent of total impact), metal fabricating industries (15 per cent), food and beverages (10 per cent) and other manufacturing industries (20 per cent).19/ At the level of the economy as a whole, 50 per cent of the impact will be in manufacturing, followed by transportation, storage and communications, wholesale and construction.

38. In considering what the implications of the industrial applications are for developing countries, it is necessary to bear in mind that a variety of applications are still taking place. The actual applications in any given industrial sector will depend on:

an awareness of technological opportunity for improvements;

an awareness of the economic justification through cost saving or increased output;

available funds and personnel.

39. Possible factors favouring or retarding the diffusion of micro-electronics in selected industrial sectors are presented in the Annex. 20/ A study of these factors, and the fact that in capital-intensive industries with long plant lives the replacement costs will be high, point to the fact that though industrial applications of micro-electronics have started, the process is a continuing one which may span many years.21/

19/ M. Prentis, "The impact of CAD/CAM technology in Canada". In Organisation for Economic Co-operation and Development, op. cit.

20/ Taken from J.R. Bessant, E. Braun and R. Moseley "Microelectronics in Manufacturing Industry: the Rate of Diffusion". In The Microelectronics Revolution, Tom Forrester ed. (Oxford, Basil Blackwell, 1980), pp. 210-213.

21/ A relevant point in this connection is that while the cost of chips has come down, the cost of sensors and actuators has not.

40. Since a major portion of capital equipment is imported by most developing countries, the industrial applications in equipment will be evident only as and when such equipment is imported. In this sense the impact of industrial applications may be felt in developing countries over a period of time rather than in one concentrated impact. This does not mean, however, that near-term applications will be impossible or non-existent. In those developing countries which already produce industrial equipment, it is both possible and necessary to incorporate micro-electronics applications to improve the productivity of such equipment. It will also be necessary to identify applications in small and medium industrial units which are a characteristic of many developing countries.

41. It should, however, be noted that even if the impact of industrial applications may be distributed over a time period, the long-term impact in several industrial sectors is too important to be ignored. Besides, the impact on comparative advantage in international trade will begin to be felt from now onwards. In this connection it will be useful to distinguish between process industries and industries such as engineering which involve assembly operations or the use of substantial manpower. In the process industries the productivity improvements will be essentially in terms of better process control with a somewhat reduced requirement of manpower. On the other hand, the impact on engineering industries involving assembly operations will be more substantial since introduction of micro-electronics through such methods as numerically controlled machine tools, computer-aided design, computer-aided manufacture and robotics will not only substantially improve productivity but replace manpower. This is particularly relevant to the more advanced of the developing countries which have started production of engineering and capital goods. For example, the application of micro-electronics in a sewing machine has reduced some 370 parts. Electric motors are now produced in Japan through robots. Such examples go to show that the beginnings made in export of engineering and capital goods by some developing countries

will be substantially affected. 22/ Likewise, the exports of ready-made garments will be affected, though the developing countries which export such garments now are relatively few. 23/ The field of custom-made shoes will also be affected. 24/ Thus many of the manufactures which developing countries have begun to export may be affected.

42. It should, however, be noted that comparative advantage in international trade is a function of several factors and not technology alone. Besides, comparative advantage is a changing factor which ultimately will have to be monitored at a country and product level.

43. In regard to international trade, micro-electronics also offer possibilities for developing countries to better process their agricultural products and raw materials for export. Even in regard to manufactures preferential trade arrangements between developing countries may provide a means of offsetting possible declines in comparative advantage. Possible losses in export earnings could also be cut by building up exports of software or imaginative uses of the export processing zones.

44. A particular need in developing countries is for intensifying and promoting applications in small and medium industries. Such applications are reported to have commenced in developed countries. This, coupled with the fact that small-lot production has been rendered economic through microprocessor applications, would appear to pose problems even for small and medium industries in developing countries.

45. An important interdependence can be seen in relation to capital goods, machine tools and electronics software. Numerically controlled machine tools on the one hand, and capital goods industries and new developments in production systems on the other hand are mutually dependent.

22/ In 1975, capital goods and consumer durables were 20 per cent or more of total exports in Argentina, Brazil, Hong Kong, Malaysia, the Republic of Korea and Singapore. See Table V.12, UNIDO, "World Industry since 1960: Progress and Prospects" (United Nations publication, Sales No. E.79.II.B.3), pp. 170-171.

23/ See H.J. Rush and H.K. Hoffman, "Micro-electronics and the garment industry: not yet a perfect fit". Paper prepared for the International Conference on Informatics and Industrial Development, Dublin, March 1981. See also "Computers in garment manufacture", Journal of Asian Electronics Union, February 1981, pp. 5-7.

24/ For a very short and tentative examination of the issue, see G.K. Boon, "Technology and Employment in Footwear Manufacturing" (Leiden, Sijthoff and Noordhoff, 1980), pp. 163-164.

but both are critically dependent on electronics software.[25/]

46. The impact of micro-electronic applications in industrial sectors on employment is an important consideration and one that has caused particular concern. Observations so far on the implications of micro-electronics for employment range from speculations and hypotheses to limited empirical studies. Many observations in this regard on the implications for developed countries appear to point to a position that technical change will in the long run and on balance not create unemployment because of its productivity effects. This would, however, depend on the availability of capital which is limited by saving propensities. Many arguments in the industrialized countries for the application of micro-electronics are implicitly based on the recognition that the alternative of not applying micro-electronics may also result in unemployment by worsening the competitive position in international trade.

