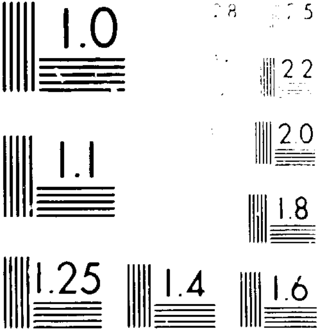
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TECHNOLOGY PERSPECTIVE OF MICRO-ELECTRONICS IN THE COMING DECADE AND ITS IMPLICATIONS FOR DEVELOPING COUNTRIES.

by

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ABBREVIATIONS

A/D	Analog to Digital
AM	Amplitude Modulation
CMOS	Complementary Metal-Oxide Semiconductor
CCD	Charge-Coupled Device
COS/MOS	Complementary Symmetry/Metal-Oxide Semiconductor
CLASP	Coplamos Large-Stage Programmable Process
CPU	Central Processing Unit
CAI	Computer Aided Instruction
D/A	Digital to Analog
C-MOS	Complementary-Metal-Oxide Semiconductor
D-MOS	Diffusion-Metal-Oxide Semiconductor
E-PROM	Erasable and Programmable Read-Only Memory
EAROM	Electrically Alterable Read-Only Memory
FET	Field-Effect Transistor
H-MOS	High-Performance Metal-Oxide Semiconductor
IC	Integrated Circuit
I^2L	Integrated Injection Logic
I/O	Input-Output
JFET	Junction-Gate Field-Effect Transistor
LED	Light-Emitting Diode
LAI	Large Area Integration
LSIC	Large-Scale Integrated Circuit
MOSFET	Metal-Oxide Semiconductor Field-Effect Transistor
MOS	Metal-Oxide Semiconductor
NVM	Non-Volatile Memory
NMOS	N-Channel Metal-Oxide Semiconductor
Ns	Nanosecond
PCB	Power Circuit Breaker
PCM	Pulse-Code Modulation
PABX	Private Automatic Branch Exchange
PMOS	P-Channel Metal-Oxide Semiconductor
RAM	Random Access Memory
ROM	Read-Only Memory
SCR	Silicon Controlled Rectifier
SOS	Silicon-on-Sapphire
TMS	Tonfrequenz-Multiplexsystem
TMS	Test Monitor System
VHSI	Very High Speed Integration
VLSI	Very Large Scale Integration
VMOS	Virtual Memory Operating System
VTR	Video Tape Recorder

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INTRODUCTION

1. The economic impact of micro-electronics for the advanced as well as developing countries is becoming widespread. In the advanced countries such as the United States of America, Japan, and European countries, there is enough capital and technology to promote the state-of-art, and the social and economic structures are readily accommodating the sophisticated application. It is also anticipated that the increased affluence of the micro-electronics-based industry will inevitably spill over into the developing countries.

2. The effects of the micro-electronic development of the advanced countries on the world economy are too serious for the policy-maker to neglect. The development of micro-electronics is providing infinite ways of applications for automation of the process and operation of the machine, by which advanced countries are substituting labour with automated machines. Since a micro-electronics system can control process, material movement, shaping, cutting, mixing, assembly, quality inspection, testing, etc., there is theoretically no need for any labour except initial machine-operating instructions.

3. As a matter of fact, the relative manpower in the advanced countries has been sharply decreasing in manufacturing industries and agriculture. In the United States of America, for example, the industrial manpower decreased from 61 per cent in 1950 to 37 per cent in 1980. In the Federal Republic of Germany, the change in industrial manpower is moderate but in agriculture the share is down to 5 per cent in 1980 from 22 per cent level in 1950. Manpower has been increasingly absorbed by the service and information sectors which are growing.

4. In the future, micro-electronics can automate house appliances, and make TV and telephone function as the terminals of the available public services. In the office, paper can be reduced and business conferences replaced by the call of a picture phone. The application of a microprocessor would automatically deal effectively with repeated motions and controls in industry. A semiconductor device will improve the accuracy and efficiency

of almost every aspect of work. The impact on socio-economies is great and the quality of life in the future will depend mainly upon micro-electronics.

5. The microprocessor can be produced and programmed at such a cheap price that it can have widespread application. In other words, the digital signal computer and analog signal will be processed in the microprocessor to get the desired function. The analog signal is generally converted to digital for data processing and the Digital to Analog (D/A) converter will change back to the analog signal. The future microprocessor can do Analog to Digital (A/D) data process and D/A functions on a chip, which means one microprocessor unit can act as a local brain to control the circumstances in complex motions; process or direction. The next interface required is either local to local or local to central, which can be done by telecommunication. The gradual merging of data processing and communication will upgrade the efficiency and the quality of life of future societies. This study will summarize the emerging and anticipated innovations in the home, office, factories and schools.

6. The major goal of the study is to find out methods of micro-electronics application for developing countries which will improve their economic conditions. There is a fear that the impact of micro-electronics will affect developing economies adversely. Some economists even claim that the microprocessor automation will widen the economic and technological gaps between the advanced and developing countries. Before making such a hasty judgement, it is necessary to look at the function of the microprocessor which can be operated by an unskilled person to produce a sophisticated result. In the absence of a microprocessor this task would be performed by a highly skilled person. Many of the products such as Amplitude Modulation (AM) radio and vacuum tube at the later stage of product life cycle still require a lot of manual work. These products frequently require a special skill at certain manufacturing steps. If developing countries intend to develop the technology or train engineers to the degree required, it may take too long to achieve within the product life. When developing countries adapt micro-electronics to

the particular phase of production with the help of other experienced countries, the product may be commercialised in time. The type of products and adaptation methods should be carefully selected through the study of the economic structure of the country. Since most developing countries have an agro-based economy with low purchasing power, further study has to be concentrated on improving the agricultural productivity and the related supporting industries.

7. There are several basic common problems in developing countries. A large number of the work force is engaged in primitive agriculture and the illiteracy rate is so high that a long training period is required. The productivity must be improved by utilizing cultivation machines. As the number of farmers decreases with mechanization, the displaced work force should find other jobs such as forest and cottage industries. In other words, the follow-up tasks are the processing of farm and forest products, food preservation, and cottage and small industries dealing with the primary treatment of the natural resources. In order to carry out these tasks, simple machines and tools are needed which can be produced at small-scale machine factories. The products needed are power tillers for cultivating, transporting, drilling, seeding and fertilizing; centrifugal water pumps; woodworking machines; and tools such as lathes, power hacksaws, drills, cutters, spanners and hammers, etc. The manufacturing of such products is a relatively labour-intensive operation but some operation, particularly component production requires an advanced technology. Since it will take too long to train labour, developing countries must take a short-cut through the application of micro-electronics to overcome the difficult parts of process and operation. Micro-electronics can also contribute to controlling the environmental conditions of food preservation and critical operation of food and forest processing. While most of the processing is manually done, the recipe control of food or surface finish in woodworking can be controlled by application of microprocessors.

8. In order to diversify the skills, developing countries need to educate people through mass communication such as radio and television At the beginning television may be installed at the community centre

of each village. Since foreign exchange is scarce, it is preferable that consumers are recommended to make their own products. When the final products are locally produced, inspection and quality are controlled by microprocessor, the radio and television can be easily assembled, and later the telephone. When the products are distributed to the rural area, the educational level will be increased significantly and the subsequent chain reaction may lead to modernization and <u>inter alia</u> to better family planning education, savings in capital and better community life.

9. In regard to international co-operation, which is particularly essential for programmes of action, the comprehensive programme including education, training, technical co-operation and exchange is suggested.

I. HISTORICAL SKETCH OF THE MICRO-ELECTRONICS INDUSTRY

10. Electronics started as early as 1883 through Edison's discovery of the amplifying effect in a vacuum tube. However, the real electronic age started at the beginning of the twentieth century when radio was commercialized by application of the triode vacuum tube. Since 1930, each decade has given birth to a leading product. The radio was commercialized in the 1930s, television in the 1940s, computer and transistors in the 1950s, Integrated Circuits (ICs) in the 1960s and Large-Scale Integrated Circuits (LSICs) in the 1970s.

11. The radio was the first electronic equipment widely used for entertainment. During the Second World War the radio production was greatly enhanced and expanded to be used as a means of military communication. The radar and oscilloscopes were also commercialized at the same time. In the 1940s television became the most sophisticated home entertainment. When the transistor was produced in mass quantities in the 1950s it gave a new prospect for the computer industry to improve its size and performance. The IC development in the 1960s was expanded into Metal-Oxide Semiconductor Large-Scale Integrated Circuit (MOSLSIC) in the 1970s, which is miniaturizing practically every component of electronic equipment. Developments in the micro-electronics industry industry are as follows.

Semiconductor Industry

12. The semiconductor industry has been evolved in the last three decades. The discrete devices such as transistors were developed in 1950s and the IC in 1960s. 1970s was the LSIC decade when all or most of the system could be integrated. Some of the highlights are reviewed in the following paragraphs.

13. In 1948 Shockley, Bardeen and Brattain completed the transistor development as a form of point-contact transistor using Germanium chip. The working part of the device consists solely of two fine wires that run down to a pinhead of Germanium chip soldered to a metal base. The substance on the metal base amplifies the current carried to it by one wire and the other wire carries away the amplified current. The announcement was

sensational because it contains no vacuum, grid, plate or bulky glass envelope. However, the first transistor was half an inch long and continuous refinement was necessary. By 1950 Teal of Bell Laboratories was able to perfect crystal-growing with dopants. Pann developed ultra purification of crystal by zone refining technique. Thus, material technology became one of the most important factors for the semiconductor devices.

14. In the early fifties the manufacturers such as Raytheon, General Electric Company and Western Electric continued the campaign to reduce the size, weight, and power requirements of the transistors sold for about US$15 per unit. But the end of 1952, the transistor could be used as oscillator at over 1 MHz, which expanded the new operation. In 1953 GE engineers found unijunction transistors which would operate at higher frequencies and stumbled upon an oscillation signal. In 1957 GE engineers also developed Silicon Controlled Rectifier (SCR) whose forward current could be blocked under control of a gate electrode. In the following year Compagnie Francaise Thomson-Houston (France), a GE affiliate in France, developed the Junction Field-Effect Transistor (JFET). In 1968 Esaki invented fast tunnel diodes operating on the quantum mechanical probability of electrons tunnelling through an energy barrier.

15. In the late fifties the development of III-V compound semiconductor such as gallium arsenide and indium phosphide was very active. As early as 1955 Braunstein observed infrared radiation by carrier injection in the compounds. In 1960 Allen and Gibbons made Light-Emitting Diode (LED) with gallium phosphide. In 1962 Bell Laboratories developed laser, a coherent infrared radiation observed from forward biased gallium arsenite np junction. Discrete development continued in 1960s; Gunn diode developed in 1963 by Gunn and avalanche diode in 1964 by Tombson and DeLoach. Raytheon, Philco, General Electric, Radio Corporation of America (RCA) and Sylvania were competing with each other to commercialize such discrete devices.

16. 1960s was the IC decade. The planar process was the key of the IC. The Fairchild team of Noyce, Moore and Hoerni developed the planar process in 1958 with which transistor structure could be diffused in from one side by series of oxidation, photoresist mask, etching and diffusion.

It first applied to a batch production of the oxide passivated, higher performance and smaller transistor. The IC ideas were first conceived by Dummer of Britain in 1952 but Kilby of Texas Instrument (TI) later realized it on a single chip. Kilby first built a flip-flop by an interconnecting discrete device. He then built phase-shift oscillator on 1/16-by-3/8 inch chip using the planar mask technique and the monolithic IC technology was discovered in 1959. A similar IC idea was conceived by Noyce in Fairchild when the TI announcement was impending. Once the groundwork had been laid by Kilby and Noyce, TI and Fairchild took up IC manufacturing. Fairchild announced a micrologic family in February, 1960 and TI a custom IC in March 1960. By the end of 1961 both were producing commercial ICs in quantities.

17. While the bipolar IC was actively developed in 1960s, another significant progress was achieved in the area of Field-Effect Transistor (FET), particularly metal-oxide semiconductor FET (MOSFET). Shortly after Teszner of GE in France introduced JFET in 1958, RCA built thin-film FET. Hofstein and Heiman had been working on silicon insulated gate FET and reached conclusions in 1962. They reversed the reverse-biased junction control structure of JFET with a metal gate insulated from the silicon by a layer of silicon dioxide, leading to MOSFET. RCA had fabricated a large array of several hundreds by 1963. The process was far simpler than that of bipolar circuits, requiring less than half as many processing steps. It consumed far less power, and therefore a greater level of integration was possible. However, it was plagued with oxide defects and other problems that the bipolar experience could not aid. Thus, the scientists and engineers took up the study of the oxide stability problems. General Microelectronics and General Instrument started MOS IC production in mid-1965 and others followed thereafter opening the MOS age.

