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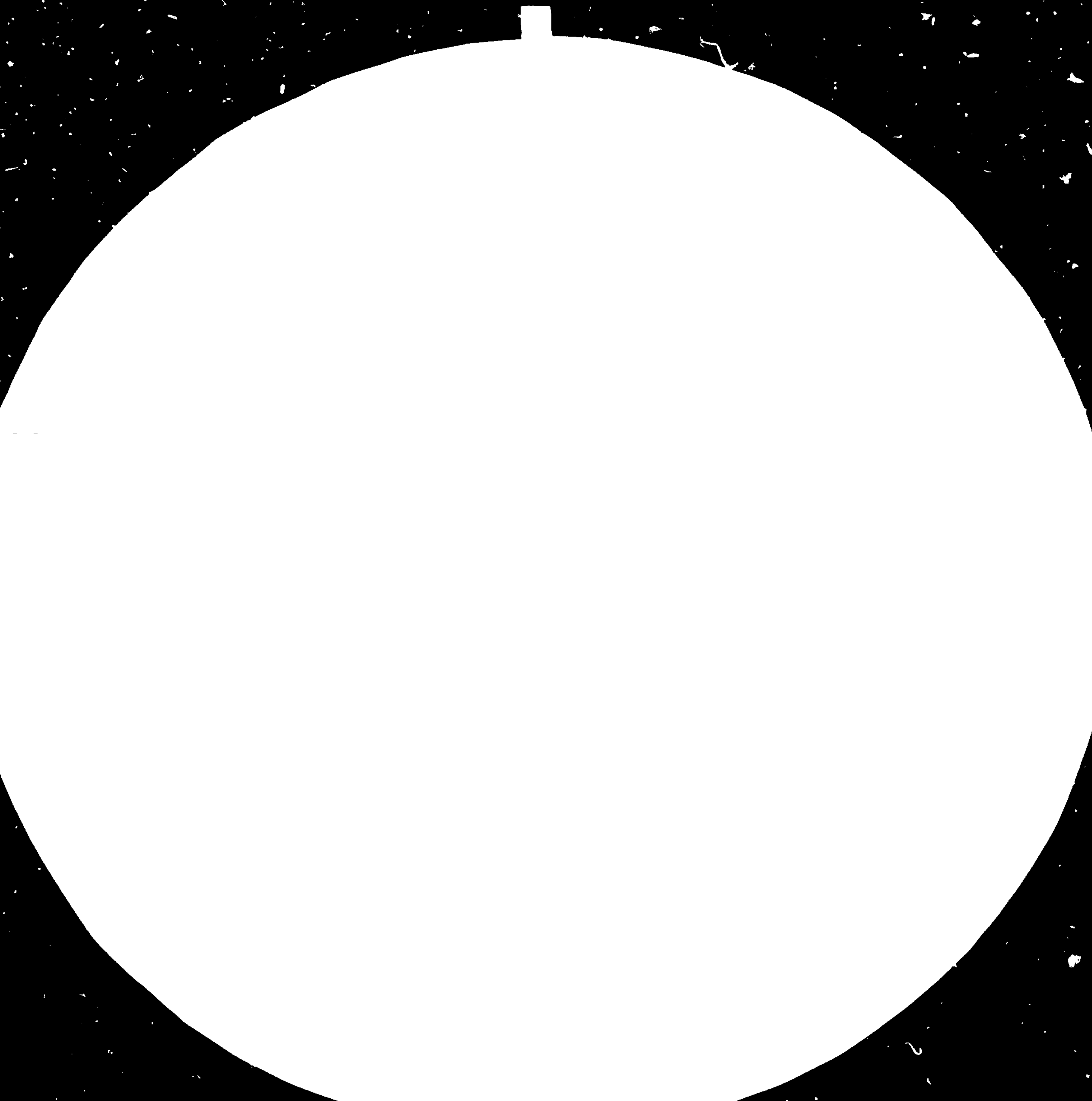