47. A survey made in Japan on the impacts of micro-computers on employment revealed the following position: [26/]

Manufacturers					Users		
Development, Design	Mfg.	Sales, Maintenance	Parts Maker	Product Area	Engineers	Skilled Workers	Unskilled Workers
o	x	o		Analytic, Measuring	-		-
x		x		Process Control			-
o		x	x	Manufacturing Automation	-		
o		o	-	Ordinary Office Machines	-	x	x
o		o		Commercial Machines	o		x
x		x	x	Automatic Station Equipment	-	-	x
o		x		Watches	-	-	-
		x	-	Calculators	-	-	-
o	x	x	x	Sewing Machines	-	-	-

(A decrease in personnel does not necessarily mean a negative factor for the development of manufacturers, or users.)

o Positive
Negative
x No change
x Unknown
- Not applicable

25/ See S.M. Patil "Technological perspectives in machine tool industry, with special reference to micro-electronics applications" (UNIDO/IS.230).

26/ N. Maeda, "A Fact Finding Study on the Impacts of Microcomputers on Employment". In Organisation for Economic Co-operation and Development, op. cit., pp. 155-180.

48. The impact of the application of micro-computers in Japan is at present most conspicuous on equipment manufacturers. Case studies indicate that there has been a technology conversion and an increase in employment in the development and design departments. Manufacturing departments in general have less personnel, while marketing departments have more personnel due to an increase in demand. Parts suppliers are beginning to have less work as the number of parts required decreases. The impact on users in general is a reduction in personnel. It is possible that the impact on limited areas such as measurement, testing, analysis and instrumentation engineers will be fairly marked.

49. Though there are not sufficient empirical studies on the employment implications in individual industry sectors, the potential implications for employment in various industries have been gathered from the Annex and presented below.

Potential implications for employment in industry sectors

Automated production possibility

- Paper and allied products
- Pharmaceuticals (batch to continuous production)
- Plastics and rubber
- Food and drink (packaging and distribution)
- Motor vehicles and accessories
- Metals fabrication
- Textiles
- Electrical and electronic products
- Chemicals (packaging)

Extensive saving of labour

- Motor vehicles and accessories
- Metals manufacture in some cases
- Textiles
- Electrical and electronic machines (some sectors, notably telecommunications)

Some saving of labour

Chemicals
Pharmaceuticals
Food and drink
Plastics and rubber
Metals fabrication

50. The studies and observations in this regard in developed countries would appear to lead to the following interrelated points:

(a) The application of micro-electronics may reduce future jobs but since the rate of growth of population is not excessive (e.g. Canada and the United States) there may not be any unemployment arising from micro-electronics applications;

(b) There will be a certain amount of frictional unemployment and displacement;

(c) Certain skills relating to micro-electronics, for example software engineers, will emerge;

(d) There will be a considerable amount of deskilling as well as elimination of jobs. There will be shifts of labour among occupations and professions but in general leading to a polarization of jobs with software engineers and information occupations on the one hand and unskilled labour on the other, with the obsolescence of certain industrial skills;

(e) In general, polyvalent skills may be required in a large number of occupations;

(f) The employment of women may be affected primarily because of office automation;

(g) Suggestions have been made for softening the impact by a reduction in working hours, a reduction in retirement age, and an increase in the period of education.

51. There is a broad consensus on future prospects in OECD countries on the following lines: 27/

27/ Organisation for Economic Co-operation and Development, "Information Activities, Electronics and Telecommunications Technologies - Impacts on Employment, Growth and Trade" (DSTI/ICCP/80.10, 2nd revision), pp. 31-85.

(a) Within industrial production, there will be a reduced proportion of blue-collar workers engaged in low-skilled, rote activities, such as assembly work;

(b) Within the services sector, there will be a reduced proportion of the more routine, information-handling occupations, such as lower-skilled clerical employees;

(c) There will be a reduced proportion of employees in lower managerial and supervisory occupations in all sectors, with a more restricted role in preparing and transmitting information to higher levels of management, for those still retained;

(d) There will be an increased proportion of occupations providing infrastructure support in the form of installing, operating and repairing the new machines and technologies;

(e) There will be some deskilling of certain craft occupations, with the skills of operatives being in part transferred to machine intelligence;

(f) There will be a reduction in jobs for women and the adjustment process will be difficult;

(g) There will be a decline in unskilled job opportunities and the adjustment process will be difficult;

(h) Craft occupations will be affected and the adjustment process difficult.

52. The impact on developing countries cannot be any different. The position, if any, will be worse because of generally low growth, structural rigidities and the already prevalent unemployment. Irrespective of what empirical studies on individual industry sectors may reveal, the general trends clearly lead to the position that developing countries may have to place less reliance on industry as a source of employment *per se*; and the question of micro-electronics considered in a context larger than sectoral employment or total industrial employment *per se*. The problem will be looked at in this larger perspective, when issues of national action by developing countries are considered in chapter V.

IV. MICRO-ELECTRONICS FOR SPECIAL APPLICATIONS TO DEVELOPING COUNTRIES

53. What enterprises of developed countries will not be doing, but what will improve the quality of life of the large masses of population in developing countries is the identification and promotion of applications particularly suitable to the rural areas of developing countries. Many of them may not require high capacity chips or sophisticated equipment but a capacity to perceive needs and design suitable applications to meet them.

54. Applications for savings in energy are particularly important for oil-importing developing countries. It is considered that as the need for highly skilled human supervision will be reduced, with industrial machinery becoming self-monitoring, self-adjusting and self-diagnosing, it will become possible to build mini-factories on a wide range of sites, without having to rely on expatriate consulting experts or on concentrations of services. 28/ Such applications for industrial decentralization, if combined with supporting telecommunications infrastructure, will reduce urban migration and the social investments that urbanization entails. The combination of solar cells with micro-electronics applications will open up new possibilities. 29/ Education, communication and entertainment needs of the rural population may be imaginatively combined with solar cells to form a system of rural applications. Applications can be thought of in agro-based industries as well as in agriculture, in controlling moisture, crop management, agro-climatic information, storage etc. 30/ Is it possible to devise micro-electronics applications to optimize operations of windmills, biogas plants, fuel alcohol stills, single-cell protein fermentors etc.? Other potential applications include those for remote sensing techniques and early warning of natural disasters.

