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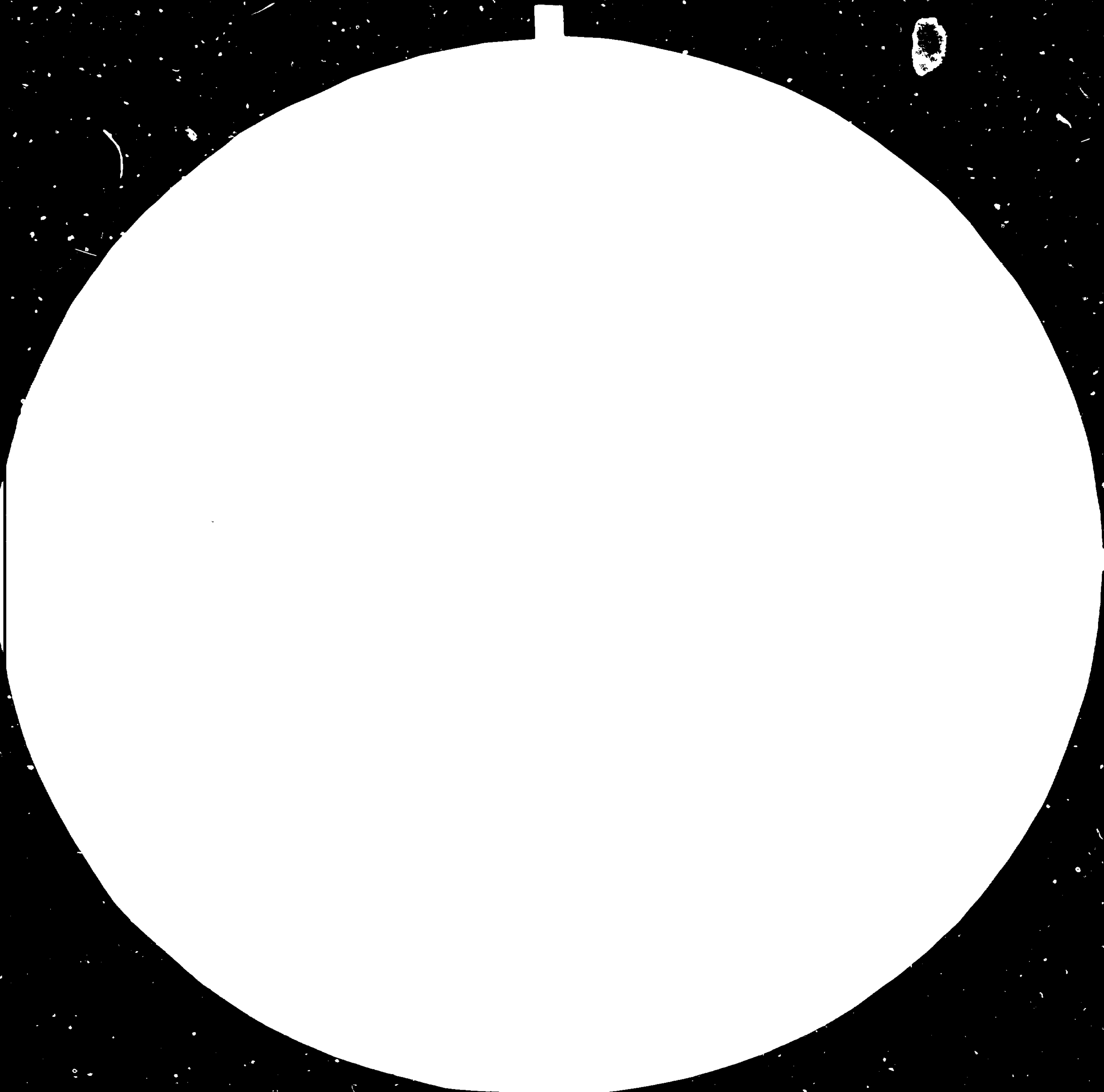

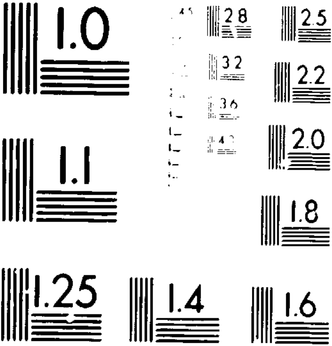

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STATE-OF-THE-ART SERIES ON MICROELECTRONICS
No. 1: VENEZUELA *

Prepared for the Technology Programme

by

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UNIDO Consultant

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EXPLANATORY NOTES

Abbreviations

CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CCD	Charged-Coupled Device
CMOS	Complementary Metal-Oxide Semiconductor
CPU	Central Processing Unit
IC	Integrated Circuits
LSI	Large Scale Integration
MOS	Metal-Oxide Semiconductor
MSI	Medium Scale Integration
NMOS	N-Channel Metal-Oxide Semiconductor
SSI	Small Scale Integration
VLSI	Very Large Scale Integration

Organizations

ESPRIT	European Strategic Programme on Research in Information Technology
IBM	International Business Machines
ICOT	Institute for New Generation Computer Technology
IVIC	Venezuelan Institute for Scientific Research
MCC	Microelectronic and Computer Technology Corporation
MIT	Massachussetts Institute of Technology
MITI	Ministry for International Trade and Industry
OAS	Organization of American States
USB	Simon Bolivar University

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SUMMARY

The study reviews the state of the art and anticipated future developments of the Venezuelan microelectronics industry as well as research undertaken; applications of microelectronics products nationally developed and existing as well as possible co-operation at regional and international levels in this field.