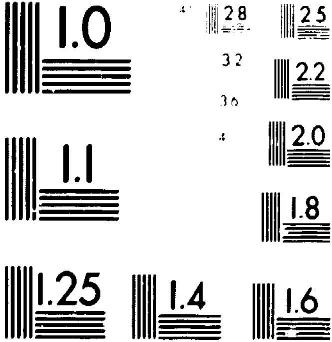
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PROSPECTS OF MICROELECTRONICS APPLICATION IN PROCESS AND PRODUCT DEVELOPMENT IN AFRICA

1984

BY

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PREWORD

The attached paper "Prospects of Microprocessor applications in Process and Product Development in Africa" was prepared for this meeting, at its originally scheduled date some two years ago. The paper was intendedly predictive and prescriptive. The imposed delay in presenting the paper has had both negative and positive consequences. It has lost something of its novelty value; the early 1982 message of the potential and the challenge of the microprocessor for development is by now well recognized. At the same time, however, it has been gratifying to observe the accuracy of the predictions, the continuity of the described trends and growing validity and usefulness of the recommendations. Despite the legitimate cautions (Wad, 1982) and especially despite some rather pessimistic prognostications on job loss effects for the Third World, who today can seriously and responsibly question the importance of microelectronics in development?

The relevancy and currency of the recommendations have remained intact. If anything they can be restated, with emphasis, for Africa. The progress made in microelectronics in Southeast Asia and even many parts of Latin America has been impressive. African countries should not allow themselves to fall behind. The theme of this meeting sets the proper tone for the direction of such progress.

Before continuing on into the body of the paper it would be appropriate to call attention to some of our recent work in a closely related area, the application of microcomputers to development.

Last week our own centre, IBM and VITA (Volunteers in Technical Assistance) formally launched a microcomputer applications training Institute in Nairobi. The Institute is supported by a large grant of equipment and funds from IBM with additional funding from USAID. It will provide qualified groups with applications training from such sectors as agriculture, health, education, small business, etc. The programme also allows for contributing computers to groups that have achieved an acceptable skill level and who have developed an applications and training programme of their own that acts as a multiplier for the original training effort. Similar institutes are being worked on with the collaboration of other computer firms, notably NCR.

This leads to the final point to be made in this preword. This concerns the role of the private sector.

Strategies designed to capitalize on the opportunities of new technologies for development and to influence the direction of R&D and applications efforts will have the greatest possibility of success if they can be done in ways that involve collaboration with those elements of the private sector that are active contributors and users of the technologies. The rate of technological and of the consequent economic change in these fields is far too rapid for sluggish bureaucracies. If we stay aware of and understand these new technologies and the potential possibilities and consequences of their impacts then we need not fear to seek out collaborations based on mutual self-interest.

PROSPECTS OF MICROELECTRONICS APPLICATION
IN PROCESS AND PRODUCT DEVELOPMENT IN
AFRICA *

by

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* The views expressed in this report are those of the author and do not necessarily reflect the views of the secretariat of UNIDO.

SUMMARY

1. With electronics already critical for development, advances in microelectronics, especially microprocessors, make Africa's involvement in the microelectronics revolution inevitable. Many of the products and processes used in Africa will contain microprocessors in the future, requiring, at a minimum, the capability on the part of Africans to use and maintain them in appropriate systems. In addition, recent advances in microprocessors have given this technology precisely those characteristics that make it appropriate for use in developing countries. By putting the computing power of a large main-frame computer on a chip costing just a few dollars, by making these chips cheap and easy to use, and with skill requirements predominantly in software programming capability, microprocessor utilization comes well within the reach of African countries. For Africa, the microprocessor has opened the door to a vast array of needed applications, applications which can help overcome one of the greatest problems of developing economies: the shortage of trained middle level technicians and analysts. By training people to be skilled in identifying applications and in designing the necessary software, developing countries can generate an enormous multiplier effect in the skills area. Contrary to some of the conventional wisdom, microprocessors can actually work to the advantage of the developing countries of Africa if a strategy is carefully worked out.

2. It may be useful to concentrate on the skills area rather than on efforts to compete in mature sectors such as television, radio or calculators, or in those fields dominated by capital-intensive, closely controlled production systems, such as video cassettes.