28/ See "Development in miniature" by Rowan Shirkie and Jean-Marc Fleury, IDRC Reports, Vol. 10, April 1981, pp. 5-7

29/ See Sang Joon Hahn, op. cit.

30/ Venezuela is reported to be experimenting with a computer-based agro-climatic information system. See "Modelling the tropics: can it be done?" Agribusiness, Aug/Sep 1980, pp. 25-36.

55. It has been observed in this connection: "Provision of education to eradicate illiteracy, healthcare to improve the standard of living, and community services to upgrade the quality of life, to the geographically dispersed small communities of people in countries like India pose a tremendous challenge. It is clear that the mere magnitude of the problem (the number of people to be serviced and the distances to be covered) makes it infeasible to tackle these problems through conventional means. One cannot hope, in the foreseeable future, with the resources available, to provide conventional schools, diagnostic clinics, hopsitals and so forth to service the inhabitants of each village. Apart from the problem of constructing structures to house such service centres, the generation of qualified manpower to manage them cannot be coped with. Radically innovative, unconventional solutions would have to be found and tried. .... Preprogrammed, prepackaged service equipment which could be operated by para-professional personnel - if developed and deployed in sufficient numbers - could offer a viable solution." 31/

56. Biotechnology offers great potential both in developed and developing countries. Here the interface between micro-electronics and biotechnology which has already led to "bio-informatics" will be of great value and may dimensionally improve biotechnology capacities, for example through sequencing DNA; building up and processing quantitative metabolic information and analytical data that characterize various cells and organic molecules; 32/ and in general expanding and integrating the vast quantities of information in biotechnology. 33/ The potential offered by biotechnology is particularly importan in developing countries, where the turnover rate of organic material is often very high and hence micro-organisms constitute an unrecognized resource with a great potential as a source of as yet unexploited enzyme systems. A systematic screening of this "treasure chest" will be considerably facilitated through micro-electronics. 34/

31/ R. Narasimhan, op. cit.

32/ Carl-Göran Hedén, draft report to UNIDO on "The potential impact of microbiology on world affairs".

33/ See, for example, Genetic Technology News, Vol. 1, No. 2, March 1981.

34/ UNIDO, "Draft report on Exchange of Views with Experts on the Implications of Advances in Genetic Engineering for Developing Countries", Vienna, Austria, 4-6 February 1981, p. 11.

57. Applications such as those mentioned above could contribute to improving the quality of life for many people either through providing income-generating opportunities or through direct improvement in welfare. In the use of such applications however, low incomes and the skewed distribution of rural incomes are constraints which could however be overcome in several respects through social investments. It is also important to bear in mind always the particular social and cultural conditions into which such innovations will be introduced. Due regard to these conditions in the design and implementation of innovations will help to ensure that negative consequences and social disruptions are minimized. It should also be remembered that new applications stand the risk of failure if they are not backed up by adequate efforts for education and awareness.

58. As already stated, such applications require for their development a combination of perceptions of developing country conditions and requirements, and a capacity to design micro-electronics applications. The latter is very limited in developing countries. The extent to which R+D institutions in developing countries have addressed themselves to rural problems is also, by and large, limited. In the circumstances the task is a challenging one, for which the initial impetus may have to be provided by international action in the form of pilot demonstration projects for the identification of the right problems and the development of right applications.

V. NATIONAL ACTION BY DEVELOPING COUNTRIES

59. The starting point for any action by developing countries is an overall appreciation of the potentials and problems of micro-electronics applications in developing countries. In a field so recent and full of changes, attention to the collection of data and presentation of issues which will enable such appreciation has so far been inadequate and has to be made good immediately. This will be but one step which should lead to methodologies for such appreciation and assessment at the level of each country. In the absence of an appreciation of the issues, there could be reactions such as that micro-electronics is too sophisticated a field to be germane to the problems of the developing countries or that they will accentuate unemployment problems in those countries. It is necessary to consider such points in perspective, drawing upon the discussion in the foregoing pages.

60. Taken as a whole, developing countries have time and again stressed the need for application of modern technology to solve their development problems. This does not mean of course that should any particular modern technology prove to be against their interests they should necessarily apply it. Micro-electronics can hardly be ignored because of its wide-ranging impact and contribution to productivity. Any attempt to ignore it is unlikely to be successful in an interdependent world economy. Granted that the technology gap between developed and developing countries should not widen, but should on the other hand be reduced, ignoring micro-electronics will enlarge the gap into a gulf.

61. Some of these problems may be more noticeable in the more advanced of the developing countries (e.g. comparative advantage in manufactured goods), while in others the problems may be latent, thus postponing any spur to action. Action will be speeded up if the doubts, questions and problems are articulated and their validity assessed in specific national contexts.