18. With the MOS technology, the IC designers started to develop more complex and high density circuits. The Read-Only Memory (ROM) look up tables and character generators for displays appeared in early 1967. 64-bit Random Access Memory (RAM) was offered by Fairchild. Automatics demonstrated a high performance Silicon-On-Sapphire (SOS) circuit using an insulating substate

in 1966. Around this time IC manufacturers switched to 1-inch wafer processing to accommodate more complex MOS ICs. Three chip-makers were established in 1966 in the Bay Area, another three in 1967, thirteen in 1968 and eight in 1969, making twenty seven companies in the 1960s at Silicon Valley.

19. An era of process competition and experimentation took place in the early-to-mid-1970s. The clean rooms were getting cleaner as circuit features got smaller. Ion implantation method which would introduce dopants over a greater range of concentration and with more precise control, was applied as supplement of diffusion. The manufacturers of MOS devices found that N-channel could give a greater boost in speed than their P-channel. Intel, a Fairchild spin-off, had only applied N-Channel Metal-Oxide Semiconductor (NMOS) process on its LSI circuits. About this time bipolar was pushed off from LSI but in 1972 integrated injection logic (I^2L) gave a new hope in bipolar. It was devised independently at International Business Machines Corporation (IBM) in West Germany and Philips in the Netherlands. I^2L process offered high density and low-power, retaining the bipolar speed which was extremely attractive to the integration of analog and digital circuits on one chip. While Intel was promoting the front-end technology, it found the floating-gate avalanche cell applicable to Erasable and Programmable Read-Only Memories (E-PROM) in 1972. Boyle and Smith of Bell Laboratories conceived the charge-coupling principle used for Charge-Coupled Device (CCD). Bell Laboratories also announced a significant discovery of bubble memory in 1969 in which small cylindrical magnetic domains would remain stable under application of an external magnetic field. In the meantime RCA had been working on Complementary MOS (CMOS) which lifted its speed and saved power to rival NMOS.

20. Together with the development of processing, a significant progress was made in LSI design. The revolutionizing achievement was the design of microprocessor performed by Intel. In 1969, the Busicom Corp. of Japan asked Intel to design calculator ICs. The Busicom's requirement was unique calling for a chip set to support a family of calculators.

Hoff of Intel suggested to build a general purpose computer for each aspect of ROM programming. With Busicom's approval Intel succeeded to develop 4004 microprocessors in 1971. The first 8-bit microprocessor 8008 was offered in a sample quantity in early 1972 and Intel then opened the era of one-chip computer. This consequently led to the age of Very Large Scale Integration (VLSI). In order to support the complex chip process, the equipment makers developed sophisticated equipment such as E-beam pattern generators, wafer steppers, projection aligners, dry etch processors, etc. At this point, the semiconductor industry became the most complex industrial technology and the key to future progress.

21. Some of the development highlights can be chronologically illustrated as follows. In 1973, Intel, TI and Mostek began to reach the market with 4K RAM. 16-bit NMOS microprocessor was introduced by GI which promised minicomputer performance on a single-chip. Fairchild applied CCD array to the first solid-state video camera. American Microsystems Incorporated (AMI) started to design micro-controllers for house appliances. The first 8K CCD shift register from Bell Northern was comparable with PDP-11 made by Digital Equipment Corporation (DEC). Digital multimeter was designed to compete with analog voltmeter. Intel started mass production of 8-bit microprocessors 8080 and 8085 for microcomputer system components.

22. In 1974, 8-bit CMOS microprocessor from RCA was intended for low-power industry and consumer. Philips announced I^2L products such as digital tuner, telephone tune control and frequency divider. Bell Laboratories and RCA developed light modulators for the fiber-optic communication. Toshiba built the first 12-bit microprocessor with P-channel Metal-Oxide Semiconductor (PMOS). RCA developed 525-line CCD television camera, CMOS processor on sapphire, and 16K CCD memories to replace disk and drums. In the later part of 1974, Intersil introduced 12-bit CMOS microprocessor, whereas Analog Devices built 12-bit D/A converter from a pair of custom LSI chips.

23. In 1975, Fairchild produced 4K RAM with I^2L technique. RCA announced 1K RAM on sapphire while Intel commercialized 1 megabit Charge-Coupled Device (CCD) to compete with disk and drum. Digital electronic tuning systems for European television were designed for on-screen display of channel, time and tuning scale. The first use of 16K RAM in a commercial

system was announced by four phase systems. Laser-based photorepeater from GCA Corporation (GCA) had a resolution of 1 micrometer.

24. In early 1976 Texas Instrument, Intel and Mostek entered 16K RAM market. TI also introduced single I^2L watch chip and started to sell the completed LED watch for US$ 19.95. Low-temperature nitride process permitted for silicon wafers to be sealed hermetically. RCA built a smaller and better 8-bit CMOS processor with I^2L process. Siliconix developed the first commercial Virtual Memory Operating System (VMOS) power device that switches 1 Amp in 5 nanoseconds. A new dedicated microprocessor such as TMS 1000 appeared to aim at the low-end market. Industry first I^2L RAMs arrived on the scene; Fairchild built 4K dynamic and TI 4K static. The fastest 16K ROM from Mostek operated at 350 ns to boost throughput of microprocessor systems. TI started the first commercial bubble-memory production with 92K device aimed at disk and drum storage memory. AGE-Telefunken developed 10-by-10-cm solar cells with better than 10 per cent efficiency. Solar technology used thick-film screened-on inks to put contracts on silicon solar cells. Motorola made I^2L PLL frequency-synthesizer for Citizen's Band (CB) radio.

25. In 1977, industry's first High-Performance MOS (HMOS) emerged from Intel with refined NMOS and AMI with VMOS. Precision Monolithic made the first 12-bit D/A converter with its high-performance bipolar process. In June 1977, TI announced the first single-chip microcomputer 9940, which was the most powerful single-chip controller in the industry. Using I^2L Analog Device made a self-contained microprocessor-compatible 10-bit A/D converter on a single chip. IBM developed an integrated package containing all the electro-optical elements of a fiber-optic transmitter. Motorola got a contract to supply Ford with a custom microcomputer for fuel and emission controls. Mitsubishi and Nippon Electric Company of Japan succeeded to build 4K static RAM with a Diffusion-Metal-Oxide Semiconductor (DMOS) technology which operated at less than 100 ns. IBM reported a new type of bubble memory,

yttrium iron garnet bubble lattic which has higher memory density. 1/

26. In 1978, 16-bit I^2L microprocessor from Fairchild was applied to execute instruction of Nova microcomputer. Fujitsu offered first 64K RAM built with 2 micron polysilicon gates. Standard Microsystem developed a Coplamos Large-stage Programmable (CLASP) process, which greatly speeds turnaround time of ROMs compared with the standard metal-mask process. TI used P-Channel Metal-Oxide Semiconductor (PMOS) LSI to make low-cost simple spelling which is the first speech synthesizer from contents of ROM. IBM developed 1 micron light bubbles, analogous to magnetic bubbles, in magnesium-doped zinc-sulphide thin film. TI announced first 16K static RAM and first quarter-million-bit bubble memory chip. Nippon Telephone and Telegraph Public Corporation (NTT) in Japan developed X-ray lithography system with alignment accuracy of 0.1 micron.

27. In 1979, a dramatic progress was made in 64K RAMs through the efforts of National, Siemens and Bell Laboratories. Intel introduced superfast static RAM. Upon finishing the VLSI programme, the Japanese disclosed a partial list of their development to include 128K ROM, 1-megabit wafer-size RAM, and 5000-gate logic array. Fairchild announced high-speed bit-slice of 8-bit wide for the system design flexibility. TRW Incorporated built 35-MHz A/D converter fully parallel with great accuracy. Intel also made a new analog microprocessor which combined A/D and D/A converters on the same chip to do real-time signal processing. Hitachi announced 484-by-384 element MOS imager for a colour camera exhibiting television-like resolution.

28. In 1980, LSI chips for voice synthesis were receiving intensive attention. National's synthes er is based on the ability to perform A/D conversion of the speech wave form and store it in memory for subsequent retrieval. AGE-Telefunken utilized old iodine vapour deposition for low temperature epi, virtually eliminating diffusion effects. Jet Propulsion Laboratory

1/ Status 1980: A report on the Integrated Circuit, Integrated Circuit Engineering Corp., Scottsdale, Arizona, USA, 1980.

projects solar cell cost of 56 to 69 cents/Watt. Hughes Aircraft had devised a direct-write-on-wafer with a routine line pattern of 0.5 micron for E-beam. Massachusetts Institute of Technology (Academic Institute) (MIT) is developing optical A/D converter two to four times faster than silicon designs. Computers are used to control the complex VLSI production in every stage of fabrication. 12-bit converter from Harris offers absolute accuracy in military temperature range.

29. The latest development of IC is being termed Very High Speed IC (VHSIC) in the United States of America. It is planned to develop a processor by 1986 or 1987 which is laid on 1 cm chip with 0.5 micron pattern, is equipped with 250K gates and is capable of performing from several million to hundred million executions per second with a minimum of 25 MHz. 2/

Computer Industry

30. The concept of the computer started in the seventeenth century. The earliest mechanized computer was no more than an adding machine that could both add and subtract. In 1642 Pascal built a machine to aid in adding columns of figures. This calculator had number wheels with parallel and horizontal axes. The position numbers were entered by horizontal dial wheels coupled to the number wheels by pin gearing and their sums or subtracts could be read through the window. In 1673 Leibniz completed a calculator using a device known as the Leibniz wheel. Its function was not only addition and subtraction, but also multiplication and division. The Leibniz wheel was employed through the Second World War. In 1820 Thomas introduced his arithometer by improving the four basic arithmetic operations of the calculator and the first commercial production was realized. In 1823 Babbage developed his Difference Engine as the early digital computer. The machine was to perform all arithmetic operations using 20-digit registers and delivering a printed output. His work was not completed but a general-purpose computer, very close to the Mark I, was conceived from his

2/ Electronics, Vol. 53, No. 9 (April, 1980).

Difference Engine. Babbage foresaw the distinct needs; the store where the information and instruction were entered into the machine by punched cards, and the mill or processing unit where operations were performed by use of the stored information and instructions.

31. During the period of 1848 and 1854 Boolean developed the numerical analysis of the mathematical equations which can be solved with a digital computer. It was possible to express a logic in very simple algebraic systems which has only 0 or 1 as an answer in numerical terms. Thus, modern computers can make use of this binary system, with their logic parts carrying out binary operations. In 1890, Burroughs invented the adding and listing machine and Hollerith helped solve the compilation problems of the early data processor. Hollerith formed the Tabulating Machine Company in 1896 and joined with another company in 1911 to make the Computer-Tabulating-Recording Company which became the International Business Machines Corp. (IBM) in 1924 under Watson.

32. The electromechanical analog computers and calculator developments continued through the 1930s, especially through the effort of Bush at MIT. Since the mechanical analog devices suffered from the inherent inaccuracy, other researchers began exploring a new type of computing machine which would automatically follow a set of instructions and operate on more accurate discrete values. IBM and Harvard University jointly developed the automatic sequence controlled calculator in 19[illegible] The first modern computer, called Mark I, was 51 feet long and 8 fe[illegible] high, contained 800,000 parts, offered 60 registers for constants and 72 storage registers for addition, handled 23 decimal-digit numbers, and performed additions in 0.3 second and multiplication in 3 seconds. Mauchly began to develop an idea to use vacuum tube to perform calculations in 1942. Under a government contract, the University of Pennsylvania made the first electronic digital computer known as Eniac in 1946. Eniac occupied a room 30 by 50 feet with 18,000 vacuum tubes and weight of 30 tons, consumed 150 kilowatts, and performed addition in 0.2 ms and multiplication 2.8 ms with a clock rate 100 KHz. 1950s was the

celebrated decade for computer industry. The tiny transistor was in production to replace vacuum tubes and the magnetic-core developed by Wang offered large, fast and economical memory to computer designers, and Printed Circuit Board (PCB) miniaturizing were revolutionizing their work to advance the computer industry to a sophisticated degree. In addition IBM, NCR, Remington Rand and Burroughs went into computer making in the early 1950s. By the middle of the decade, GE, RCA, Philco and Honeywell joined.