3. In contrast, simpler microprocessor-based information and control products have a number of very desirable features. They can be made cheaply from standard, off-the-shelf components which can then be customized by developers. Products can be very reliable, less sensitive to harsh environments and hard use, more serviceable and smaller. These products are easier to develop and easier to expand modularly, and they are better able to withstand inadequacies in other systems, skills and materials. They facilitate small-scale decentralized operations. They should not be confused with more complex information processing systems such as minicomputers or other processors, which are far more demanding of technical skills in their use. A key insight is to recognize that in the microprocessor the high technology is put in by the manufacturer; their use requires relatively low skills.

4. It is essential that African countries gain control over this technology in time to cope with the inevitable involvement, however reluctant, which will be induced by imported products. Even more significant is the opportunity to control the applications of microprocessors in Africa and to use them advantageously as a means to effect internal economies. The appendix to this paper describes several illuminating examples of products that can be manufactured using microprocessors which can have dramatic consequences in such sectors as industry, energy, transportation, food processing, agriculture and health care. However, these suggested applications, since they still reflect developed country experience, do not scratch the surface of the potential applications that this electronics automation revolution will make possible for Africa. By becoming knowledgeable and involved in this advanced but easily adopted technology now, developing countries of Africa may be able to leap-frog to a certain extent their current technology gap and land positioned for the electronics world of the future.

5. The costs of adopting microprocessor technology are relatively low. Chips and other components continue to drop in price, and those needed for developing country applications tend to be of lower memory capacity and therefore cheaper. Assembly costs will be less than with comparable non-microprocessor electronics products, and software for relatively simple devices will tend to be inexpensive. The costs of developing expertise to create software, to develop systems, and for maintenance and service are not prohibitive, and have long-term payoff in upgrading skills. An educational and communications infrastructure will be necessary to build this capability.

6. The strategies recommended for facilitating the use of microprocessor-based products and processes in African countries are primarily bottom-up or user pull, relying on carefully identified user needs and current practices within existing applications, later extending to less familiar domains. The approach would be to build out from existing African institutions, programs and expertise, while linking to relevant technology suppliers and to manufacturers in developing as well as developed nations in possible joint ventures. The goals would be to build up self-sustaining capacity through training of trainers, accumulation of experience and confidence among users through model applications, and a rapidly accelerating second phase large scale effort to maintain timely advantage in a rapidly-developing technology. An agenda for achieving these goals is suggested.

I. ELECTRONICS IN AFRICA

7. Already of central and accelerating importance in every aspect of life in the developed countries, electronics is likely to be one of the determining factors in the rate and direction of development in Africa. Inevitably, development will bring with it increased involvement with products and systems utilizing advanced electronics--in industry, transportation, health, agriculture, the village, the home, and every other sphere of social endeavour. Some parts of this involvement will be induced without choice. Automobiles, machine tools, consumer products, information processing systems and much else that we use now contain such electronics and these will become even more electronics-intensive in the future. The expanded use of such products, processes and systems requires that African countries should have the capacity to be in full control of how they are developed or selected, and to ensure their proper use and maintenance. This demands the build-up of a trained capacity and infrastructure.

8. Beyond this induced effect, major autonomous opportunities for enhanced development will become available through the application of advanced microelectronics. New and improved products and processes will become available to better utilize such scarce resources as capital, energy, materials and high-skill labour, so vital to industry, trans portation, agriculture and other key sectors. Also, the opportunity to enter into production in new technology fields and/or at low scale may become possible for African countries through the exploitation of microelectronics technologies which permit better process optimization and control, faster set-ups and change-overs(allowing for efficient small-lot production levels).

9. In the more developed, and even in some of the newly industrialized countries of South East Asia and Latin America, the capacity to exploit this electronics revolution has grown on the shoulders of a tradition of several decades of electronics manufacture and use. Africa's technological position in electronics is far less favourable. By contrast, a recent ESCAP survey of electronics in South East Asia evidenced a growing capacity for the manufacture of electronics components and products (but not in microelectronics applications), in nations as varied as Bangladesh, Thailand, Malaysia, Singapore and Pakistan. A comparable technology base in Africa is lacking, but the nature of technological development in microelectronics in recent years has made it more feasible to enter the field at this time than at any previous point since its inception. The technology has become easier and cheaper to exploit at the application and user levels.