62. In regard to the effect on employment, the cautious optimism in developed countries that on balance and over a period, employment

opportunities may not be affected but rather a redistribution of occupations may result, because of the overall consequences of technical changes, may not necessarily apply ipso facto in a developing country context. However, it is necessary to look at the problem closely in order to avoid vague or generalized apprehensions. In process industries involving the use of local raw materials or natural resources (for example, sugar, cement, and metallurgical industries), employment losses may be essentially in the instrumentation and quality control fields but against these there will be productivity gains. In engineering industries, employment losses may be more direct, particularly where exports or unprotected internal markets are involved. Some of these may be direct reductions and others may be more in the nature of future employment opportunities forgone. Employment in industry in developing countries has so far been limited and how critical will these employment losses be to the overall employment and will they be sufficiently critical to forgo the benefits of micro-electronics applications? The services sector, whose share in employment is low in the developing countries, but whose growth is important for them, may be improved qualitatively and quantitatively. All this would seem to indicate that reduction in industrial employment may be only one of the considerations that have to be taken into account in decisions on micro-electronics applications and the considerations should go beyond effects in individual sectors to the totality of costs and benefits of the applications.

63. In regard to technological capabilities, no doubt there is the challenging problem of building up software capabilities. On the other hand, the fact that micro-electronics replaces many intricate shop-floor skills is an advantage to developing countries, which have not yet built up such skills, thus saving training time and effort and enabling them to enter the export market, if they can, in an earlier phase of the product life cycle. 35/

35/ Point made by Sang Joon Hahn, op. cit.

64. As regards capital, developing countries will require it for investment in micro-electronics and telecommunication industries. Developing countries which have policies that encourage foreign investment in these areas may have less of a problem for fixed capital. 36/ There will be a need for substantial investments in education and training for software. Investments in building up industrial skills may no longer be necessary in those cases where micro-electronics has displaced them.

65. In regard to industrial equipment, the question whether or not capital shortage will be exacerbated will depend on prices of industrial equipment for which developed countries are mainly dependent on industrial ones. Here the trends are only now beginning. Barring monopolistic pricing, given the reduction in micro-electronics costs, substituting them for instrumentation or metallic parts may reduce the price of the equipment, but on the other hand, the convenience and versatility of micro-electronics may contribute to larger plant sizes involving more capital costs and making them more inappropriate for developing countries. Herein lies another reason why possibilities of induction of micro-electronics applications in small and medium industry deserve attention.

66. To promote micro-electronics applications as well as additional capital shortages that may ensue, co-operation among developing countries, regional action, aid by the oil-rich countries and special lending policies by international lending agencies may be avenues to be pursued.

67. As for technology transfer, it will arise in regard to technology for micro-electronics manufacture; applications in industrial process and equipment; other applications; and software. Some relevant questions that require examination are:

36/ This by itself is not put forward as an argument for foreign investment. It may also be interesting to note in this connection that the telecommunications industry in the world is dominated by about a dozen transnationals.

(a) In what ways is transfer of technology in this field different from the general pattern of transfer of industrial technology?

(b) What are the present trends in such transfer and what measures are needed to be taken by the developing countries?

(c) How to ensure that transfer of technology contributes to the strengthening of endogenous capacities?

(d) How could the technology package in this field be unpackaged?

68. It is also important to keep under review the global structure of the micro-electronics industry, the characteristics of technology suppliers and the changes taking place. Many micro-electronics firms are becoming transnationals and non-electronic transnationals are getting involved in micro-electronics; small firms come into and go out of existence; micro-electronics firms are going into and out of applications; and equipment firms are getting into micro-electronics. The situation is Schumpeterian, swarming with innovators and entrepreneurs. 37/ It is changing over time and between countries, but needs review because of the implications for technology transfer, not only in the micro-electronics industry but in the downstream industries as well.

69. Sufficient empirical evidence has not been gathered and analysed to enable an assessment of the issues posed in the two foregoing paragraphs. Such an assessment would, however, facilitate the elaboration by developing countries of appropriate strategies for technology imports. A few general observations can, however, be made. Technology transfer for manufacture of chips and for assembly can be distinguished. The former would be in the high technology area with corresponding terms and conditions, while the latter, provided there are local capabilities, could be more easily subsumed in the general patterns of technology transfer hitherto being followed 38/ with the chips being bought out. As regards the downstream industries, technology transfer can be again expected to follow the

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37/ See J.A. Schumpeter, The Theory of Economic Development (Oxford, Oxford University Press, 1949).

38/ See, for example, Guidelines for Evaluation of Transfer of Technology Agreements, Development and Transfer of Technology Series No. 12 (ID/233).

general patterns for transfer of industrial processes and equipment. In the field of special applications, however, the local technological capabilities should be such as to be able to identify and specify local requirements clearly and order or design special chips and software programmes. A capability to identify and specify local requirements and to unpackage the increasingly intertwined hardware and software packages is essential to avoid the risks of excessive costs and inappropriate technologies, and overzealous salesmanship in general. In countries with regulatory mechanisms for import of technology, a capability to assess the social costs and benefits of technology transfer would be particularly necessary in cases of technology transfer involving the downstream industries and equipment as well as special applications. Local capabilities and awareness are thus basic to successful technology transfer.

a. Policy framework

70. The discussion in the foregoing paragraphs, which is brief, general and unsupported by empirical data, which do not exist, shows clearly, however, the interplay of forces that impinge on the developing countries. This should not by any means lead to an underestimation of potential adverse effects or the problems involved but on the other hand underlines the need for a close watch and a coherent strategy. The important question is even assuming the balance of effect will be disadvantageous, whether the unavoidable disadvantage cannot be turned into one of advantage, by developing and utilizing applications particularly relevant to developing country conditions, in particular those that will improve their rural areas and their quality of life. 39/ A positive and determined approach in this direction may have a pay off commensurate with the general expectation that modern technology should be applied to serve development.

39/ Even if a Government decided that micro-electronics applications should be discouraged as being harmful to employment, how will it enforce its decision? By discouraging or not permitting micro-electronics manufacture? By prohibiting imports of technology? By screening all equipment to be imported?