33. Various computer models were designed by the major computer companies without using LSIs. IBM by far was the leader and its product line was diverse. IBM introduced model 1401 in 1959, 1441 in 1962 and 1460 in 1963. The transistorized and the large-scale 7090 line was expanded to include the top-of-the-line and lower-priced. In 1964 IBM introduced the popular 360 series which was truly general-purpose and had better performance than 1401 or 7090. Until recently, 360 has been widely used. Sperry Rand finished a supercomputer called Univac in 1960 and was able to negotiate in the large-scale scientific computer market in the late 1960s. Some of the development fund for large-scale computers in the United States of America came from the space programmes such as US$23.5 billion Apollo project. Burroughs meanwhile slowly moved into the computer market from business machines and introduced a large-scale B500 Solid-State computer in 1961, followed by B5500 with throughput capability of three times the medium-scale B2500 featuring monolithic ICs. Burroughs also developed a supercomputer B6500 in 1972, as attempted earlier by IBM and Univac. The supercomputer in 1960s did not keep one company from making a commercial success of its effort. CDC also introduced a big model 6600 in 1963 followed by 7600, to compete with IBM 3600 series. With its abundant resources, GE developed a computer with the time sharing mode to compete with IBM but since the conservative management style could not compete in the ever-changing business, GE sold its computer division to Honeywell in 1970. The forerunner RCA, however, introduced several models, 301, 501, 601 and Spectra 70 before it moved out of business in 1972.

34. One result of the change in the computer industry during the 1960s was the birth of new and foreign developers to bring new technologies to the market. DEC was credited with creating the minicomputer market by introduction of its programmed data processor, PDP-8. In 1969, DEC introduced PDP-10 with 36-bit mainframe. The most significant development was PDP-11 which based an innovative hardware architecture, centered on a single bidirectional asynchronous bus. The Data General is a spin-off by 3 notable ex-DEC designers who started to make the Nova system in 1968. It introduced a series of models, Nova 1200, Nova 800 and the Supernova SC in 1970, to establish its firm position in minicomputer business. Utilizing its instrument experience, Hewlett Packard (HP) developed 2116A instrumentation computer in 1966.

35. In Asia, the Japanese Government, the Ministry of International Trade and Industry (MITI), organized the Japan Electronic Computer Company which involved seven companies, such as Hitachi, Fujitsu, Nippon Electric, Toshiba, Oki Electric and Mitsubishi Electric. MITI subsidized US$37 million for a five-year development plan of large and high-speed computer. Fujitsu promoted Japan to the big leagues of data processing in 1968 by announcing its Facom 230 series which increased the domestic market share later on. 3/

36. The European companies such as Philips and Siemens started to develop general purpose computers in 1960s. Philips for example announced P1000 in 1962. Thus, the fast growing business of computers was among the advanced countries.

37. The 1970s was the decade of revolution for the computer business in the light of MOS LSI development. Ever since Intel announced 4004 microprocessor in 1971, attempts have been made to design general purpose computers as single chip by ROM programming and RAM addition. The powerful digital computers shrunk midway through the seventies to fit on a tiny chip of silicon smaller than a fingernail. More important even than the single chip was the fact that the IC computer had

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3/ Ryoichi Mori, Yuzo Kita and et al., "Microcomputer Application in Japan" Special Report, The Japan Electronic Industries Development Association.

become so cheap that equipment designers in every field had to consider adding it to their products. The computer system design was reduced to microprocessor chip design and some of the semiconductor houses naturally became system-end-producers. For example, National Semiconductor had built IMP-16C minicomputer using LSI whereas Intel introduced Intellect 4 and 8, respectively, using 4004 and 8008 microprocessors. Most of the major semiconductor companies succeeded in making single chip computers and were able to customize it by ROM programming technique. The chip-sized microprocessor became popular usage for the control of microwave oven, television, burglar alarms, toys, stereo, organs, industrial processors, point of sales, automobiles, medical equipments, etc.

II. FUTURE PERSPECTIVE OF MICROELECTRONICS TECHNOLOGY AND ITS IMPACT

Rapid Evolution of Integrated Circuit and Microprocessor

38. No single invention is so radically changing modern industry as the microprocessor or computer-on-a-chip, a tiny slice of silicon that is the arithmetic and logic heart of a computer. So powerful is this semiconductor device that it is rewriting the economics of computing and stretching the imagination of equipment designers. Already, some thoughtful observers refer to the microprocessor as the engine that is powering a second industrial revolution, one in which brainpower will be multiplied with even greater force than the steam engine multiplied muscle power.

39. The initial surge of microprocessors came in 1976, when semiconductor producers shipped an estimated 2.3 million of the devices. In 1978, the annual volume had already swollen to nearly 27 million units. In 1979, microprocessor shipment in the United States of America amounted to 57 million units. This year it is expected to reach 100 million units. At the same time the computing power of these devices will increase, and their price will continue to fall.

40. Already, the growing complexity of these devices, their soaring numbers and the increasing diversity of the machine has begun to work major changes in entire industries.

41. The semiconductor producers are changing rapidly and compete increasingly with some of their customers. the minicomputer builders. Makers of electronic instruments have had to redesign whole product lines to remain competitive. And both producers and users of microprocessors have had to allocate new resources to solve the software problems posed by these machines. Despite all this ferment, ultimately the microprocessor is believed to become as basic to industry as steel.

42. No equipment industry has been hit quite so hard or so fast by the

microprocessor as electronic instrument manufacturing. The computer-on-a-chip has made obsolete almost over-night the industry's entire product line by creating ingenious instruments and an era of truly automated measurement. At the same time, the rapidly spreading use of microprocessors beyond the traditional electronic industry is accelerating demand for the industry's products such as the oscilloscopes, voltmeters, logic analysers, and hundreds of other instruments. These are the basic tools today in research and development laboratories, factories, and product test and repair facilities.

43. Quite simply, the computer-on-a-chip now enables an instrument to take over the technicians' former job of running a test and analysing the resulting data. Thus, even as instruments have become increasingly complex, they have also become easy enough for the lay person to operate. And the microprocessor also gives instruments the ability to "take" and swap data with a computer and a variety of other instruments.

44. When instrument makers began designing microprocessors five years ago, it was more for sales appeal than anything else. But once they found out how much they could do with the powerful chip, the race was on. What is happening in the electronic instrument business could be a foretaste of the future for many other industries that manufacture industrial equipment.

45. In 1978, Data Quest Inc., a Cupertino market research team, estimated that 40 per cent of the instruments sold were designed around microprocessors.

46. New mass spectrometers from Hewlett Packard and other manufactures no longer require trained chemists to prepare samples, read out data, interpret results. Equipped with a microprocessor, one of these instruments can now automatically analyse a sample, identify the elements, measure them to parts-per-million, and even print out, for example, how the results compare with the limits imposed by the government. The broad market for such an ingenious instrument ranges from local water analysis to police crime laboratories.

47. A microprocessor-controlled mobile X-ray system introduced in 1978 by HP automatically computes and sets correct exposure, adjusts for the type of film and lines up an increasing number of new instruments, runs self-diagnostic tests.

48. The dramatic advance in the IC technology greatly depends upon the progress of solid-state technology. The future chip will have a high density, speed and capabilities by integrating different types of devices. The fundamental technology will be improved by electron-beam, wafer stepper, dry process and doping by ion implantation. Since a VLSI chip contains as much as one million devices/functions, most of the future equipment, inclusive of computer, will be designed on the chip level. For the simpler operation, a large part of software will be hard-wired in the memory section of the chip. Thus the future technology will be focused at process, design of VLSI system and the system application.

49. The miniaturization of IC chip has bearing on both cost of production, and cost of operation. Since VLSI can contain more functions, cost per unit of function can be dramatically reduced. Cost of operation and maintenance can also be reduced owing to simplicity of equipment using advanced chips. The price of computers will be greatly reduced.

50. Above all VLSI will be the focal point of the future technology. The major impact of VLSI will be on computer architecture of the mainframe, minicomputer, and microcomputer. As the microcomputer performs higher levels of function, the burden will be more on software cost. Consequently, more of the architectural solutions will put the software burden onto silicon.

51. The diagnostic features will also be integrated on the processor chip because its complexity will otherwise give the users formidable testing difficulties. In the application area, the microprocessor based robot's technical achievement will guarantee the continued search for the machine that will be the perfect slave.

Automation of Industrial Production

52. Automation of industrial production has been pursued in two ways. The first category is represented by the production of a uniform product such as iron and steel, petroleum and chemicals. The second category is represented by production of the discrete products such as pen, camera, and automobile engine. In the case of mass production a costly automation equipment can be justified because of wider distribution. In contrast to the mass production process of uniform products, introduction of automated equipment is, off hand, prohibitive for batch production of diversified products. However, programmable automation is directing its attention to the batch production of discrete products. Underlying thoughts of a new system of programmable automation are equipping facility with the intelligence of the microcomputer or the minicomputer which justify economically the small quantity production of batch products as an ordinary case of mass production. This new system of automation is being coined as programmable automation or flexible automation. The ultimate goal of the programmable automation is achieving automation of the entire factory. Automation of the entire factory is expected to consist of the following subsystems:

(a) Automated design system which accommodates conversation between designer and machine;
(b) Optimum production planning system;
(c) Automated system of component production;
(d) Material handling system;
(e) Automated assembly system;
(f) Automated inspection and testing system;
(g) Production information system.

53. An automated factory which includes the preceding elements in its entirety is today non-existent. However, some elements of automation equipment which support each subsystem are in practical use.

54. The following are some of the systems which are in use today:

Numerical control of fabricating machines;
Computer-aided design;
Computer-aided manufacturing;
Automated warehousing;
Industrial robot;
Automatic counter and testers.

55. Industrial production requiring repeated motion and other controls can be done by microcomputers or the application of microprocessors. Since the controller of any machines and equipment is an electrical part, the microprocessor will be used to automate it for convenient operation. In order to handle the real signal at the production line, the analog signal should be converted to digital form so that the computer can process it and convert it back to the real signal for instruction. The future microprocessor can do A/D, data processing and D/A functions on a chip, which means that one microprocessor unit can act as a local brain to control the circumstances in complex motions, process of direction.

56. Most of the future machining equipment will first be digitized. The present NC machine is still expensive but the microprocessor adapted to NC machining will eventually be cheaper than any manual operation. Thus, the future machine shop will be operated not by employees but with the digital data input. The data can be generated with computer-aided design to which the human idea is applied. Another example is the chemical plant. There are only limited numbers or control factors in the chemical process such as temperature, pressure, concentration, flow rate and time. Since the future semiconductor sensor can monitor all those variables, data processing units will easily control the production. When the image sensor is added to this, the system can become a robot which will appear in most of the factories around the end of the twentieth century. The robot will do all the local complex functions. The next interface will be either local to local or local to central, which can be done by telecommunication.

57. The automation of software production is also on the horizon. One can feed the specifications into a computer to produce a programme. The manual programming of software will gradually disappear because the manpower cost cannot compete with hardware. When VLSI chips such as 64K or 256K memories are produced in quantity the hardware programme will be cheaper than software. Thus, the software will either be produced by automation or replaced by hardware.

58. According to imaginary scenarios of Dertouzos in "The Computer Age", 4/ the future consumer can order a new pair of shoes at a centre that will accurately measure feet with an instrument which simultaneously uses the information to code an order card. The consumer will pick a show model, request alterations to suit personal taste, and have the order card processed along with an automatic payment card. The design will be processed by the order card and the shoes will finally be assembled by a robot. The whole procedure for the shoes tailored to individual taste will only take 11 minutes.

59. Present robots can only repeat the prearranged sequence of action. When they are equipped with sensors, particularly for sight, the robot can interpret the sensory feedback in accordance with the knowledge of the task and recognize what action to take. The robots will be able to communicate with other computers, thereby establishing networks of controllers. Thus, future industrial automation will essentially have two components: the general-purpose programmable robot and the microcomputer-based controller. To the automated equipment in a factory another computer could be added that deals with information as order handling, inventory control, accounting plant maintenance, etc. Automated networks also could control a transportation system in which a great deal of data must be monitored, processed, integrated, and converted into specification. The cost/performance capability of programmable robots could become competitive with those of unskilled workers by the turn of the century. The advent of the microprocessor has made industrial robots, for example, more useful and versatile than ever before. Today, instead of performing just one simple task, they can be repeatedly programmed

4/ Michael L. Dertouzos and Joel Moses (ed.), "The Computer Age: A Twenty-Year View", the MIT Press, Cambridge, Massachusetts and London, England, 1980.

to switch jobs and to do highly complex ones. And for the first time, the new technology has made robots cheaper and more efficient than many of their human counterparts: for a "wage" of just US$4.60 an hour, the average cost of maintaining them, they perform tedious and dangerous work with a high degree of reliability. The average human worker on an automobile assembly line, by contrast, earns US$16 an hour. By some estimates, from 50 to 75 per cent of all USA factory workers could be displaced by intelligent robots before the end of the century. As the cost/performance ratio of programmable controllers improves, they will replace today's electronic controllers. Another significant change may be that one can work at home with a personal computer through interface with the robots at the factory.