10. Facing an explosive revolution in terms of the complexity and variety of available microelectronics componentry and systems, those who fail to become involved now will face a much more difficult challenge in the future and consequently, a much greater likelihood of finding themselves locked into a condition of dependency. Those who do enter now will be much better able to control the direction of technology development for their own appropriate use and benefit. The implication for Africa is that steps should be taken expeditiously to prepare for this new technology and ensure for African nations their proper role in microelectronics as an element in their strategies for technological development.

11. While this historic necessity for developing nations to become meaningfully and appropriately involved in electronics is virtually self-evident, the nature of such an involvement is too frequently misunderstood. It is simply not true that any kind of involvement in electronics technology is "a step in the right direction". To the contrary, it is easy to fall into the trap of setting up inappropriate electronics sectors. Most specifically, African nations do not need to reproduce the electronics development pattern of developed or of other developing countries.

12. Electronics in its various forms and applications plays a large and growing role in our societies; in communications, entertainment, education, industry, increasingly in agriculture, etc. Naturally, nations are concerned with questions of control and of self-reliance with respect to these areas. Because of the large potential scale, there are also concerns, about the large outflow of precious foreign currencies to acquire the needed products. Unfortunately, the resulting import substitution strategies and the often associated protectionism has had less than fortunate outcomes in many (though not all) cases. The large scales involved are also viewed as great opportunities for employment, given the high labour content up till recently (but much less so now), and as export potentials with big value-added content. Such perspectives have provided a good basis for strategies for some nations at some points in time, in some areas of electronics. For others, they lead to a waste of resources and to ineffective, even totally impractical, strategies.

13. It is recommended that African nations should not, with some exceptions, set up plants to manufacture products that must be manufactured in closely controlled plants to meet the cost and quality standards needed for international competitiveness, where the rates of change in technology are discouraging to a potential new entrant, and where well-entrenched competitors enjoy substantial market and production advantages. Such areas include electronics products and components as video cassette decks, complex calculators, integrated circuits, microprocessors, etc., that are currently manufactured in large volumes in Japan, the U.S., Korea, Hong Kong and various other countries. Nor should they invest heavily in highly matured areas (such as black and white TV, simple radios) where cottage industries with easy access to cheap components can easily outperform formalized industries as product assemblers. Instead, they should seek to enter fields that maximize their own comparative advantage, their technological learning potential and their ability to serve their own national needs and those of their regional and other trading partners. The recent revolution in microelectronics provides African nations with a unique opportunity to leap-frog, to a certain extent, over their technological gap in electronics.

II. THE MICROELECTRONICS REVOLUTION

14. In a matter of two or three decades, the electronics industry has advanced its technology from one that required many individual, relatively large, costly and unreliable vacuum tubes wired up through complex, costly and unreliable circuitry to perform a given function; through a stage in which the tubes were replaced by individual small and eventually much cheaper and more reliable transistors (these were to fall in price from $100 to $1 by the late 1950's, in less than a decade); to the stage,

in the early 1960's, in which a large number of these individual transistor building blocks became integrated into logic blocks to build small and medium-scale integrated circuits. The change from vacuum tubes to transistors enabled the industry to go from a developmental phase of computer technology, to commercially viable large-scale computer systems with acceptable down-time characteristics, so spawning the main frame computer industry. It was this same level of technology that enabled the $1,500 to $3,000 four-function electronic calculator to be developed in the mid-1960's ("too little for too much"). The small-scale integrated circuit was to bring down the cost of such calculators to between $700 and $900, and launched the minicomputer and computer machine controls industries.

15. Just about the time the medium-scale integration technology had run its course, the very-large-scale integration using MOS or metal oxide semiconductor technology came about. This technology allowed the integration of entire functions into a single chip as used in the calculator, the machine control, display controls, etc. Now, literally hundreds of thousands of transistors could be integrated into a single chip to provide a functional block of a very complex nature, such as a calculator, typewriter or CRT terminal control. The problem was that each one of these special building blocks had a limited market because they were designed for specific functions, not useful to everyone and therefore the vast reductions in price which came from economies of scale simply could not take place. There was considerable concern in the industry at this time as to how to achieve the volume needed to make this technology viable and cost effective.