71. All this implies a selective approach which is more difficult than complete adoption or complete negation of micro-electronics. Selectivity requires clarity of objectives and constant vigil. To ensure selectivity, there is need for a micro-electronics policy, which, as we have noted already, should be combined with a telecommunications policy. But such a policy is conspicuous by its absence in many developing countries. It goes without saying that since conditions in developing countries vary considerably, country-specific assessments have to be made by the respective countries so as to match policy actions to local situations.

72. Though starting only recently, several Governments in developed countries are now actively pursuing a micro-electronics policy both to stimulate production of chips themselves and to foster their employment in government and services. It will be useful to review such actions briefly.

73. Following, among other things, the report of the Advisory Council for Applied Research and Development (ACARD), the Government of the United Kingdom has undertaken a micro-electronics drive,with £400 million in public funds, devoted to the micro-electronics industry support programme (£70 million) to stimulate production; the software products scheme; the schools' awareness project; and the microprocessor applications project (£55 million), administered through the Department of Industry. In addition, a further £250 million are channelled through the National Enterprise Board. The Government of the United Kingdom has put into operation a four-point programme comprising:

(i) an awareness campaign with the aim of reaching 50.000 key decision-makers in three years;
(ii) a concentrated programme for education and training;
(iii) direct support to industry, including industrial awareness and training and feasibility studies and consultancy support for public procurement;
(iv) public procurement.

74. The practice of the Government of the United States is to support the micro-electronics industry in two ways, namely through:

(i) procurement;
(ii) direct support for devices to meet defence requirements.

The support of the Government of the Federal Republic of Germany appears to be essentially through funding R+D.

75. As far back as 1971 Japan adopted a national policy for the promotion of selected industries including micro-electronics, defined the parameters of the promotion plan, laid down guidelines for production technology and rationalized the production. The promotion plan involved:

(i) financial aid for research and development of major technologies;
(ii) financing projects for improvement of production technology and rationalization of production.

Up to 1977, over 21 areas had been promoted in the semi-conductor industry, involving over 60 different projects.

76. Starting from 1977, when it decided to take action to encourage development, production and use of integrated circuits, the French Government has undertaken to:

(i) inform industry about the ways in which micro-electronics could improve the products;
(ii) facilitate training in micro-electronics for managers and engineers in the firms concerned, to enable them both to communicate with component manufacturers and to master the utilization of micro-electronics;
(iii) promote the creation of specialist agencies in micro-electronics applications which will play the same role as computer service and consultancy companies.

77. In Ireland, the National Board for Science and Technology has undertaken a major study on the trends in micro-electronics technology

and its applications and to assess its impact on the Irish economy over the period up to 1990. The agriculture, industry and services sectors have been investigated with regard to specific activities in each of them. The policy issues being examined include:

education and training
re-training
promoting awareness
infrastructural requirements
consultation with workers
planning

78. A micro-electronics policy, leading to a micro-electronics strategy, in a developing country may involve the following components,40/ the sequencing depending on the situation of each country and the whole strategy fitting into the specific socio-cultural context:

Monitoring and awareness

(a) Monitoring on a continuous basis, through a multi-disciplinary national team, the developments in micro-electronics technology and its impact on priority areas in industry and other sectors, in particular in terms of skill and infrastructure requirements and comparative advantage in international trade;

(b) An awareness campaign directed to a target audience of decision-makers and end-users.

Endogenous capacities and applications

(c) Promotion and establishment of a micro-electronics industry, ranging from assembly to design and manufacture of chips and instrumentation, the actual feasibility being dependent on local requirements and applications, comparative advantage, technological capabilities and other relevant factors;

40/ Several considerations of a policy nature have been indicated in the discussion in the preceding chapters and are not repeated here.

(d) Promoting applications, based on identified national tasks, in priority areas in industry and other sectors, including the accessing, handling, processing and use of information;

(e) Short-term and long-term programmes of education and training in hardware and software, to meet local requirements and, where possible, for exports; existing programmes and institutions should be kept under review and reoriented as appropriate;

(f) Setting up or encouraging applied R+D, particularly in the fields of special applications of importance, including the training and sensitization of R+D personnel in those fields; special attention should be paid to the possible applications of micro-electronics for the development of rural areas, the satisfaction of basic needs and for finding solutions to other particular concerns of developing countries;

(g) Setting up and/or linking national institutions to develop endogenous capacities and applications mentioned above;

(h) Reviewing or formulating appropriate policies for transfer of technology and investment and the encouragement of endogenous capacities and applications.

<u>Review</u>

(i) Keeping under review the implementation of the several elements of the strategy and ensuring coherence and consistency of the strategy with overall development aims and other sectoral strategies, in particular a telecommunications strategy.

79. Each one of the above elements has to be elaborated into a series of measures depending on each country's conditions. To illustrate, [41/] hardware development may require government financing of hardware development; bank loans for new units and for restructuring industry;

41/ See R.E. Kalman, "Measures for Promoting Indigenous Informatics and Technology". Paper prepared for the International Conference on Informatics and Industrial Development, Dublin, March 1981.

bank loans for computer rentals; tax concessions; and government purchases. Promotion of software industry may require government financing of software development; bank loans for software industry; tax concessions; compilation of a programme register to avoid duplication and promote distribution of available programmes; protection of software. Promotion of applications may require identification of priority applications; applications in small enterprises; and applications in central and local government offices. Improving human resource environment may include testing informatics specialists; computer-aided learning; awareness programmes for the general public.

b. Technological capabilities

80. The concept of technological capabilities, which usually has emphasized manufacturing skills rather than technological services, may require a substantial restatement in the light of the developments in micro-electronics applications. The developing countries will require capabilities in the field of electronics manufacture and assembly; while such capabilities are not totally different from manufacturing skills in general, the capabilities required for applications of micro-electronics are non-existent in most developing countries and are lagging behind hardware development even in the developed countries. The manpower required will include programme designers, system analysts, data-base designers, programmers, controllers and managers, in addition to the more basic specialists in operations research, mathematical logic and scientific management. The objectives in the development and use of software should be not only to meet routine requirements but to promote the design of applications for local problems and also to serve an export market where possible. In the final analysis, the actual impact of micro-electronics on developing countries will be largely determined by their capacity to develop and apply software.