Perspective of Infrastructure

60. The future of micro-electronics will also change the infrastructures surrounding the human society, such as transportation, travel service, hospitals, schools, stores, utility service, community administration etc. The data processing, telecommunication, intelligent terminals, automated network, television terminal, computerized office equipment, and other equipment will be integrated and fully utilized for the community service. Like the robot performing local tasks in a factory, the local computer will process each service function in conjunction with the intelligent terminal, point of sales, other electronic peripherals and terminals. The capacity of the local service computers will be varied depending upon the community size and they will be connected to the corresponding central computers at the headquarters or central government. In case of transportation and travel services involving other countries, the central computer will be interfaced with that of other countries via satellite. Thus, the world will eventually become one infrastructure.

61. In transportation, the computer will control traffic in the modern cities, as well as automatic mass transit and microprocessor-based locomotives. For the traffic control and relief of congestion, the variable message of the electronic sensors buried along the road is

analysed at the central computer to optimize the traffic regulation at the intersection or notify the road condition to police. The energy shortage will eventually accelerate public transportation. As the mass transit becomes imperative the automation must be accomplished as soon as possible, as there will be an increasing problem of manpower cost, system efficiency, and a great number of passengers accommodated. The technology will involve self-ticketing, automatic entry and exit of the passenger, with the accounting tied to the system via distributed processing network. The diesel locomotives can also be digitized to optimize the throttle settings, fuel consumption, and diagnostic and testing capabilities at on-board. The locomotive may eventually be remotely operated and the defects such as hot spot bearings can automatically be detected with infrared. A development significant in the near future will be the magnetic levitation locomotive running on tracks at high speed. The vehicle-mounted magnets lift the car away from the rails and it moves at such a fast rate that only an automatic electronic system can control.

62. A part of the air travel services is already computerized. This service will be expanded to other transportation such as railroad and bus. In the future, all types of reservations including hotels can be done through the telephone and the bills will be automatically charged. This will save a trip to buy the ticket but one has to guard against the private phone being used by an unauthorized person. For safeguard purposes each should use a secret code number instead of the phone number. For the efficient service, information from each local service system must be gathered at the central system. The central system for each of the services of bus, railroad, air, sea and hotel will interface with the equivalent system abroad.

63. Medical electronics will continue to grow for the benefit of patients and the carrying out of diagnosis. The most exciting prospect is diagnosis by means of computerized scanning, which will remove the need for an exploratory operation. Patients will be examined on an out-patient basis, reducing the hospital loads. The surgeons, aided with computer-generated

diagnostic information, and knowledge of precisely where and how to operate, will increase efficiency. In addition to the diagnostic scanners such as X-ray tomography, and nuclear, fluoroscopic and ultrasonic scanners, there will be progress in the use of electronics to deal with illness. For example future pace-makers will have a significant logic component to emulate the natural pacing characteristics of the heart, dictation pulse stimulation based on a variety of inputs. The computerized medical bank will record individual histories, state or nation-wide and local physicians will be able to tap the patients' previous treatment and response record. Upon entering the latest symptoms, the computer will also predict the probable outcome of the doctor's therapy. The automatic diagnosis and therapy, together with automatic patient monitoring will reduce greatly the hospital costs and increase efficiency.

64. Micro-electronics will have a growing application in education. The computers in the classroom have so far been programmed for drill and practice routines, for simulations, and teaching programmed languages. In the home computer era, people will depend less upon the traditional public school but look for new and better education programmes from central education service or community school systems. With the aid of text books and home terminals, children can learn more than in the conventional school and have access to accurate answers to their questions from the central data bank.

65. The stores at local communities will also be influenced by electronics. Although a large department or chain store can directly respond to the consumer market place through interface with the central data bank, the consumers should pick up the commodities and groceries at the local stores. The future merchandise may have price and guard-marks. The sensors of the point-of-sales can read the price either as cyclopean or letter form to calculate the payment. The point of sales can be connected to the nearby bank so that the total revenue of the day is automatically saved. The customers do not need to pay cash or write cheques, but show the computer eye the secret saving's account number. The guard-mark can be removed only by passing through the point-of-sales.

If an item with the guard-mark passes through the exit the electronic sensor will recognize it, which will prevent shoplifting. The backlog record and ordering processes will also be done electronically.

66. Utility metering is another up-coming automation. Electronic meter reading will save a great deal of manpower for the utility companies. The amount of consumption for electricity, gas, and water can be recorded by non-volatile memory and the data can be transferred to the central processor whenever needed through the communication line. The monthly bills are automatically printed and conveyed to the mail box.

67. The computerizing of the government and public administration will not only increase the efficiency but also reduce corruption. The recording, editing, indexing, sorting and retrieval at the local community office can be electronized. In the electronic office any data required for a long period can be recorded on microfiche. Each community system can be interconnected to the central government and national statistics can periodically be issued.

Office Equipment and Communications

68. Accurate and timely information will be very important in the future. The most expensive application on computers will take place in the telecommunication and office equipment area. The telephone exchange system will be digitalized to link with the data processing. In the office, papers will be replaced by display and other means of office equipment. Various types of office equipment will be connected to PABX system in the building to communicate with a central computer, conference system, paging equipment, dictation equipment, public address equipment, data bank, system management centre and other PABX.

69. The future electronics office will integrate data processing and work processing with electronic mail, voice and data communications. The first major step towards the integration of telephone, typewriter, mailbox and copier with a common information base would bring a

tremendous amount of efficiency to the office. The contact point to the common information base will be PABX to which all the office equipment such as the word processor, telex, phones, facsimile, date terminals, videophone, etc. are to be connected. Industries over the past 30 years invested a yearly average of US$20,000 per blue-collar worker to realize 95 per cent improvement in individual output. In the office, business investment approximately amounted to US$2,000 for each employee over the same period to squeeze out a mere 4 per cent gain in productivity. Thus, the office staff in the western industrialized countries is esimated to have grown by 45 per cent although overall work forces have increased only 6 per cent. Since the office is the centre of decision-making, the efficiency is more important than the production line. Therefore, large investment is expected in the future. One possible problem may be the human factor, the human beings willingness to adapt to new modes of technology. However, employees are getting more familiar with the tools and computers. In 1970 only 25 per cent of the work force operated the computer. It is expected that by 1985 more than 60 per cent will deal with them and another 20 per cent or 25 per cent will have at least some knowledge of their function.

70. The office will eventually become paperless and all incoming and original data will be converted into either electronic store or microfilm, depending on the nature of the material. All data can then be edited, indexed, sorted, retrieved, and converted into paper form, and, if necessary, communicated through the mail. The correspondence coming into the office is usually stored in the computer system, while documents, catalogues, and other lengthy materials go on film where they can be called up for viewing by an automated microfiche retrieval system.

71. In addition to the conventional telecommunication, the video will play an important role in the future. Two types of video technology may be involved in communication. Bulk transmission of information will be largely displayed on the television set, and person-to-person telecommunication will be carried out via telephone networks linking

picture-phones or television sets. One makes a journey to talk face to face with the other party or leave some evidence such as a signature. The video conference system can save the expenses of the journey and time, and facsimile can transmit the signed contract sheet. Since the control exchange system can be linked to the international satellite telecommunication, the interface can be made with any other countries with a similar facility.

72. Another future technology to play a major role in information processing is optical communications and voice processing. Miniature semiconductor lasers, fine and highly transparent glass fibers, new ways to manipulate laser beams and optical imaging methods will yield new techniques for transmitting information. It will be possible to develop more intelligent equipment that will be operated by verbal commands, announce if there is anything wrong with itself, diagnose itself, and tell us how it is to be used.

Home Electronics

73. The future home electronics will be changed to interface with the digital processing and communication system. Even the broadcasting will be done in Pulse-Code Modulation (PCM) mode and the most of home entertainment equipment will be digitized for higher fidelity and easier interface. As a result of the semiconductor innovation, the microcomputer will eventually become the true home terminal, controlling all the entertainment equipment and home appliances in accordance with the programmed instructions. Like the PABX at the office, the home computer will become the contact point with the outside telephone cable fiber [illegible] In the meantime, the television receiver or similar equipment will act as a two-way terminal, communicating with various data bases as well as receiving the information and entertainment that can be selected by the consumer. Examples are viewdata, teletext in Europe and microcomputers in the United States of America.

74. The future scenario for information teleprocessing at home can be expressed in four technical terms:

The introduction of personal computers in the home;
The availability of more intelligent, easier-to-use programmes;
The spread of hidden computers;
The development of distributed processing systems.

Most of the application of home computers will be easily accessible to the user, who will not need to be aware of its operating details. The home computer will be a terminal for the world of stored information rather than a processing machine. Another possible function will be interaction in the market place in which the seller who needs merchandising or servicing will find his customers by consulting, or the suppliers may display their product on the television terminal upon personal request. The biggest advantage to society from the eventual development of the information market place will be the individualization of products and services such as personalized newspaper, made-to-fit furniture, and tailored service. One of the effects of the mass media and production in the past century has been to homogenize experience by providing each person with the same television shows, newspapers or similar product. The personal computer can work to reverse this trend by allowing different individuals to specialize in different areas and build up their self-esteem by virtue of their proficiency.

75. When the future home appliance, entertainment equipment and facilities are properly connected to the home computer, all of them can be controlled as required. For example, in the morning the television will give a greeting at the time desired to get up and run through the new brief of the previous night with appointments for the day. In the meantime the curtain will automatically be opened and the bath water will be turned on at the right temperature. A person can go to work after breakfast prepared by a robot, push the phone switch to the "out" position so that all the incoming phone calls can be recorded and the desired message can be delivered. If a person wants to operate by remote control any of the equipment at home, a telephone call with instructions will suffice to control the home computer.

76. In the future television viewers will gain control of their sets by utilization of innovations such as the video cassette recorder, video disk, and pay-programme selector. In the next two decades the two-way cable television will finally be realized and television will not be able to depend on the mass audience. An evergrowing number of cable television subscribers will be attracted to the pay-television package that community antennae television operators offer. A personalized television programming can be done as a follow-up phase. All broadcast material could carry coded classifications for sports, news, drama, etc. The video recorder would then select according to the coded classification as desired.

77. There will be countless new innovations affecting home life but the above illustrations are the realistic ones in the immediate future.

Examples of Future Technology

78. The application of micro-electronics technology encompasses such an extensive field that no single company can possibly cover the entire field. Each company tends to specialize in a specific area and ultimately integrate vertically with the other companies' products. For the impact of micro-electronics technology see Table 1.

79. Automation of industrial production converges at the versatility of the robot and the synchronized system of robots. The current state of the robots is confined to performing limited adaptive control. Leaders in the makers of robots are Unimation, FANAC, SRI and other American companies. Further development of the robot is foreseeable in the next decades. It will not be surprising if these leaders succeed in manufacturing a robot which is compatible with the system of plant automation. Of course, the future robot will perform more complicated functions accurately and under the context of factory automation. 5/

5/ Louis Kraar, "Japan's Automakers Shift Strategies", Fortune, August 11, 1980.

80. A dramatic application of computer technology is X-ray tomography for medical purposes. EMI Technology Corporation is leading this field. This technology has been fully developed and has been used in many hospitals. In the next ten years, the cost of the equipment is expected to be reduced further and usage of the equipment will be widespread. Almost all medical instruments will have substantial intelligence in the coming decades.

81. One of the technical advances in communications will be optical fibres in the coming decade. GE and many other companies are developing optical fibres to replace the copper wire for communications. This invention is expected to revolutionize communications, but also exert positive impact on communication equipment such as the teleconference system, video phone, facsimile and the military communication system.

82. Electronics lead in entertainment for the home. With the increased number of home appliances and the personal computer, home electronics will gradually be converted from entertainment to utilitarian. Apple, Radio Shack, and Commodore appear to be the leaders in the field of personal computers today. These personal computers will be connected by large-scale computer networks for database access, mailing, and complex processing. Another approach is the viewdata and teletext which are less expensive than the computer.