16. In the early 1970's, a large-scale integration chip was introduced that could be programmed to carry out an enormous variety of information processing and control functions, be mass-produced and therefore, undergo the so-called learning curve and the price reductions that result from high tooling and high production. This was the Intel 4004 microprocessor. The initial microprocessors had the short-comings of all infant technologies. They were slow, stupid and very difficult to work with and program, but the above cited advantages outweighed all of their short-comings and produced the microprocessor revolution. Since then, microprocessors have steadily become smaller, smarter, cheaper and easier to use. Coincidently, within a couple of years the factory cost of a simple calculator fell to $4 or $5 as the price of high volume, dedicated integrated circuits fell even further.

17. Consumer products (such as games), commercial products (such as copiers and word processors), and industrial controls (such as in machine tools), are now at the same threshold stage with respect to applications possibilities as was the semiconductor industry when very-large-scale integrated chips were developed. It is now possible, with microprocessors, to build special purpose products, machines and systems that can carry out an enormous range of functions, and at a very reasonable cost of development and production. And microprocessors are by no means the only area of singificant recent advances in micrcelectronics. Voice chips, optical electronics, wafer chips too small to assemble by hand, and much more, are adding to an

arsenal of componentry that makes it possible to develop products, processes and systems which are very smart, easy to use and comparatively cheap for what they do, most reliable even under adverse environmental conditions, very fast, very flexible (they can be tailored to special needs, built up on modular designs and stages, etc.), small, and also low in energy consumption. Relatively speaking, such products and processes are also cheap and easy to develop and produce (compared to products using discrete components, for example). It is characteristics such as these that make modern microelectronics so attractive to producers of virtually any kind of product. It is these same features that make these new technologies especially "appropriate" for developing countries, in certain respects, despite their "high technology" content.

18. The key insight is to recognize that the high technology is put into the chips by the semiconductor manufacturer and what is passed on to the user is simple and small. In this sense, it represents a fusion or synthesis between the emphasis on "appropriate" or low cost relevant technology and advanced technologies. Though among the most advanced of current technologies, the value of the current "micro" end of the spectrum of the electronics revolution is precisely that it permits the development of low-cost, small-scale, easy-to-use applications.

19. This must be contrasted with the situation at the other, or "macro" end of the electronics spectrum, where the introduction of large-scale, computer-based systems into enterprises requires in the first place, the setting up of a substantial infrastructure for training and technical support for maintenance, repair and assistance in programming and applications, together with systems design studies, etc. In looking at the applications of microprocesses, we are simply finding better ways to use a very novel, but cheap, type of general purpose tool, into the design of which a tremendous amount of research and development resources have already been poured.

20. Understanding this "counter-intuitive" nature of the microprocessor in particular is important for achieving its full significance for African countries. The natural reaction that it must be inappropriate in Africa because it is high technology is simplistic. The worldwide advent of the microprocessor is inevitable, but timing is critical if the developing world is to harness and control it advantageously.

21. This technological revolution makes available a confusing plethora of components, products and systems, giving the user the computational, information handling and control capabilities of main-frame, large-memory computers at a fraction of the cost. It is vital to distinguish among these, however.

22. At the "micro" level are the chips, the custom IC's, the micro-processors that can be designed and programmed to perform certain specified functions, as components in some products. These integrated circuits are always used in conjunction with other components in a circuit and it is in this "build-in" condition that they are interfaced with a user (or with other elements of a larger system). Even a microprocessor can be obtained as a single package or be an assembled multipackage of processor-related components (a central processing unit, the CPU; an arithmetic logic unit; time and control circuits; internal storage

registers). When a microprocessor is combined with the appropriate memories and input and output (I/O) ports, it becomes a microcomputer. Some low end processors have combined a limited amount of memory and I/O capability in the same package to effect a single chip microcomputer system. A circuit design may include other kinds of chips (e.g., a voice chip) depending on the application. Whatever the architecture, we are still at the chip or multi-component level, to be incorporated into a device.

