DEVELOPMENT IN MINIATURE

Will developing countries use microelectronics — or be used by them?

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The computer has disappeared. But it didn't go away, it became invisible. Microelectronics technology — based on the now famous silicon chip — has reduced the size, cost, and energy of processing and storing information to minuscule proportions. At the same time, it has expanded the power and usefulness of electronic information handling, and spread it to virtually every area of human activity.

For the industrialized countries, microelectronics will be the key to enhancing the productivity of manufacturing processes and the efficiency of business. Communications and a wide range of goods and services will be transformed with the addition of computer intelligence.

The electronics industry has rapidly become a major economic force in the world, generating over $US. 100 billion in sales each year, and it is still growing. Analysts believe that it will overtake the automotive industry within the next 10 years to become the world's largest manufacturing enterprise.

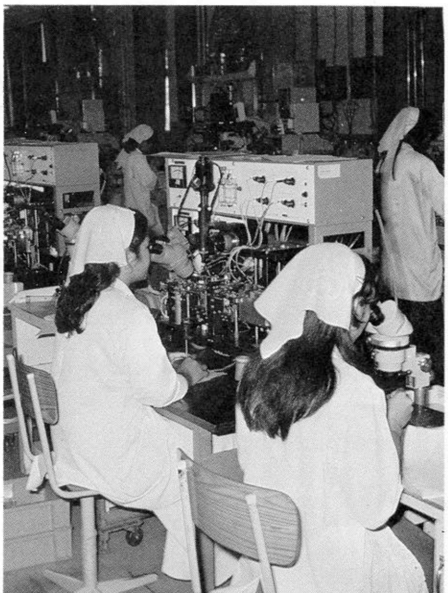
The Organization for Economic Cooperation and Development (OECD) has stated that "the electronics complex will be the main pole around which the productive structures of advanced industrialized societies will be reorganized." And others have even suggested that it will be the state of a nation's electronics industry that will determine whether or not it is a developed country.

The shifting patterns of global production, trade, and investment that are wrapped up in the revolutionizing microelectronics technology will pose very special challenges to developing countries. At the same time, poor countries may have an opportunity of leapfrogging centuries of industrialization and bring some of the most advanced products of technology to bear on problems of education, health, food production, energy, and manufacturing.

But before developing countries see much of the positive side of microelectronics, they will almost surely suffer from the fallout of the industrial explosion in the North.

The flexibility and low cost of chip technology allows computer intelligence to be applied at many points throughout manufacturing processes. This can be done using microcomputers to control whole systems, or by directly including microprocessors in machines — robots. Robots already weld and paint cars, mine coal, assemble refrigerators, drill aircraft parts, and handle radioactive materials in nuclear power plants. They can and will do much more in the near future.

About 60 percent of modern manufacturing is done in batches too small for mass assembly lines. Reprogrammable, microprocessor-controlled robots can be employed in such small-lot manufacturing to reduce costs to about one-tenth of what they are now. Within 20 years — some forecasts say within 10 years — robots will provide half the labour in batch manufacturing. By early in the next century, robots are expected to produce half of *all* manufactured goods.



Above: *Women in Malaysia assemble electronic components — eye damage comes with the job.* Opposite: *A silicon chip, containing over 65 000 connection paths and 36 000 transistors, "packaged" for business communications applications. Photo: Mitel Corporation.*