83. Another emerging technology is the high performance computer-based on the advanced IC technology and computer architecture. An example of such is the VHSI project. TI and National Semiconductor are involved in the project. Another effort is the Large Area Integration (LAI) development. Many academic institutions and major computer companies are involved in the development. Japan is involved in the advanced computer development. The project is led by ETL (Electro Technical Laboratory) with industry participation like the VLSI project.

84. Among advanced Input-Output (I/O) systems is the voice I/O, pattern, recognition applications (character, image), graphics and so on. The leaders are Heuristics, TI, Bell Laboratories, NASA, Evans-Sutherland, Tektronix, Japanese computer makers etc.

IMPACT OF MICRO

Field of Emerging Technology	Present State of Technology
1. Automation of Industrial Production	. Industrial Robot can only repeat the prearranged sequence. . Automatic Counters and Testers . Computer Aided Design
2. Infrastructure Surrounding the Human Society	. TV Terminal . Telecommunication . Data Processing . Computerization of Diagnostic Scanning
3. Office Equipment	. Word Processor . Telex . Phones . Facsimile . VTR . Telecommunication
4. Home Electronics	. Timber . Microwave-Oven . Colour TV . Stereo Amp . Cassette etc.
5. Advanced VLSI	. Use in Microcomputer
6. Advanced I/O	. Character Recognition . Voice Synthesizes . Colour Graphics

TABLE 1

O-ELECTRONICS TECHNOLOGY

In 5 Years	In 10 Years
. General Purpose Programmable Robot . Automated Numerical Control of Fabricating Machine	. Robot will do all the local complex functions (Interface by Tele-communication) . Automation of Software Product . Automation of Entire Factory
. Automatic Mass Transit . Self-Ticketing . X-ray Tomography . Intelligent Terminal	. Microprocessor-based Locomotives . Automatic Entry and Exit of Passenger . Nuclear, Fluoroscopic and Ultrasonic Scanner . Automated Network
. Computerized Office Equipment will be integrated and fully utilized for the community service. . Video Phone	. Communication by Optical Fiber . Integration of voice, image.message and text data communication.
. Entertainment Appliances such as electronic toys, connected to the home computer . Video Disc	. Microcomputer will control the home appliances. . Panel TV . Two-way Communication Systems
. Improvement of VHSI . Initial Development of LAI . Use in computers	. Development of LAI . Development of Integrated Equipment Component . Use in Aerospace Industry and Robot
. Limited Image Recognition . Voice Recognition . Advanced Graphics	. Image Recognition . Cost effective voice recognition . Inexpensive graphic I/O

III. THE POTENTIAL OF THE TECHNOLOGY FOR DEVELOPING COUNTRIES AND ITS SOCIO-ECONOMIC CONSTRAINTS

Automation and Employment

85. Can technological progress create net unemployment? It is argued that technological progress means more output per unit of input. This increase in productivity is transferred via lower prices and higher incomes into greater purchasing power and thence into demand for the increased output. Furthermore, technological innovation enhances the competitive strength of many manufactured products in international trade. Certain countries such as the Republic of Korea, Hong Kong and Singapore depend on exports for their economic expansion. Thus alternative employment opportunities opened by the technological progress will automatically expand enough to absorb the manpower released through technological change. This automatic adjustment is based on the assumption of a free competitive market with a completely mobile supply of manpower and capital and elastic consumer demand. In reality, however, a free competitive market does not exist and thus a considerable degree of restructuring of the existing employment pattern will be needed as a result of introducing the new technology.

86. The more rapid the pace of technological change, the more frequent and drastic are the consequent shifts in manpower requirement. New skills are called for and old ones become obsolete. New industrial communities are built up and old ones abandoned as firms tend to move away from centres of labour supply and nearer to new markets and sources of energy. Thus automation increases the bottlenecks which have always tended to check economic growth in modern industrial societies. The matching of supply and demand for particular skills at particular locations has always been hampered by obstacles of occupations and geographical mobility such as inadequate training facilities; labour market information; social, cultural, and family ties; inadequate housing; and the added expenses of relocation. In a setting of continuous change in manpower demands, the impact of these obstacles on labour mobility is enormously magnified.

87. In every economy there are frictional elements such as the rigidities and inelasticities in the labour market, which create structural unemployment by interfering with a smooth adjustment between demand and supply factors of production. Technological innovation is not a direct cause of such structural maladjustments, but it does aggravate them by accelerating the tempo and scope of economic change. It creates new products and new industries; constantly alters plant requirements for capital, workers, and various kinds of skill; shifts the geographical distribution of industry; and accentuates differentials in wage costs, productivity, and level of mechanization between firms and between various sectors of industry. The quickened pace of technological changes makes the required adjustments to them more difficult, and thereby greatly magnifies the proportion of the problem of structural unemployment.

88. With the introduction of micro-electronic automation, however, a major revamping of production methods will take place and the unemployment question has to be re-examined. In a recent publication, The Third Wave, Alvin Toffler asserts that micro-electronics could shift literally millions of jobs out of the factories and offices into the home. 6/ Thus, smaller work units are common by decentralization and de-urbanization. It may, of course, not be possible to do 100 per cent of production activities at home. But it is estimated that between 35 per cent to 75 per cent of the entire work force could work at home if we provided the necessary micro-electronic communications technology. If significant numbers of employees in the manufacturing sector could be shifted to the home, then it is safe to say that a considerable portion of the white-collar sector, where there are no materials to handle, could also make that transition. Even today we have witnessed that an appreciable amount of work is being done at home by such people as salespeople, brokers, accountants, lawyers, and doctors.

89. It might be premature to predict such days of working at home would come soon, but within a reasonable time period, say ten to twenty years, we will experience the decentralization of industries from a single

6/ Alvin Toffler, The Third Wave, William Morrow § Co., New York, 1980.

factory in an urban centre to smaller cities throughout the country. The decentralization of industrial facilities will ease the heavy burden on the urban planners, thereby alleviating the urban congestion, pollution, and crimes. Energy-saving from the reduction of commuting distance will be a definite positive side effect of the decentralization. A balanced development through the country and more effective utilization of limited landscape and land-based resources are clear benefits of decentralization by the introduction of micro-electronics automation.

90. The socio-economic problems generated from the concentration of population in major metropolitan areas of developing countries of Latin America and Asia are serious enough to warrant attention. Redistribution of the population and industries in developing countries will benefit from micro-electronics automation.

91. On the other hand, the export-led economies of many developing countries need to maintain comparative advantages of their exports. The quality of export products, which are labour-intensive light manufacturing goods, needs to be improved and without the help of micro-electronics it is difficult to maintain the lead. With growing exports, new employment opportunities are opened up and the workers who were displaced by the new technology can be reabsorbed by the expansion of production in alternative industries, or the same industries in which they used to work. The problem of unemployment which may be caused by the micro-electronics automation can also be mitigated by the reduction of working hours of individual workers. We are well aware of the fact that an average person worked nearly sixteen hours a day at the time of the Industrial Revolution. Consider the case of the coal miner during the second part of the nineteenth century, working twelve to fourteen hours a day, six days a week, in poor conditions and earning barely enough to keep his family nourished. Today's miner still works hard, and in unenviable conditions underground, but the working day is eight hours and forty hours a week in a normal situation. This has been possible by continuous technological progress, and thereby increased labour productivity. In the next decade or two, today's eight

hour day will become a five or even a four hour day.

92. Today most of the manufactured goods go through a relatively short product life cycle. This trend is natural in the light of rapid technological innovation and product improvement. How quickly new improved products can be introduced into domestic as well as international markets determine survival and advancement. Many developing countries try to train employees to work with the ever-changing technologies, but the pace of training and education is too slow to cope with the rapid change of technologies.

93. Applications of microprocessor technology in industry would enable many manufacturers to produce products with relatively unskilled labour. Computer-aided process control and monitoring applications would enable the manufacturer to make the most of available labour and still maintain an acceptable profit margin. The potential of the micro-electronics technology in developing countries is enormous particularly since highly skilled labour is not required to operate machinery. It would create a better environment and enrich the quality of life.

Capital Requirement

94. The economic development in developing countries is always limited by certain productive factors. Among the productive factors, capital may be regarded as the most crucial one. Increased investment necessitates more domestic savings or foreign capital. However, the extent to which foreign loans can be serviced and repaid will ultimately depend on domestic savings in the future.

95. An increase in voluntary savings through a self-imposed cut in current consumption is unlikely when the average income is so low. It is hoped that when income rises, the marginal rate of saving may be greater than the average rate. In order to accelerate the rate of domestic savings, the governments of developing countries are compelled to resort to "forced" saving through taxation or credit expansion. The country's taxation potential depends upon a variety of conditions: the

level of per capita income, the degree of inequality in the distribution of income, the political leadership and administrative powers of the government. It is generally true in developing countries that the actual ratio of tax revenue to national income is at present less than the tax potential. The potential can be more fully exploited, especially if the increase in taxation is undertaken gradually over a number of years. The saving that is forced by additional taxation, however, is likely to be less than the additional tax revenue, since there may be a reduction in private voluntary saving. Nonetheless, an increase in taxation remains the most expeditious way of meeting a rise in capital expenditure.

96. The problem of capital formation in the developing economies breaks down into three main parts. The first concerns the financing of social overhead investment for building the infrastructure of the economy. The second deals with an intermediate zone in which the actual investment projects are in private hands but the funds are made available through government finance. The third deals with the necessary incentives to private investment both domestic and foreign, as they are influenced by taxation and other fiscal measures. In all three categories, government effort is directed toward maximizing savings and mobilizing them for productive investment.

97. Since the 1950s there has been an increasing amount of capital flow from advanced countries to developing countries in the form of public financial aid and loans, private foreign investment, and non-monetary transfer of managerial and technical knowledge. The public financial aid in the form of a free grant has diminished gradually while the loans from international organizations such as the International Bank for Reconstruction and Development and the Asian Development Bank were on the increasing trend. Throughout the 1970s increasing attention was being focused on the contribution of private foreign capital. Private loans from transnational banks of advanced countries have been an important source of external capital for developing countries. Also a growing number of transnational firms is investing heavily in developing countries in the form of direct investment. The transnational corporations are engaged in international operations in search of lower production cost, raw materials, avoiding high tariff, and new markets.

98. As a result of steady increase of domestic savings and foreign capital inflow, the developing countries have grown impressively over the past twenty-five years: income per person has increased by almost 3 per cent a year. Between 1960 and 1975 Gross Domestic Product increased at a rate of 6.1 per cent in advanced developing countries.

99. As output and income grow, there are substantial changes in economic structure, with the manufacturing industry increasing its share of the total output at the expense of the agricultural sector. Some of the developing countries are now manufacturing technologically sophisticated equipment, particularly in the field of electronics. These advanced developing countries rely heavily on exporting manufactured goods in the process of economic development. Large advanced countries tend to be less trade-oriented because they genrally have more diverse endowments of resources and can rely on larger domestic markets to justify production on an economic scale. Countries which are rich in natural resources tend to industrialize more slowly than those poor in resources because they must export manufactured goods from an early stage in order to meet their import needs. The investment priority is, therefore, set by the economic conditions of each developing country.

100. When investment resources are scarce as they are in developing countries. rational allocation of capital is of the greatest importance. If public investment absorbs a large percentage of the total resources available, or the government attempts to influence the direction of private investment, it becomes necessary to establish "investment priority" for determining the optimal investment capital allocation.

101. The most general objective of economic development is to maximize the national income or the rate of economic growth. For this objective, the incremental capital-output ratio is a useful approach. This approach measures the amount of additional investment required to produce an additional unit of output. The overall capital-output ratio can be used as a tool for estimating capital requirements for the whole economy, while capital-output ratios for individual sectors, industries or processes may be used to estimate capital requirements sector by sector or project by project.

102. If a developing country uses the capital-output ratio method, it tends to labour-intensive production which requires a relatively smaller amount of capital but turns out a relatively larger amount of output. This is possible by the contribution of labour which is abundant in general in developing countries. As a matter of fact, many developing countries invested in light manufacturing industries such as textiles and food processing in the early stage of their development. However, new technological innovations increase the level of productivity while the cost of capital goods decreases. The result of the reduction of capital-output ratio, and thereby permits going in for more sophisticated industrial production. A good example of this type of technological innovation is micro-electronics. The microprocessor-led technological revolution will eventually redirect the flow of capital investment in advanced countries as well as developing countries. Until now the private industries in export-oriented developing countries have maintained their comparative advantage in agricultural products and less sophisticated manufactured goods. The comparative advantage in these industrial sectors is gradually being eroded by the challenge of developing countries. Thus the advanced developing countries need new technologies to improve their product quality and produce more sophisticated manufactured goods for export, and thence maintain the comparative advantage of new products on the international market. Export-oriented developing countries cannot maintain a high level of employment without increasing their exports.