23. There is a major shift in level from these micro systems to that of the minicomputers, which we may call a small macro system. These small computers, word processors, etc. with their input keyboards, CRT and printer output terminals, and whatever else they need, make use of many microprocessors to build up their required capacity. They are not to be confused with microprocessors or microcomputers, but frequently are. Somewhere between minicomputers and microprocessors and microcomputers lie single board computers, and some microcomputers are capable of receiving more than one program software package. The key difference, however, remains in the quality of the interaction between the processor and the source of the information inputs, as discussed above.

24. It is also possible to have systems made up of a series of micro and/or minicomputers linked together, feeding into a main frame computer. Such applications can facilitate the integration of many decentralized operations, each optimally planned and controlled and rationalized at a central planning and control location.

25. This micro/macro difference in function level has critical implications for the types of applications involved, skills and infrastructure required for development and use, and impact generated. In general, while the development skills needed with respect to the incorporation of microprocessors in products is high, that required for use of the products is low. By contrast, the minicomputer comes as a ready-made package, but demands a high level of use skill. In both cases it should be noted that the basic skills required are those of programming (which is becoming easier) and, most importantly, of understanding the needed applications. As far as impact on productivity and employment is concerned, the arenas will tend to be different. The microprocessor impact is most likely to be seen in production and processing (in all sectors, e.g., health, as well as industry), enhancing productivity and reducing the need for intermediate level personnel (the semi-skilled checkers, controllers, analysers, etc.) and not much, as has been claimed by some, of the low skill level. In a sense, the microprocessor is likely to provide developing countries with a comparative advantage viz-à-viz developed countries by helping to eliminate their shortage of semi-skilled workers and by reducing the incidence of errors and other problems caused by low-skill labour-intensive operations.

26. The applications of microprocessors come embedded in free-standing products or sub-assemblies which are new or improved (less costly and better performing). These are generally used to perform some productive, control or informational process such as a smart machine tool or irrigation system; a product or material inspector or analyser function (e.g.,

a blood analyser); as a device to control conditions in chemical or food processing so as to achieve better optimization characteristics; or a device to control an automobile engine to enhance fuel consumption under varying conditions.

27. The impact of the minicomputer will be felt in the office and in macro planning, affecting mid-level clerical personnel as well as the character of top level activities.

28. Often, the microprocessor must be used with a sensor or transducer which supplies the input information. It has been said that the use of the microprocessors will be limited in developing countries by the cost of needed sensors. Even though there is some validity to this view in the short term, and, for certain applications in developing countries this may represent a limitation for some time to come, it misses two critical points. First, transducers fall rapidly in price (through new designs and higher volumes) once such new and wider applications become possible. This has already happened, for example, for heart rate sensors, and is likely to occur also for those sensors which have wide-spread application only in developing countries. Second, and relatedly, for the type of sensing needed (which is determined by the designed microprocessor function) very simple sensors can often be used to replace previously costly ones. The same type of impact has been felt in other related areas of componentry (e.g., switches, power supplies, analog to digital converters) where the microprocessor revolution has triggered the development of new generations of microprocessor-compatible components. And finally, of course, we should not expect to see microprocessors in wide-spread use in every area where they could be used; only in those that pay.

29. The very rapid introduction of new microelectronics technologies, the continuing fall in component prices, the steady trend towards ever smarter but easier to use devices are but stepping stones to the future. We need only recall that it has taken little more than a decade to go from the 1K (thousand byte) memory microprocessors to 64K and 256K versions.

30. For Africa the implication is clear. Now is the time to build awareness and sensitivity to the opportunities, to begin the real learning that comes from actual involvement, to monitor developments, to develop and use the capacity to cope with imported products containing advanced microelectronics, and to begin self-sustainable development and control of those aspects of the technologies most appropriate to real needs and growing resources.

31. In the next sections some insight will be provided into the advantages and opportunities of the currently most important element of the microelectronics revolution, the microprocessors, as well as, the economic, skill, and social considerations involved, leading to the elaboration of a strategy for implementing this technology in Africa.