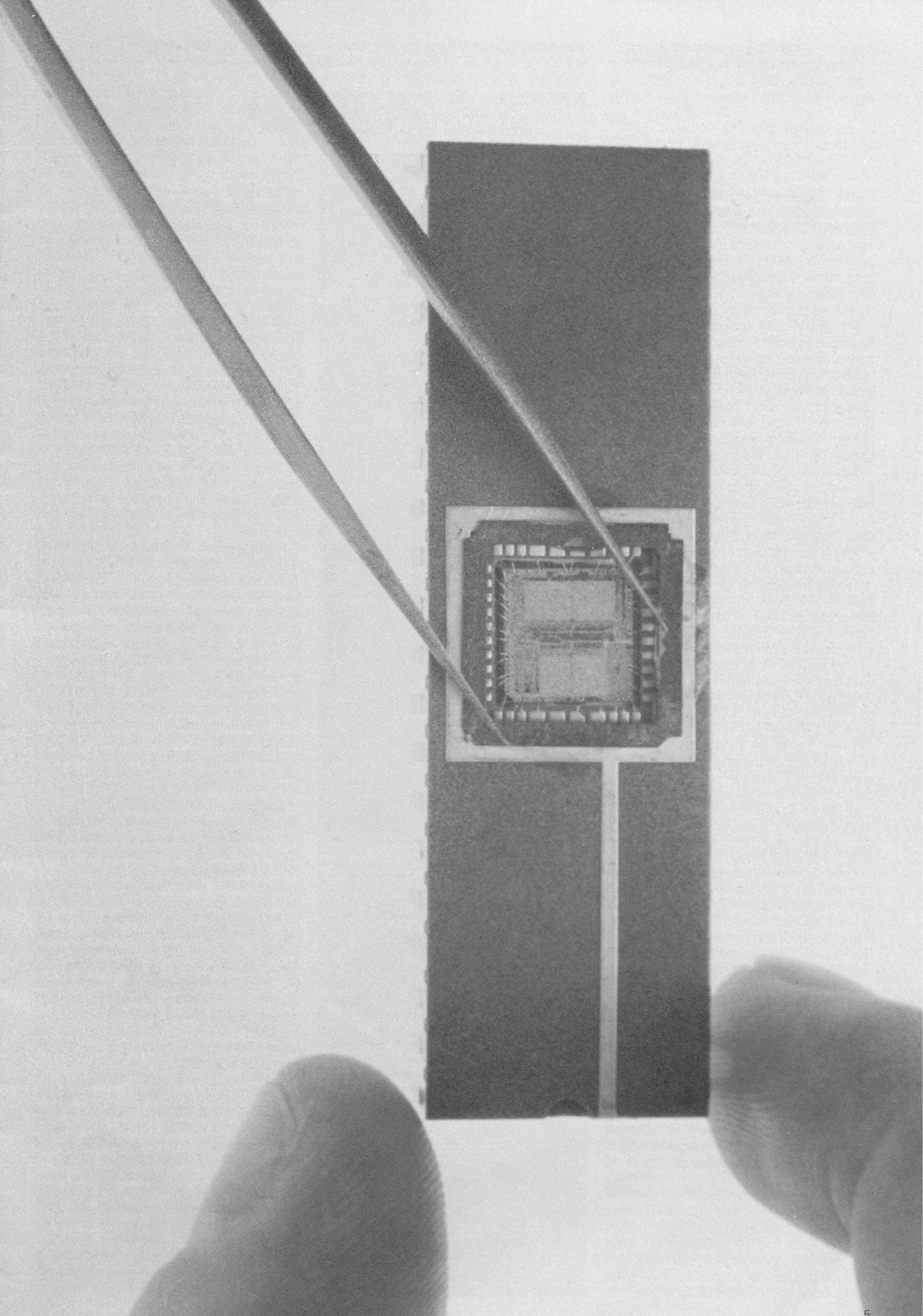
Such computerized assembly will change the competitive status of many industries and, indeed, it is the robot strategy by which the North plans to regain its economic advantage over developing-country manufactures. Microelectronics in factories will devalue one of the poor countries' greatest assets — cheap labour. The spectre of masses of jobless industrial workers has already begun to haunt the governments of the North. What of the South — especially those newly industrialized countries, whose measure of development success has been gained largely by penetrating markets in the North with cheaply produced goods?

THE RURAL TERMINAL

Some futurists foresee that the computer has a positive role to play in the development of poor countries, and advocate a strategy based on the use of microprocessors. In his latest book, *Le Défi mondial* (The global challenge), Jean-Jacques Servan-Schreiber writes that the implementation of a "planetary Marshall Plan" hinges on the computer. He suggests that each village, no matter how poor and remote, be equipped with a computer terminal linked to a central network. With this terminal, the peasant farmer would have access to all of the information required to ensure good family health and improve agricultural yield. According to Servan-Schreiber, the village terminal could promote mass education without the intervention of foreign experts, while allowing the villagers to determine their own needs.

There is no lack of Third World intellectuals who, suspicious of the enthusiasm with which experts in the North push intermediate or appropriate technologies, wonder why the developing countries would not benefit rapidly from microelectronics, in the same way that they were quick to adopt the transistor radio.