103. Application of micro-electronics technology tends to reduce capital requirement indirectly. Since the technology is likely to have industries decentralized and urban areas deconcentrated, urbanization and infrastructure can be considerably reduced. For instance, mass education through audio-visual network systems could save an enormous amount of investment requirements for education. Investment requirements for urban environmental control could possibly be reduced.

104. The private sector will be relieved of the burden of paying very high land prices for its industrial plant sites in urbanized areas if industrial location is decentralized. Thus the released capital can be invested in micro-electronics automation.

105. In recent years, students moved to large cities in order to receive better educational services in the Republic of Korea as well as many other developing countries. This trend requires a large sum of investment for construction of educational facilities in already over-crowded urban areas, while leaving the existing facilities under-utilized in rural areas. With the introduction of micro-electronics automation, existing educational facilities are to be more evenly and efficiently utilized without much additional capital investment.

106. The microprocessor revolution will thus redirect investment capital requirements from large urbanized industrial centres to smaller cities where new work units are gradually to be settled. Traditional industrial location theory points out that industries which produce weight-losing products should be located close to the raw material deposits, and industries which produce weight-gaining products need to be located near the consumption centres. This principle, however, has not been strictly followed in the Republic of Korea due to the fact that the labour force is concentrated in a few industrial centres, and, therefore, private industries are placed in populated areas regardless of sources of raw materials. Countries poor in resources like the Republic of Korea have to import most of the needed raw materials and transport them to inland industrial locations. If industries are dispersed by the micro-electronics automation, new locations could be the sites near the seaports where imported raw materials arrive. Processed or manufactured products can easily be exported from this point, which will save transportation cost and time.

107. As industrial development is accelerated by the microprocessor revolution, intersectoral multiplying effects will be magnified, and, therefore, increase national income. For instance, improved agricultural productivity increases rural purchasing power. This means increased demand for manufactured goods and more industrial production leads to higher income and higher saving. Increased saving is the source of expanded investment in high technology industries. High technology products enable the developing countries to maintain the comparative

advantage in international competition and also upgrade their standard of living. The microprocessor revolution will undoubtedly bring further technological innovations in developing countries as well as the advanced countries. The impact of these technological innovations on various sectors of the economy will have a multiple effect.

Urbanization

108. Economic development in many developing countries is generally accompanied by a shift of human and other resources from agriculture to the manufacturing and service sectors. Manufacturing and service industries are predominantly located in urban areas, thereby, migration from rural to urban areas follows as industrial activities expand. It is observed that the migration to urban areas is mainly in search of better employment opportunities and higher wages. The young generation go for educational purposes.

109. The movement of labour from farms to cities has been dramatic in the Republic of Korea since the early 1960s. Employment in agriculture including forestry and fisheries fell from 63.1 per cent of total employment in 1963 to 41.8 per cent in 1977. During that period, manufacturing sector employment rose from 8.0 to 21.6 per cent. The movement of productive manpower from the agricultural sector to manufacturing sector is expected to continue. This means that migration from rural to urban areas will continuously take place in the future as in the past. Most advanced countries are 65 to 80 per cent urban, 65 to 80 per cent of the total population live in urban areas with a population of 50,000 or more.

110. In 1975 in the Republic of Korea the urbanization rate was 50.9 per cent and it is expected to continue until the rate reaches about the 75 per cent level. As urbanization progresses the following problems have arisen.

111. Housing. The quality and availability of houses are serious socio-economic problems in most developing countries. Housing is an important

determinant of welfare, life style, and social status. Thus in most countries it is usual to have government regulations and direct involvement in the construction of housing units. There is a continuing controversy about the efficiency of government programmes. Migration, especially of the poor, to cities means that urban housing becomes scarce, expensive and inadequate and urban squatter settlements are the symbol of this problem in many developing countries. Squatters pose serious problems for governments. Their settlements are illegal, unsanitary and sometimes occupy landspace needed for high priority public purposes. The average living space for a person in the Republic of Korea is 6.6 square meters which is about one-fifth of that of the United States of America and the price of land and homes is often too high for an average wage earner to afford during a working life.

112. The introduction of micro-electronic automation is expected to disperse the population concentration in urban areas. Computer-operated production systems could shift millions of jobs out of factories and offices located in urban areas into smaller work units such as production facilities in much smaller cities or individual worker's homes. With advanced microprocessors technology, the need for urban concentration of plants in many developing countries will be substantially lessened. Production activities are possibly carried out anywhere in the country where the raw materials are available through the help of computer-aided systems, including telecommunication. Thus a particular industrial location for an industry is not as limited as at present. We would, therefore, witness reverse migration from congested urban areas to smaller towns throughout the country. This will be a significant positive impact of micro-electronics technology on population movement. We can expect to live in a much improved environment and most of the problems associated with the scale urbanization may gradually disappear.

113. Urban transportation. The economic function of an urban area is to offer accessibility for the working population to their respective work places. Concentration into several urbanized megalopolises is convenient for workers, entrepreneurs, and consumers under the current

production and consumption patterns. Moving people and goods within the urban centres and throughout the country necessitates well developed transportation systems. In almost all countries, urban transportation is based on a complex interaction between the government and private decisions. The government must build and maintain mass transit and highway systems. Large sums of public and private capital are invested in building and operating road and transit systems. Nevertheless, no country has come up with a satisfactory answer to the urban transportation problem. The limited landspace for roads, the high cost of energy, traffic jams, and pollution are serious threats to the urban quality of life.

114. The micro-electronics revolution is expected to decentralize industries throughout the country thus alleviating the urban transportation problem and substantially reducing the consumption of oil and electricity needed for urban transportation.

115. Prior to industrialization production and consumption took place at one location and the need for transportation of produced goods to consumers did not exist. The advent of the industrial society introduced producers and consumers. This split led to the rapid spread of exchanges and the market system. As industrial development continued, more efficient systems of transport have also been developed. Nevertheless, there is no ultimate solution to the transportation problem. If a situation could be reached in which production and consumption were in one place, the problem of transportation would be minimal. 7/ Micro-electronics automation would assist in reaching such a stage of economic activities in the near future.

116. Today many transnational firms are engaged in production and marketing activities on a global basis and these activities will be enhanced further by the introduction of micro-electronic automation. Also the international migration from developing countries to advanced countries in search of jobs will fall sharply if jobs can be found in their own countries. It is also well known that a large business enter-

7/ Christopher Evans, The Micro Millennium, The Viking Press, New York, 1980.

prise at one location does not necessarily mean the most efficient operation. Elementary economies teach that "diseconomies of scale" set in as the size of a plant gets too big. Thus some corporations are actively searching for ways to reduce the size of their work units. The micro-electronic automation will be a definite help for the corporations' efforts of going into decentralization of production facilities and activities.

117. Environment. All economic activities extract raw materials from the environment, process them, and return the waste residual to the environment, for example, agricultural crops are processed for human use. Consumers return waste materials to the environment. All materials removed from the environment must eventually be returned to it. Materials discharged into the air and water cause the worst form of pollution. Therefore, dispersal of industries into small communities would help to solve some of the pollution problems arising from densely polluted areas.

118. Today many countries rely on computers to control the quality of the air and purify water. Computer-aided meteorological research helps in controlling the pollution elements. Micro-electronics technology also helps to develop alternative pollution-free energy sources such as solar hydrogen, thus reducing our dependency on fossil fuels and helping to reduce air pollution.

Socio-Economic Constraints

119. It is argued that social inadequacies, disorders, and inability to meet the needs of industrial societies are caused by an increasingly over-burdened, under-staffed, and under-paid educational system. This is more so in developing countries where the desire to modernize their primitive industries through education is intense. Education is often narrowly conceived as something done primarily in school. The advent of computer-aided societies and the accelerated tempo of socio-economic changes however reshape our stereotyped notion of education. Economic activities are changing so rapidly under the pressure of scientific and

technological advances that a person now entering the work force is expected to change job skills several times throughout a career. It is becoming increasingly apparent that lifelong education and retraining will supersede the traditional approach to formal education. Scientists, engineers, and technicians have been among the first to feel the need to be continually brought up to date in their rapidly changing fields.

120. The technology of computer communication could increasingly emphasize instructional and self-tutoring features to test and improve user performance in the short run and accelerate learning processes in the long run. Computer education is already becoming an important institution. Thus computer-catalyzed education could increase the number of the educated masses in many developing countries where the illiteracy rate is extremely high and building traditional educational systems is very costly. Without having built expensive conventional educational facilities, every country in the world can offer education to almost the entire population regardless of their geographical setting and age through the computer-aided educational system.

121. In the perspective of the individual life span, the current practice of mass education in youth followed by a comparative educational vacuum in adult years is a prime example of time failure. With rapid advances in science and technology and with changing social conditions it would be desirable to have a shorter initial educational experience followed by educational opportunities throughout life. This would meet the needs of multiple occupations during a lifetime.

122. In June 1980, the Republic of Korea Broadcasting Station organized a college preparatory programme for high school students as well as those who had already graduated from high school but had been unable to enter college. The response from the students was immediate and enthusiastic. Since television sets are available in almost every Korean household, young people would not have to leave their rural homes, and thereby reduce the size of rural-urban migration. This gives an excellent

example of how technology-aided education can successfully be implemented in many developing countries.

123. Today many developing countries in Latin America, Asia and Africa are suffering from a high illiteracy rate and unfortunately these countries do not have enough capital to invest in building conventional-type education systems. The wide spread of microprocessor technology will eventually reduce the cost of computers, and computer-aided educational systems will be a short cut in educating and training in developing countries.

124. Skilled labour is an essential element of modern production systems. In spite of the abundant supply of labour, developing countries have frequently encountered insufficient supply of skilled labour as they expand new production facilities and equipment. The insufficiency in skilled labour affects the quality of the final products and utilization of machinery and production facilities. 8/

125. Industrial skill is usually gained through experiences in practical work processes. Through the stimulation of technique and extensive use of audio-visual equipment, the problem of gaining skills can be resolved. Micro-electronic products are the bulk of simulation and audio-visual equipment. Developing countries will easily overcome the problem of the lack of availability of skilled labour though selecting appropriate simulation and training aids.

Impact on International Economic Relationships

126. A pattern of international economic relationships has evolved between the advanced and developing countries. Many developing countries are endowed with rich natural resources, agricultural land, large populations, raw materials, agricultural products and cheap labour. These aspects can be utilized in return. They receive from advanced countries manufactured goods, capital, and technology.

8/ Gunnar Myrdal, Asian Drama: An Inquiry into the Poverty of Nations, Vols I, II, III, Pantheon, New York, 1968.

127. Industrialization of developing countries is closely related to international economic relations. The light industry which is particularly appropriate in view of the economic conditions of developing countries has opened a path toward industrialization. As the developing economies are industrialized, heavy reliance on foreign capital and technology is expected. Higher employment, exploitation of natural resources, import substitution of manufactured goods, and opportunities for exports are the merits of industrialization. For those reasons, industrialization of developing economies is deemed highly desirable.

128. Since the end of World War II, advanced countries have become more conscious of economic development and welfare on a global scale. Developing countries are claiming their right of survival. A considerable amount of capital has been transferred from the advanced to the developing countries to finance infrastructures such as irrigation facilities, transportation, communication, health and education. Along with public grants and loans, commercial loans have also been made available for industrial development. Due to lack of domestic savings, many developing countries adopted a national policy of inducing foreign capital.

129. Apart from international cultural exchange and trade, a sophisticated form of international transaction is technology transfer. One of the critical elements of the industrialization process is deemed to be technology. Modern industry depends on the advancement of technology. A technology-intensive industry will need intensified transfer of technology to expand particularly the adaptation and application of micro-electronics in a developing country.

130. An explosive application of micro-electronics technology is expected to take place in developing countries. Adaptation and usage of micro-electronics in the field of education, for example, will find limitless demands to fill the needs of literacy, secondary education, and vocational training. The micro-electronics revolution in the developing countries will enhance infrastructures such as education, communication, transportation, and health. Vast improvement in the productivity

of agro-based industry will also be achieved.