81. The following table summarizes the profile of needs for education and/or training: 42/

42/ Constructed from observations in I.S. El Miligi "Notes on Computer Education and Training in Developing Countries". Paper prepared for the International Conference on Informatics and Industrial Development, Dublin, March 1981.

Type of manpower	Education	Training
Professionals		
1. Systems analysts and computer managers	High level	Intensive
2. Computer scientists	High level	Intensive
3. Application staff	Varying levels	
4. Data preparation staff, operators and programmers	Average	Intensive
Non-professionals		
5. Users		For understanding
6. Public		General sensitization - seminars, mass media and mass education

82. Obviously longer lead time is required to produce professionals such as systems analysts and computer managers through education. Training programmes could be established more quickly. However, both educational and training programmes require a concerted effort, far beyond conventional "encouragement", if sufficient manpower has to be developed not only to meet the internal requirements but also perhaps for the export market. 43/ The reduction in costs of micro-electronics hardware has made it possible to train a larger number of persons in a practical way. 44/

43/ See in this connection Dieter Ernst "The Software Market - Conditioning Factors and Possible Future Trends. An Analysis Undertaken from a Third World Perspective (Preliminary Draft)" (BP.8). Paper prepared for Exchange of Views with Experts on the Implications of Technological Advances in Micro-Electronics for Developing Countries, Vienna, 10-12 June, 1981.

44/ See, for example, "Microinformatics in 1980", Intergovernmental Bureau for Informatics (STAR/3002), pp. 69-72.

83. So far, training in these fields in developing countries has been largely part of the sale of computers. However, it has been suggested: "Because of the heavy handed marketing procedures the developing countries are likely to overinvest in hardware and thus underutilize the available capacities. The suppliers in their turn may oversell packages of software which are not fully tested, and hence the additional time and cost for debugging and streamlining over and above the normal requirements of maintenance and repair." 45/ Decisions about training have often been left with the hardware manufacturer, with the consequent emphasis on operational skills. Management skills, particularly in systems and methods, have often been neglected. In the computer systems supplied to developing countries on a turnkey basis, the hardware costs may be only around 40 per cent. There is no reason why the rest of the activities - integration, interfacing installation, commissioning, maintenance, software development, training etc. - should not be done locally.

84. Software should be looked at in the broader sense of the requisite technological capabilities and should not be confined to select groups of programmers, system engineers and operators. These specialized skills are crucial, of course, but it is equally important for developing countries to try to develop a software/micro-electronics consciousness among as many people as possible. Persons working in all fields must be trained and encouraged to think about the possibilities of using micro-electronics to assist their own productive activities. Developing countries must build up the capacity to recognize that prepackaged technology could be unpackaged to serve local needs as perceived by themselves.

85. Much of the software ought to be developed in the culture in which it is to be applied. Educating the whole population is as important as the training of specific experts. Innovative training programmes may be required encompassing, for example, undergraduate education; continuing education and vocational training; micro-informatics clubs; and individual learning kits and individual micro-computers. The curriculum should include access to computers. It has been suggested

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45/ Keynote address of I.H. Abdel-Rahman to the International Conference on Informatics and Industrial Development, Dublin, March 1981.

that every student in a university should have an opportunity to be familiar with the computer and its applications. The innovative programmes followed in Japan 46/ are of particular interest such as the formation of 'clubs' and the effective use of the audio-visual medium for spreading awareness. For example, a television station in Japan embarked on a television computer course that lasted seven years and reached a total audience of four million.

86. Systematic efforts by developing countries in this respect have been lacking, though several countries have established electronics centres or similar institutions. 47/ Regional efforts 48/ in education and training may provide the initial impulses in this field for a number of small countries. An interesting example in a developing country is that of Singapore. 49/ The steps taken in Singapore are worth quoting *in extenso*:

> "To begin with, computer studies as an examination subject will be offered to all A-level students with effect from this year. Over 200 mini and microprocessors will be installed in all secondary and pre-university schools within the next 18 months. Teachers have been undergoing training since mid-80 to ensure proper staffing in the schools. The National University of Singapore has revamped its syllabus to include a large element

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46/ See also in this connection Shigeichi Moriguchi, "Policy and Planning of Computer Education", Computers in Education, O. Lecarme and R. Lewis, eds. (Amsterdam, IFIP, North-Holland Publishing Company, 1975); Shigeichi Moriguchi, "Experiences around University Computer Centers". Paper prepared for Exchange of Views with Experts on the Implications of Technological Advances in Micro-Electronics for Developing Countries, Vienna, 10-12 June, 1981.

47/ For example, India, Pakistan and the Republic of Korea. See, for example, K.V. Ramanathan, "Semiconductor Industry and R+D in India", M. Aslam, "Implications of Micro-electronics in Developing Countries". Papers prepared for Exchange of Views with Experts on the Implications of Technological Advances in Micro-electronics for Developing Countries, Vienna, 10-12 June 1981.

48/ An example of regional action is the consultative meeting on electronics held in the ESCAP region in August 1980.