Science fiction writer Arthur C. Clarke, famous for having predicted the advent of communications satellites, foresees the proliferation of "pocket professors" throughout the Third World, just as transistor radios are now found in even the most inaccessible villages.



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The "pocket professor" would resemble a calculator and would be fed from an extensive library of educational programs recorded on memory modules. The student would select a desired course by plugging in the appropriate module. The student then simply pays close attention to the messages appearing on a display. Instruction might also be spoken: the electronic synthesis of human speech has now been mastered and "speak and spell," talking math-tutors, and other devices are already being marketed in North America. Mass-produced, these calculator-teachers would give rapid access to knowledge without the need to set up a costly school system or train thousands of teachers.

Nevertheless, microelectronics will not be invading developing-country villages in the near future, according to Kurt Hoffman of the science policy research group of the University of Sussex, England. Hoffman is studying the impact of microelectronics on industrialization and the Third World. His research is funded in part by IDRC. "What possible use could a poor illiterate farmer make of a terminal?" Hoffman wonders, "How could he actually use the information once it was provided?"

Hoffman feels that microelectronics will have an essentially negative impact on the Third World, although "it won't be the end of the world. Countries like Taiwan, Singapore, and Hong Kong will be quick to adopt the new computer assisted equipment," he says, "but the poorest countries will be unable to follow suit. It seems almost unimaginable that extremely poor countries will be able to take part in, or benefit from, the microelectronics revolution."

MICRO-INDUSTRIALIZATION

Even so, Hoffman does admit one small glimmer in an otherwise gloomy forecast of microprocessor-generated shocks for developing countries. Their use in industrial procedures and machines will mean automatic detection of breakdowns and damage. By coordinating the data gathered in real time by a group of sensors or fault detectors, the microprocessor-controlled system will take care of a number of tasks previously performed by operators. All this will help reduce the need for highly skilled human supervision as industrial machinery becomes self-monitoring, self-adjusting, and self-repairing (or, at least, self-diagnosing). It will consequently become profitable to build mini-factories on a wide range of sites without having to rely on expatriate consulting experts or on concentrations of services. These mini-factories — Kurt Hoffman already sees the first prototypes in the pulp and paper sector — will facilitate rural industrialization. In fact, it is quite possible that "small is beautiful" will become a reality, not through a return to simpler technologies, but through microelectronics.

The fact remains, however, that the bulk of expert opinion specifically concerned with the impact microelectronics will have on the Third World holds that the new technology will drive a wedge into the gap between rich and poor countries, widening it further.

Inevitably, the equipment and machines incorporating microprocessors will be more complex. Moreover, many instructions will be written in read-only memories, combining in one "package" both hardware and software. A mechanical device can be understood by taking it apart piece by piece, but it takes another computer to understand a microprocessor. Consequently, the new "smart" machines will remain just so many undecipherable "black boxes" to their users in the Third World. The technology transfer process will require increasingly complex methods, and it will no longer be possible to effect the transfer without the knowledge of the manufacturers, whose power will increase dramatically. Since most of the new data-processing techniques belong to the private sector, its members will be in an even better position to exact profits from their investments.

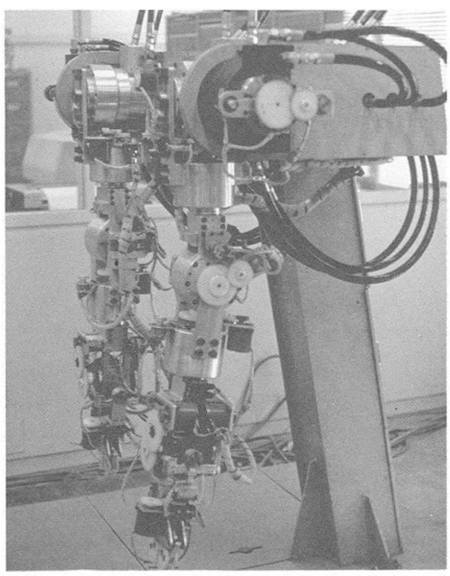

Photo: T. Kasvand

A prototype industrial robot controlled by a microprocessor — the steel-collar worker.