131. At the early stage of micro-electronics application, developing countries have to import a considerable quantity of electronic components and finished equipment from advanced countries. The burden of foreign exchange could prohibit the initial stage of the micro-electronics revolution. It seems important to secure financing to meet the import of electronic products. Before getting involved in vast imports it is desired to promote joint foreign ventures with the help of transnational corporations. The inflow of foreign capital and technology is inevitable because of the lack of domestic savings and domestic technology. It is clear that such arrangements as joint ventures or transnational corporations are transitional. As developing countries grow, the relationship with advanced countries will change.

IV. ISSUES FOR FURTHER CONSIDERATION

132. Recently many international organizations and development agencies have tried to assist developing countries in introducing industrial technology. Machines and equipment introduced to many developing countries fell into disuse, broke down and remained unrepaired due to short supply of skilled labour and lack of managerial experience. Rather than sophisticated and complicated technologies for large-scale factories, the need is for intermediate, soft or alternative technology.

133. Many developing countries are encountering serious common problems of rapid urbanization together with inadequate employment opportunities. A new approach to assist developing countries requires the emphasis to be put on rural development. Such an approach would urge labour-intensive production with low capital, energy and skill requirements instead of building a capital intensive plant. It would call for resources to be channelled directly to basic human needs. It would urge self-sufficient food production. It would also favour decentralized and small-scale facilities suitable for villages.

134. Two categories of developing countries have emerged: relatively advanced developing countries, and developing countries where the level of GNP is as low as US$500 per capita.

135. In a developing country of the first category where industrialization has considerably progressed, control technology by use of microprocessors could gradually be adapted as in advanced countries.

136. Many in the second category of developing countries remain far from the stage of industrialization and lack technical manpower. Since the difference in living standards between the urban and rural community is apparent, migration into urban areas poses serious problems. In order to resolve or to mitigate the problem of urban migration as well as to contribute to improvement of income and quality of life in the rural community, a higher priority should be placed on the development of rural industry.

137. In order to secure a feasible scale of economic activities, the size of a micro-urban community with a population of 30,000 to 50,000 is contemplated. Additionally the following assumptions are put forth to provide the underlying conditions for application of micro-electronics technology:

(a) It is attempted to build a micro-urban community in the prevailing tropical and rural setting of developing countries;

(b) Population of the community will range from 30,000 to 50,000. The corresponding households will range from 3,000 to 5,000;

(c) The new community will be sparsely populated due to its rural setting;

(d) The population relies for their food stuffs on self-supply. Major income sources of the population are sales of commercial goods and crops;

(e) Industrial plants are rare or ineffective. Small-scale handicrafts industry is under operation;

(f) Electric power and telephone services are not available;

(g) Compulsory education at elementary level is not even well defined;

(h) The community as a whole has access to both national road and railway networks but the quality of service is considered poor. The local access within the community is extremely poor;

(i) Administrative service is maintained at bare minimum.

138. Taking into consideration the preceding assumptions, it becomes clear that modern technology such as micro-electronics technology could take root in the environment. Application of micro-electronics technology in areas of communication, education, energy and agro-industry appears promising, It does not preclude the need for complementary technology required for this application.

Communication

139. For the selection and installation of communication network, the following conditions should be taken into account.

(a) Subscriber clusters (See Figure I)
   (i) Density of subscriber and number of cluster;
   (ii) Distance between cluster and toll traffic;
   (iii) Distance between clusters and density of cluster.
(b) Subscriber behaviour:
   (i) Subscriber traffic;
   (ii) Call distribution;
   (iii) Adaptability of party line.
(c) Toll traffic:
   (i) Originating/terminating traffic of a cluster.

140. Given that the size of a cluster is small, distance between clusters is over 10 km, and a self-contained cluster has very low traffic to and from the metropolitan centre, the following network is recommended:

(a) Clusters number 1, 2, 3, 4 and 5 shown in Figure I are equipped with radio relays with the function of central relay;
(b) Small clusters of number 3A and 1A can be equipped with a subscriber radio system.

141. A call from cluster number 3A to the metropolitan centre has to be relayed through a radio relay system of clusters number 3 and 4 in sequence. The radio relay is to be inactivated except to monitor for call-ins. Power requirement and consumption could be reduced by the preceding mode of operation. For the switching function of traffic a PABX with charged power could be used as in many advanced countries.

142. To save the power consumption, CMOS microprocessor is suggested for components of PABX. It is further recommended that each circuit be equipped with a mode of power-off and on.

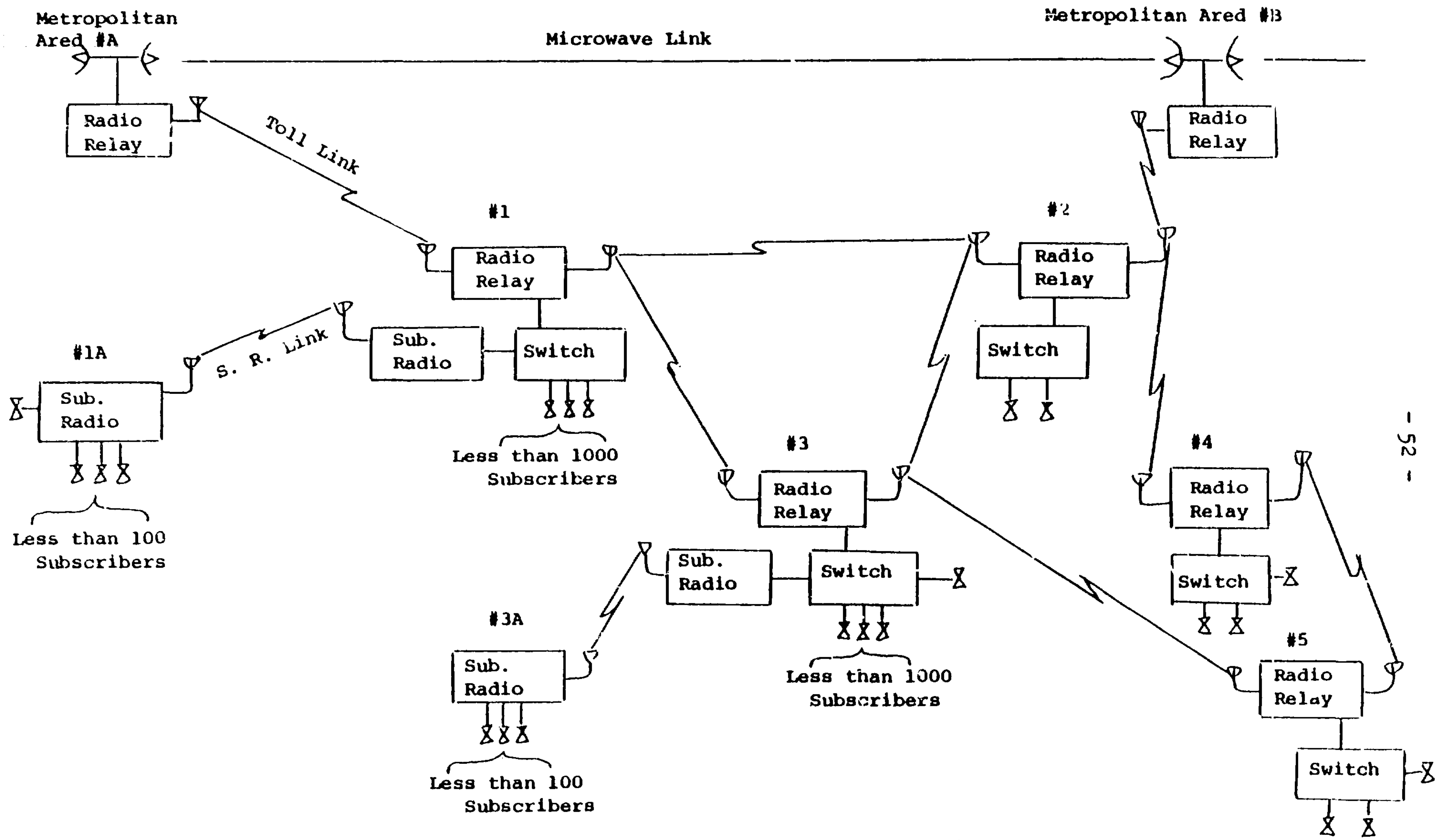


Figure I - Subscriber Radio System

143. The suggested system is a modified version of the subscriber radio system of Farinon Co. 9/ Where a heavy traffic occurs between clusters such as regions in the United States of America, Farinon's subscriber radio system is more applicable. On the other hand, for communication of occasional traffic, a modified system is considered more suitable than the established one.

Education

144. The development of a computer-based instruction system has moved into a demonstration and dissemination phase. The prospect of CAI (Computer-Aided Instruction) lies in its ability to individualize and personalize the instructional processes and to simulate experiences not readily available. CAI lessons can serve as text, test and tutor, while compelling students to be active participants in their own learning. Students work at their own place while their CAI lesson monitors their progress and commonly prevents them from continuing to more advanced instruction unless mastery is demonstrated.

145. The most basic equipment used to deliver CAI includes a computer which stores and transmits educational material and information by means of a specialized computer language. The computer is less often seen by students and teachers than the familiar learning stations. The learning station appears as a television or teleprinter which displays instruction and graphic information and has a keyset attached to it.

146. In the near future, we will see a rich array of educational systems. National, distributed computing networks will make it possible for universities to specialize in areas of interest and to share co-operatively resources and programmes without concern for equipment or location. It will be possible to launch a communications stellite, totally devoted to science and education, and eliminate a "distance" as a physical and economic barrier to the access and use of CAI programmes.

9/ S. Jacobsson, "Microelectronics and the Third World", Wireless World (March, 1980), pp. 87-89.

147. The most significant trend in the positive change is the public attitude toward computers in education. The ever-widening acceptance and use of computers by scientists, engineers, and business, and the broad public enthusiasm for programmable calculators and computer-based games is producing a transformation in social values which will have a profound impact upon education in the future. By 1990, the cost of computer-assisted instruction will be so cheap and its applications so broad that it will be viewed as an educational necessity.

148. This world-wide development will do much to contribute to advancing the level of CAI acceptance. Currently, CAI activity in the United States of America has focused on basic skill development and has had its greatest impact on the elementary and secondary students. In the future, CAI utilization will be extended to those areas where teaching is currently difficult, hard to visualize, and almost impossible to understand with current instructional systems. This means that the major utilization of CAI will be directed towards preschool level and the top level of professional development. Table 2 illustrates this concept.

TABLE 2 Levels of Acceptance & Utilization of CAI

	Home Preschool	Secondary Schools	Higher Education	Industry	Community Institutions
1977 Acceptance	Zero	Widely dispersed emerging	Widespread	High level limited implementation	On the horizon
1977 Utilization	None	Basic Skills (Heavy)	Skill and survey type instruction (Moderate)	Testing and training drills (Light)	.Vocabulary and procedural input in health areas. .Basic skills and conditioning programmes (Light).
1990 Acceptance	Widespread	Widespread	Universal	Heavy	Broad by social and health institutions
1990 Utilization	Heavy use in concept development	Universal for skill development and high level concept development	Extensive for entry level courses and high level professional development and continuing education	Heavy in specific training skill and management development	.Heavy use by health industry for upgrading diagnostic skill. .Heavy use for rehabilitation and deterrent programmes in criminal justice.

149. In addition to the CAI system, a wider viewing of conventional television broadcasting will serve education. The key to this programme depends on the contents and quality of educational programmes of the conventional television broadcasting. It is thus recommended that educational programmes be improved and extended as much as possible.

Energy

150. Energy is an essential element of living. Thus, reliable energy supplies in usable forms as provided by existing technology are essential. Energy technology is being reoriented to make better use of available energy and so reduce demand.

(a) Four main areas of activity demonstrate their direction of research:

(i) Industry
- heat recovery and the elimination of heat losses
- new heating methods and improved existing practices
- reduced wastage of materials with high energy value
- manufacturing processes involving less energy
- materials and products with a lower energy value

(ii) Household
- insulation of walls
- increase of energy efficiency in the heating and air conditioning system
- improvement in the energy efficiency of consumer electronic appliances
- diffusion of heating and air conditioning system by solar energy

(iii) Transportation
- traffic control systems
- technical appraisal of each category of vehicle
- development of battery cars

(iv) Agriculture

- greater use of natural as opposed to chemical fertilizers
- biological pesticides instead of chemical pesticides
- research into improvement in the mechanism of photosynthesis

(b) Energy and micro-electronics

151. The oil crisis has brought considerable attention to primary sources of energy: solar, geothermal, wind, tides, ocean thermal, wave power, organic materials and waste. The first half of this section leads up to the analysis of the generation of electrical power from solar energy, the last half deals with the energy conservation due to increase of energy efficiency.