49/ Robert Iau, "The Computer Knowledge Industry - a Look at the Economic Rationale of a New Phenomenon from the East". Paper prepared for the International Conference on Informatics and Industrial Development, Dublin, March 1981.

of computing in its curriculum in addition to pure computer science. This will ensure that graduates would be suitably trained to be productive almost immediately. Teaching of computer usage is also included in other disciplines such as engineering, science, business administration, commerce, economics and so forth.

"A training institute known as "The Japan Singapore Institute of Systems Technology" will be set up by the end of 1981. This institute, a joint venture between the Japanese and Singapore Governments, will train software personnel for both the large and the mini computer systems. It will also offer training courses for non-computer professionals such as engineers, managers and upgrading courses for existing computer personnel in the market. A second institute known as "The Institute for Systems Studies" will also be set up. The initial objective of this institute is to concentrate its training to basic entry level software personnel but the institute will work closely in future with the National University of Singapore and computing professionals on software at the leading edge of the technology. Computing studies have recently been introduced into the two technical colleges in Singapore. Another two technical colleges are expected to be established by mid 80's and they will have computing included in their curriculum.

"On the business side of the coin, various incentives in financial support and tax-holidays will be introduced by the Singapore Government. Purchased computer equipment can be written off against corporate tax over three years. Organizations who send their EDP staff for upgrading courses either in Singapore or overseas could be subsidised by the Government up to a maximum of 70% of the total training cost. Guidelines are being prepared to allow income from software developed in Singapore and marketed overseas tax-holidays or lower rates of tax and Government will also liberalise the issue of professional and employment passes for computer experts who wish to set up offices or work in Singapore."

87. Micro-electronics applications do in fact highlight the importance of human resource development. The following observations relating to computer industry apply to the micro-electronics field as a whole and are particularly relevant for developing countries.

> "Given that the computer industry is a "people industry, the most effective way to upgrade this technology is to make the investment in educating its citizens in the use of computers. This education must be a realistic hands-on training pervading to a significant segment of the population. If this difficult and costly task is properly executed, the nation will have no difficulty in acquiring a viable EDP industry. Once the fundamental infrastructure is established, the rest will come naturally and inexorably." 50/

50/ D.H. Chung, "The Secret of American Services in EDP". In Microprocessors and their Applications, Tiberghien, Carlstedt and Lewi, eds. (Amsterdam, North Holland Publishing Company, 1979).

VI. INTERNATIONAL ACTION

88. The relatively low levels of awareness and capabilities in developing countries in this field make it imperative that international action provide support and stimulus to national efforts for at least some time to come. Clearly, the present level of attention and effort in this field is inadequate so far as developing country problems are concerned. Limited studies or a few unrelated activities are the present features of actions by international organizations. The question to be asked is whether, granted the wide ranging impact that micro-electronics has in prospect for developing countries, the nature and level of international response is commensurate with the challenge posed.

89. A series of concurrent and interrelated activities at the international level will be required. These are briefly indicated below:

Sensitization. A major effort in sensitization has to be mounted. This may include newsletters, publications, mass media and seminars aimed at target audiences in developing countries, and in particular their decision-makers.

Monitoring. In view of the rapid technological advances and applications taking place, continuous monitoring, assessment and dissemination to developing countries is necessary.

Research and studies are necessary to permit an assessment of effects on an empirical basis. To draw meaningful conclusions, the studies may have to be mostly at a national or sectoral level. Given the dynamic changes taking place, the validity of conclusions of the studies cannot be expected to extend over long periods and may require frequent verification.

Methodologies for national level investigations and action may have to be developed by international action.

Technical assistance and advisory services to assist developing countries in formulating policies and strategies and establishing human and institutional capabilities will be necessary.

Software development. This will include development of software curricula, handbooks and manuals, methodologies for software development strategies, fellowships, training courses, training institutions, education programmes etc.

Micro-electronics applications. Methodologies for, and promotion of uniquely developing country applications through problem identification, software development, pilot projects etc. Innovative projects will need to be promoted in this field.

Micro-electronics manufacture. Programmes of assistance for manufacture of hardware.

Co-operation among developing countries and regional action in the above-mentioned fields.

Special and innovative programmes, for example, transfer of know-how through expatriate nationals (TOKTEN) in micro-electronics.

Mobilization and linkages of institutional effort

90. The above possibilities are only illustrative. While some of them would depend on specific country requests, a minimum international programme may consist of the following interrelated elements:

(a) Sensitization, monitoring, research and studies and development of methodologies;
(b) Technological capabilities and software development;
(c) Applications for developing country conditions and pilot projects.

Such a minimum programme should include as an essential part the related institutional mobilization and linkages and may benefit from the guidance of a small high-level expert group.

91. Timely, imaginative, adequate and effective international action may go a long way in helping developing countries to respond to the challenge of micro-electronics. 51/

51/ See recommendations of the report of Exchange of Views with Experts on the Implications of Technological Advances for Developing Countries, Vienna, Austria, 10-12 June 1981 (UNIDO, IS.242/Rev. 1).

VII. CONCLUDING REMARKS

92. Over the last decade developing countries have considerably enhanced their perceptions on the implications of technology for development. They have also become increasingly aware of the imperative necessity for strengthening their technological capabilities and becoming self-reliant in their technological decisions. The advances in micro-electronics technology provide a testing ground as to how far developing countries are in a position to translate their perceptions and aspirations into practice.

93. The task being vast and challenging, it is necessary to identify the key result areas:

(a) Developing software capacities;
(b) Developing applications suitable to developing countries' conditions;
(c) Developing capacities for assembly/manufacture of micro-electronics;
(d) Developing the telecommunications infrastructure;
(e) Developing national capacities to monitor implications of advances in micro-electronics technology for local production and international trade over the entire range of goods and services;
(f) Formulating and implementing a national policy which will include the above.