USELESS LABOURING

A great many countries hope to imitate Taiwan, Singapore, or South Korea. These "newly industrialized countries" owe their industrialization to extremely rapid growth in exports to the rich countries. Only a dozen of these countries share almost 80 percent of all the market value of exports of the Third World. The advent of microelectronics could well undermine economic development strategies based on export.

If several Third World countries have experienced rapid economic expansion through the export of textiles, clothing, shoes, and electronic equipment, it is because their relatively cheap labour represents a distinct advantage. By automating factories and giving the brute, and repetitive tasks to robots, however, industrialized countries are preparing to make spectacular reductions in their labour costs. Kurt Hoffman and Howard Rush of the University of Sussex cite the example of a clothing manufacturer in the United Kingdom who has cut staff from 200 employees to 20 by using computer-controlled lasers to cut fabric. "Intelligent" sewing machines follow the outlines of the cut fabric pieces using photoelectric sensors, and sew various patterns following instructions provided by computer. In spite of the high initial purchase price of these machines, their output is such that it is again becoming profitable to manufacture clothing in high-wage industrialized countries.

Radios, television sets, tape recorders, and electronic games make up the third largest export category of the newly industrialized countries, after textiles and clothing. The large transnational electronics companies moved extremely quickly to open factories in other countries, explain Hoffman and Rush. Although these companies did not begin their "off-shore" operations until the mid-1960s, by 1971, 43 American firms had factories in Southeast Asia or Mexico. Here again, the move to microelectronics — in an industry to which it is crucial — could cause expatriated production to return home as quickly as it left.

The operations assigned to "off-shore" factories are mainly assembly and soldering of extremely fine wires that connect the integrated circuit components to output devices. Thousands of young women all over the world strain their eyes performing this highly demanding and precise detail-work. However, the electronics industry is just completing its tool-up for the automation of these operations. It will shortly become more profitable to bring the assembly operations back to the industrialized countries where manufacturing already takes place. Rush and Hoffman expect that the large electronics firms will be less and less interested in establishing factories in countries outside the North.

It seems so probable that robots will level the "cheap labour" economic advantage of Third World countries that some predict the failure of economic development policies based on exports. Raphael Kaplinsky of the Institute of Development Studies of the University of Sussex even goes so far as to hope for such a collapse. He realizes the economic growth of a number of Third World countries will be seriously affected in the short term, but sees this as a positive push toward autonomous development and increased trade between developing countries. "Strategies based on exports have all too often gone hand-in-hand with increased poverty and repression,'' he argues. Hoffman does not foresee such a dramatic impact. He expects that several of the newly industrialized countries will adapt quickly and continue their process of industrialization. The competition between the survivors will be fiercer, especially since those industrialized countries that miss the microelectronics boat will undoubtedly attempt to save themselves by grabbing at larger market shares of the same type of easily manufactured products.

IMMENSE POTENTIAL

In spite of the fact that the microelectronics revolution promises to be as important as the Industrial Revolution that began in England 200 years ago, some heads of state in developing countries ignore its implications. On several occasions in the course of his survey, Hoffman has been told: "This microelectronics technology is so sophisticated; it cannot possibly affect us.'' Nevertheless, a few countries are attempting to devise strategies to keep themselves in the industrial game.

In 1976, South Korea created KIET (Korea Institute of Electronics Technology) with the help of funding from the World Bank. The aim of KIET was to serve as a catalyst for the development of national potentials in the field of computing hardware manufacture and software design. In spite of the weight of official policy behind this program, Korea has made relatively few advances in the field of integrated circuits and microelectronics. One of the Institute's most important projects, the manufacture of an ultra-sophisticated colour television, seems — according to Hoffman — to have proved a failure. He also notes that the country's potential for research and development in microelectronics remains low.

India, while it has no official development policy with respect to the microelectronics sector, has a great deal of potential. Hoffman was unable to discover any precise policy pertaining to the future of the industry in India, but suggests that "possibly it's the size of the country's human technical resources that explains the vigour of the electronics sector.'' Each year, educational institutions in India train approximately 1000 electronics engineers and, according to Hoffman, a great number of these engineers specialize in software design. India has a huge pool of qualified systems analysts and programmers — some of which supply industry in the North (see Exodus of skills, page 22).

These specialists are in particular demand since the software component represents a growing proportion of the cost of data-processing systems; in five years, software will probably account for 90 percent of the manufacturing costs. American companies such as Intel and Texas Instruments have already begun negotiating joint projects with India in order to take advantage of this highly skilled labour.