(i) Generation of electrical power from solar energy

152. Solar energy could be converted into electrical energy. The photoelectric effect causes an electron to be emitted, thus generating a current when light strikes certain substances. A wide variety of schemes has been proposed, but the only one that has reached commercial development is the so-called photovoltaic effect. The heart of any photovoltaic power system is the solar cell. The most usual solar cell consists of a tiny chip of silicon. Single-crystal silicon of extraordinarily high purity is prepared and sliced into chips: one end of the chip is "doped" with a tiny amount of a trivalent impurity such as phosphorus. These different impurities set up a voltage gap across the "junction" between the two portions. When a photon of visible or ultraviolet light strikes such a cell, it creates a pair of charge carriers (an electron and a "hole"), one of which drifts to the junction, and in the process of travelling across the junction creates electric current. Such a cell can create at most a large fraction of a volt and a small fraction of an ampere, by connecting a number of such cells in series, the voltage can be raised

to an arbitrarily high level, and by connecting a number of groups of cells in parallel, the current can be raised to an arbitrarily high level. With the best presently available technology about 10 per cent of the incident solar energy can be converted into electricity, and there is hope that this efficiency can be doubled. Because of the extraordinary purity required and because each cell must be formed of a single crystal, the manufacture of these cells is an extremely tedious and expensive process, although there is hope that this process can be made much more efficient. Makers of cells are also struggling to bring down costs. Since nobody has yet found a simple and cheap way to set more sunshine onto a photovoltaic cell, large numbers of cells are needed for any energy-generating system. Costs will come down with volume production of single crystal silicon cells, or with the new devices utilizing poly-crystalline silicon cells. Further reductions will be achieved by making solar cells of less highly purified silicon, by improving sawing methods and by more efficient assembly of the modules.

153. In a remote region where conventional electric power is not available, power supply from solar cells appears practically feasible. Particularly the application to irrigation, communication, lighting, and television sets, is suitable. The appendices give, illustratively, techno-economic data for the possible setting up of production facilities for such systems.

(ii) Energy conservation by higher energy efficiency

154. Energy conservation is vitally important to the energy future. Energy conservation is generally not limited by technology, but is limited by economic factors. And conservation here does not involve significant changes in the traditional growth of economic activities, changes in life-styles, or major shifts away from energy-intensive activities, other than those that would result regardless of the overall economic assumptions.

a Energy saving in building is achieved by using the computer. The computer covers such things as:

- energy consumption
- hourly shift and daily operating information
- control utilization by shift
- performance information (stack gas temperatures, steam pressures, etc.)
- electrical power generation, fuel usage, water usage, purchased power, etc.
- air quality information

b Energy conservation in transportation involves improvement in the efficiency of transportation equipment: switching from one efficient to a more efficient mode: and switching away from overwhelming dependence on oil. Energy saving is achieved through electronic engine control and fuel management systems. Engine control system uses many integrated circuits. The original function of the system is to provide a precisely-controlled air/fuel ratio to the catalytic converter. However, a microprocessor in the system allows control for the following functions:

- electronic spark timing
- idle speed
- canister purge
- choke
- exhaust gas recirculation
- transmission shifting

Microprocessor Application to Agro-Industry

155. Potential areas of the microprocessor application to agro-industry processing of commercial crops calls for a high priority. Production of commercial crops forms vital sources of income for the rural population. Through the improvement and higher productivity of commercial

crops, a primary condition for a better quality of rural life will be achieved.

156. Typical commercial crops of tropical regions are coffee beans, cocoa beans and tapioca. Owing to the lack of infrastructure, the processing of those crops would have to be confined to primary processing rather than complete mass processing for export or domestic market. The primary processing varies depending upon their physical characteristics, for example:

Cofee beans - deshelling, drying, grading, and packing
Cocoa beans - fermentation, drying, grading, and packing
Tapioca - extraction of starch.

157. The old manual method often causes difficulties in quality and control of processes. The microprocessor warrants the replacement of the manually operated control system with an automated distributed process controller thus improving the quality and through-put of the overall process as well as the reduction of production cost. The programmability of the microprocessor offers advantages of flexible and detailed controls required at various levels of process. Furthermore, decreasing the price of the microprocessor will add another advantage to the availability. Microprocessor application does not require any particular technical requirement; several months of training for high school graduates will suffice to operate an automated control process.

V. PROGRAMMES OF ACTION

158. Two programmes are suggested in concluding this paper: establishment of a training centre for the application of micro-electronics technology; undertaking of a feasibility study.

Establishment of a Training Centre for the Application of Micro-Electronics Technology

159. Establishment of a training institute is deemed an essential course of action for the benefit of developing countries. It will mobilize especially talented persons from developing countries and have them work on practical applications. The outcome of the training can best serve the dissemination of technology to the respective countries.

(a) Areas of training
- Education
- Communication
- Energy-solar cell
- Agro-industry

(b) Training courses

Prime emphasis should be placed on engineering application of technology rather than basic research. Proven technology and products should be utilized for the application. Suggested courses are:
- Introduction to mechanical engineering
- Consumer electronics
- Industrial electronics
- Microprocessor software and hardware
- Instrumentation and control
- Radio subscriber communication system
- Solar cell power system

(c) Instructors

It is essential to select experienced engineers for instruction. To the extent possible, invitations from advanced countries such as the United States of America and Japan are preferable.

A minimum of four engineers is required to form a core of the instructing personnel. The remaining instructors would be recruited from elsewhere.

(d) Location of the Centre: the Republic of Korea.

(e) Minimum participating countries: three countries.

(f) Length of training: 6 months - 12 months.

(g) Number of trainees: 100/year.

(h) Capital requirement

Equipment	US$1.5 million
Training kit	100
Microcomputer	50
Numerically controlled machine	2
Solar cell power system	2
Radio subscriber system	1
Computer-aided instruction system	1
Others	

(i) Operating expenses: US$1.2 million/year.

Feasibility Study

160. It is beyond the scope of this paper to assure the applicability of micro-electronics technology to the suggested areas.

161. Social climate, availability of local engineers and other conditions of the beneficiary country have to be examined in terms of cost and benefit of the application. Undertaking of a feasibility study appears essential to make the application successful. A team of experts including specialists from four areas and an economist is suggested to undertake the feasibility study.

Appendix I

1. Scope

Fabricate and assemble solar cells and build systems for irrigation, power supply for telecommunication ralay, etc.

2. Plant Definition

Solar Cell Fabrication	Plant II
↓	
Solar Panel Assembly	Plant III
↓	
System Assembly	Plant IV

Note: 1. Capacity: 200 - 300 Kw/year

2. Plant I : Wafer Production Plant 500,000/year, 3" wafer production capacity. (See Appendix II)

3. Solar Cell Fabrication (Plant II)

A. Process Description

	Process A	Process B
Junction Formation	Diffusion	Diffusion
↓		
Metallization	Evaporation	Plating
↓		
Anti-Reflective Coating	Evaporation	Spin-on or Spray
↓		
Test	Simulator	Simulator

Note: 1. Process A: A typical conventional process

Process B: new low cost process

B. Cost Analysis

	Process A	Process B
Junction Formation	.40	.40
Metallization	6.40	2.00
Anti-Reflective Coating	1.00	.40
Test	.20	.20
Total	8.00	3.00

Note: 1. All units in $/Watt

2. Wafer cost is not included.

3. Labor related cost is about half of the total cost.

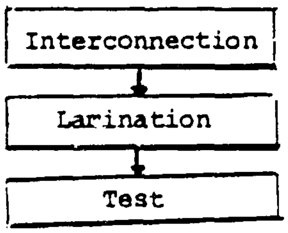
C. Capital Requirements (K = $1000)

	Process A	Process B
Junction Formation	130 K	130 K
Metallization	750 K	200 K
Anti-Reflective Coating	270 K	40 K
Test	50 K	30 K
Total	1,200 K	400 K

Note: Capacity 200 - 300 Kw/year

4. Solar Panel (Module) Assembly (Plant III)

A. Process Description



B. Cost Analysis and Capital Requirements

	Cost Analysis	Capital Requirements
Interconnection	.30	50 K
Lamination	.50	150 K
Test	.20	50 K
Total	1.00	250 K

Note: 1. Solar cell cost is not included.

2. K = $1000

5. Final Solar Panel Cost Estimation (Including Wafer Cost)

	Process A		Process B	
Wafer	1.70	3.40	1.70	3.40
Solar Cell Fabrication	8.00	8.00	3.00	3.00
Solar Panel Assembly	1.00	1.00	1.00	1.00
Total	10.70	12.40	5.70	7.40

Note: 1. All units in $/Watt

2. Wafer cost 1.70 $/Watt based on using recycled wafers

3. Wafer cost 3.40 $/Watt based on using new wafers produced in Plant I.

6. System (200 Watt)

A. Solar Panel Cost

. Using Recycled Wafers

Process A: $ 2,140

Process B: $ 1,140

. Using New Wafers

Process A: $ 2,480

Process B: $ 1,480

B. Irrigation System

. Pumping Capacity

At 2.5 m Lifting Head : 80 Galloon/minute

At 5 m Lifting Head : 40 Galloon/minute

. System Cost

	Using Recycled Wafers		Using New Wafers	
Solar Panel	2,140	1,140	2,480	1,480
Pump-Motor	250	250	250	250
Assembly	150	150	150	150
Total	2,540	1,540	2,880	1,880
	Process A	Process B	Process A	Process B

7. Capital and Space Requirements

	Capital	Space
Solar Cell Fabrication	400 K	15,000
Solar Panel Assembly	250 K	10,000
System Assembly	50 K	10,000
Total	700 K	35,000

Note: 1. Capital estimate based on Process B for solar cell fabrication

2. Capital unit K = $1000

3. Space unit = square foot

4. Capacity = 200 - 300 Kw/year

Appendix II

1. Plant Definition

A : Silicon Ingot Growing

B : Ingot Slicing

C : Wafer Polishing (Chemical)

2. Plant Capacity

. 480,000 (3" wafers) per year

. Assumption of Operation

A: 3 shifts/day, 5 days/week, with 85% yield

B: 3 shifts/day, 5 days/week, with 90% yield

C: 2 shifts/day, 5 days/week, with 90% yield

3. Capital Requirements		$ 515 K
A. Silicon Ingot Growing		$ 170 K
. Crystal Grower		
(Two 6 Kg charge capacity)	2 x 80 K =	160 K
. Annealing Furnace		3 K
. Balance		2 K
. Miscellaneous		5 K
B. Ingot Slicing		$ 220 K
. Wafering machine		
4 Internal Diameter (ID) Saws	4 x 50 K =	200 K
. OD Grinder		10 K
. OD Slicing Machine		5 K
. Miscellaneous		5 K
C. Wafer Cleaning and Polishing		$ 100 K
. Ultrasonic Cleaner		10 K
. DI Water System		20 K
. Chemical Polishing Machine		50 K
. Chemical Hood		10 K
. Miscellaneous		10 K

D. Characterization (QA) Equipments . . . . . $ 25 K

- Conductivity Type Probe 3 K
- Resistivity Probe 5 K
- Minority Carrier Lifetime Probe 10 K
- Bow and Taper Gauge 2 K
- Miscellaneous 5 K

4. Space Requirements . . . . 4000 SQ FT

A.	Silicon Ingot Growing	800 SQ FT
B.	Ingot Slicing	800 SQ FT
C.	Wafer Cleaning and Polishing	600 SQ FT
D.	Characterization Room	100 SQ FT
E.	Storage Room	300 SQ FT
F.	Office	300 SQ FT
G.	Miscellaneous (Hall Way, Rest Room, etc.)	1100 SQ FT

Note: Space can be rent at a price of about
$2 - 5/SQ FT per year.
SQ FT = Square Feet

5. Cost Projection*. . . . . $ 1.70/3" wafer

A.	Silicon Ingot Growing	$ 1.16/3" wafer
B.	Ingot Slicing	.30/3" wafer
C.	Wafer Cleaning and Polishing	.24/3" wafer

* Major Assumption

- Purchased poly silicon price $65/Kg
- Labour Over Head (OH) at 200%
- Machine Depreciation (Lifetime)
  Operation A and B : 7 years straight
  Operation C : 2 years straight