94. The foregoing identification of the key result areas does not convey the importance and urgency of action and in particular what is at stake. One can only say that developing countries have to take action on a "war footing".

95. The advances in micro-electronics technology are a challenge no less to international action and its capacity to generate and sustain support to the critical problems that developing countries face.

ANNEX

Factors in the diffusion of micro-electronics for some industrial sectors [a/]

Sector	Factors favouring the adoption of microelectronics	Factors retarding the introduction of microelectronics
1 Chemicals	Improvements in process and quality control – accuracy, reproducibility, safety New options for automated and/or continuous operation, including on-line optimization Some saving of labour Savings in energy and raw materials through better controls (especially on high throughput processes, as in petrochemicals) Improved production management by better information and monitoring systems Automation in packaging and improved stock-keeping and distribution Reduced need for work in hostile environments Improved pollution controls	Capital-intensive industry with plants of long life Tradition of incremental process innovation Tradition of low-technology process controls (except in petrochemicals) Low labour intensity. Shortages of maintenance workers and especially instrument and electronic technicians Inadequate development of sensors and actuators for some processes and vulnerability of microelectronics in hostile environments
2 Pharmaceuticals	Improvement in accuracy and reproducibility of process control Improved quality control Reduction of hazards Improved efficiency in automated weighing, packaging and distribution Some labour saving Some move from batch production to automated continuous production	Research-intensive industry with little emphasis on production efficiency and much emphasis on product innovation High profit margins even with low production technology
3 Paper and allied products	Possibility of fully automated production Improved control of processes and quality Savings in energy and in materials, especially in additives Improved materials handling and distribution systems, better waste recycling facilities Possibility of wider range of products through finer control of composition	Highly capital-intensive industry subject to trade cycles and low profit margins Low labour usage even with low technology Lack of suitable sensors and actuators No tradition of innovation
4 Food and Drink	Shift towards continuous automated production Improvements in mechanical handling of fragile products Improved process and quality control Improved control over additives in response to public pressure Automation of packaging and distribution Improved stockholding Some labour saving Savings in energy and materials Shift to process improvement as alternative to product innovation to remain competitive	Slow rate of plant renewal in relatively capital-intensive and low-profit industry High cost of materials Intense competition and pressure from legislation Labour cost relatively small portion of total costs Highly specialized process and quality variables for which no adequate sensors and actuators exist No tradition of process innovation Large-volume operations, (for instance, biscuit manufacture), already highly mechanized
5 Plastics and Rubber	Improvements in process control offering savings in energy and materials Improved monitoring and control of production process, e.g. improved scheduling Automated and integrated operations, continuous or semi-continuous, with self-feeding and optimization Handling machines for feeding	Industry has to wait for suitable modernized machinery to come on the market Low labour intensity Much of the industry composed of very small plants with very short production runs Prices determined mainly by costs of raw materials

a/ Taken from J.R. Bessant, E. Braun and R. Moseley "Microelectronics in Manufacturing Industry: the Rate of Diffusion". In The Microelectronics Revolution, Tom Forrester ed. (Oxford, Basil Blackwell, 1980), pp. 210-213.

Sector	Factors favouring the adoption of microelectronics	Factors retarding the introduction of microelectronics
	moulding presses Improved safety Some labour saving	Profit margins depressed by intense competition
6 Motor Vehicles and Accessories	Automated warehousing improving stock control Improvement over wide range of production controls, e.g. automated assembly, spot welding robots, paint spraying robots, automated machining, press transfer machinery Considerable labour saving, skilled and unskilled Some saving of materials Opportunities for computer-aided design Improved flow of production Possibility of working to finer tolerances leading to improved product quality Improved products incorporating microelectronics	Severe industrial relations problems Shortages of labour with required skills Large investment in existing production facilities Shortage of investment capital because of squeezed profit margins owing to severe competition
7 Metals Manufacture	Process control and monitoring remote from hostile environment Improved quality and reproducibility of products Savings in energy and materials Extensive labour saving in some cases Improved safety Improved working environment	Fragmented capital-intensive industry with a few large and many small firms Small firms have low level of technical awareness in management, strong traditional orientation, and shortage of risk capital Overcapacity: fierce competition forcing industry into recession Poor industrial relations Technical limitations of microelectronics in hostile environments
8 Metals Fabrication	Automated welding, handling, painting	Large diversity of products often with very small batch

Sector	Factors favouring the adoption of microelectronics	Factors retarding the introduction of microelectronics
	Computer-controlled machining Production controls, warehousing Savings in materials, energy and some labour Automated handling by robotic devices in mass production	production Retention of highly skilled labour necessary, automation in less skilled areas only Capital cost of automated machinery high
9 Textiles	Automated manufacture and continuous operations Control of manufacture, including stockholding and distribution Materials handling Weaving, printing and dyeing can be made very flexible by computer control Improved speeds and quality control Extensive savings on labour Tradition of programmable operations	Shortage of capital because of intense pressure from (mainly foreign) competition Industrial relations problems and severe problems of regional unemployment Strong commitment to existing (often outdated) plant, high capital cost of new plant
10 Electrical and Electronic Products	Improved production control Automated machining, assembly and wiring Extensive labour saving (at least in some sectors, notably telecommunications) Extensive knowhow available Product innovation and manufacturing innovation go hand in hand as many mechanical linkages are replaced by electronic logic Semiconductor industry requires adequate environmental and process control which are only possible by use of electronics	Industrial relations problems Severe competition and considerable import penetration, especially in some components Low capital availability and overcapacity in certain parts of the industry (such as consumer goods) Certain areas fragmented and not highly automated Shortage of skills in certain areas (such as electronic technicians)