India is also doing extremely well from the standpoint of hardware. For example, the state-owned firm of Bahrat Electricals Ltd., whose main client is the defence department, is manufacturing its own integrated circuit chips. In fact, of all the developing countries, India is the most advanced in microelectronics, according to Kurt Hoffman, with particular expertise in the most crucial software field.

SMALL IS POWERFUL

The first large electronic computer, ENIAC (Electronic Numerical Integrator and Calculator) hummed into being at an engineering school in the eastern United States in 1946. ENIAC had about 18 000 vacuum tubes, spread its metal bulk over a large room, and drew as much power as a locomotive engine.

Microcomputers and microprocessors today are small enough to fit into a pocket, cost between $US. 100-300, and can run on small batteries. They are also on the order of 20 times faster and thousands of times more reliable.

The advertising of IBM (International Business Machines) gleefully points out that an equivalent gain in the automobile industry would put the price of a Rolls Royce luxury sedan at about one nickel ($US. 0.05) in 1981.

The key development was the integrated circuit. Transistors are components of an electric circuit used to amplify, detect, or switch the flow of electrons. Their development in 1947 transformed electronics, as they made vacuum tube circuitry largely obsolete. Efforts to miniaturize transistors for use in military and space hardware led to techniques in which transistors were produced in batch lots in silicon wafers. Further innovation saw the integration of other components of circuitry into the same silicon chips and additional size reductions. As Colin Norman puts it in a recent Worldwatch Paper: "In three decades, a roomful of vacuum tubes, wires, and other components has been reduced to the size of a cornflake.''

Current innovations continue to pack more and more circuitry onto chips. In 10 years, manufacturers expect to cram more than a million components into their units. With the addition of information processing capacities — computing functions — to silicon integrated circuits, the microprocessor is created.

Instructions on how a microprocessor will shunt electrons within the myriad of circuits, to perform logic functions such as calculation, are established beforehand. Function determines design and manufacture. This is called programming, and it is in the programming of microprocessors to apply their enormous flexibility for handling information that the future of microelectronics lies for developing countries.

It is in the area of software — the programming and use of microprocessors — that other developing countries might best exploit the remarkable potential of the new technology as well.

The diffusion of microelectronics is determined in large part by the cost and nature of the electronic components available from manufacturers. But it will also be influenced by people who couple microelectronics experience with a keen awareness of human needs and invent uses and markets for the technology.

India has a head start. But many of the human resources in technology are drained off to richer countries, where they are employed producing pinball machines and toys, robots to make sophisticated consumer goods, or even missiles and spacecraft.

Applications of importance to developing countries will probably only be realized if those countries develop the necessary software skills. The pinch has already been felt in the global inventories of these skills. Meanwhile, a host of potentially beneficial products for developing countries await invention. They could include:

- a diagnostic tool for rural health care workers, a "doctor in a box'' that provides on-the-spot analysis, interpretation, and suggested treatment information;
- control systems for biogas generators, fuel alcohol stills, or single-cell protein fermentors. Such systems could reduce the requirements for technically intensive management skills, and make it possible for widespread adoption of these technologies in rural areas where food and energy are most needed;
- crop management calculators to aid in decision-making on inputs of fertilizers, pesticides, and irrigation; electronic weather vanes for climate information; or devices to alert farmers of ripeness, dryness for storage, or any number of agricultural information needs.

None of these applications are as fantastic as they may seem at first glance. The plunging costs of hardware bring all of these inventions well within the bounds of present capabilities. When radio was first developed, it was thought appropriate only for communications to inaccessible or remote areas — such as ships at sea or in mountainous areas. Yet now, the transistor radio is one of the world's commonest and most widely diffused technologies.

You don't need to be an automotive engineer to drive a truck. But you have to know how to drive and where you are going.

In the same vein, developing countries don't need to construct plants to manufacture silicon chips, or duplicate all the stages of nurturing a microelectronics industry to reap some of the benefits. It would appear that the strategy most suited to the Third World lies in developing the software capacity to apply the technology to its own special needs.

Microelectronics' potential to transform industry and society in industrialized countries presents the poor nations with a dilemma. Either they use the technology themselves for their own benefit, or they will be harshly used by it. □