In the main subsectors of microelectronics industry developed in the country, such as telephone production, the country is virtually self-sufficient and, as of recent times, technologically independent. In the field of professional and consumer electronics goods, the market is dominated by many foreign-based companies. A number of recently established indigenous electronic companies is producing capital goods in the areas of telephones, electricity, control and instrumentation. The development of this last category is regarded as a very significant first step in the development of an autonomous electronic industry in the country.

National R and D in the field is carried out in government and government-sponsored agencies and national universities; areas in which expanded R and D activities are foreseen include microstrip elements; gallium arsenide technology; fibre optic systems and components; solar cells; digital image processing (where personnel is expected to increase tenfold in the next five years); and software.

Manpower and training: The number of professional engineers trained and the quality of their training is not a barrier to the achievement of indigenous technological development.

A global approach to technology acquisition has not yet been fully defined for Venezuela. There is a consciousness of the need for a more systematic approach to technologies acquisition in the field.

Venezuela sees scope for technology agreements between middle-tier developing countries in Latin America and for trade agreements, policital treaties and natural resource supply contracts between developing and developed countries.

1 INTRODUCTION

Research, development, professional and industrial activities which have been carried out in Venezuela up to the present in the different areas of microelectronics are discussed in this study. The natural evolution of these activities in the near future (five years) is also discussed. Possible strategies and policies that will accelerate such an evolution are presented.

There is no question concerning the strategic importance of microelectronics in a developing country like Venezuela, an oil producer which has established definite government policies whereby oil revenues are dedicated mostly towards the improved efficiency and growth of the oil industry as well as towards investments for an accelerated industrial development in other areas. Thus, the different techniques of automatization, supervisory control, instrumentation, telecommunications, and informatics are inseparably related to the technological development of the country. If this development is to be autonomous, a significant knowledge of the areas mentioned before must be sufficiently mastered by Venezuelan technical personnel. This knowledge necessarily encompasses many of the fields of microelectronics.

Any person who might question the requirement for autonomy mentioned above, needs only to examine the amount of money that Venezuela has spent in the past, and is still spending every year, in the purchase of foreign designs, goods and services related to the electronic complex (electronics, telecommunications and informatics). Local design of certain items, as well as their total or partial local manufacture, would certainly affect the balance of payments in a positive way, just as it would reduce the dependence on foreign suppliers.

Even though the last two statements are rather obvious, several important and not so obvious questions arise inmediately from them:

Which systems should be designed locally?

Which services should be provided locally?

Which goods should be produced locally?

The answers to these questions are not easy, since they depend in a complex manner on a large variety of national factors: the actual technological level of the country, the level and the amount of the technology which is now being imported, the available qualified human resources and their evolution, and many others.

The answers also depend on international factors whose exact assesment is difficult: the international evolution of the related technologies, as well as the behavior of the price of oil in future years.

The present study will attempt to answer these questions, since it is true that once a reasonable answer is defined, the required microelectronic disciplines to be pursued in the country will become apparent, together with the mixture of research, development and professional activities required in each case.

The previous concept is quite often misunderstood by many Third World technology planners who dedicate untold amounts of time to discussions related to whether their country should dedicate more efforts to research, or to development, or to professional activities. In general these planners fail to realize that a much more difficult question is involved in defining the fields that might be developed in a given country with reasonable probability for technological and economical success.

In section 2 of the report, those different technical areas encompassed under the term "microelectronics" which are of local interest are discussed, including a brief perspective of the international development of the technology in each area, as well as an analysis of their possible national development, in view of the prevalent Venezuelan conditions.

The history of Venezuelan research and development activities since 1958 are described in Section 3, together with the local situation of professional and industrial activities in several areas of microelectronics. Research and development projects which are currently carried out at major national centers are described in great detail, including some reflections on the availability of human resources technically trained.

In Section 4 the perspectives for the future development of the various areas of microelectronics in Venezuela are discussed.

In view of the general situation of microelectronics in Venezuela, it is clear that a major coordinated effort is required in order to accelerate the technological development of this area. The concerted effort, requires effective national cooperative schemes between the national industries, between national research and development organizations, the universities, as well as effective interaction with the national government. These cooperation schemes are discussed in Section 5, together with the discussion of required multinational or international cooperative activities. Special emphasis is placed on the need for cooperation among countries with similar technological problems.

Finally in Section 6, on Conclusions and Recommendations, the strategy that a country like Venezuela should follow in order to achieve a more balanced technological profile, will be outlined.

2 AREAS OF INTEREST IN MICROELECTRONICS

The term microelectronics encompasses such a variety of different fields and activities that it is seldom utilized as such in technical journals, where much more specific labels are used. For the purpose of the present study we will refer to the following specific areas of activity:

1) integrated analog and digital devices and circuits (low power), 2) thin and thick film hybrid circuits and their related technologies, 3) microwave integrated components and circuits, 4) optoelectronic and other components for fiber optic systems, 5) power devices (diodes, transistors, and silicon controlled rectifiers), 6) photovoltaic solar cells, 7) computer aided design, 8) computer aided manufacturing, 9) microprocessor applications, 10) software development.

In publications of a general character [1], these and other areas are usually associated with the activity termed microelectronics. The areas selected for analysis in this study are those most relevant to local development in Venezuela in the near future.

2.1 Integrated devices and circuits

Among the various areas within microelectronics, the sector of integrated circuits has really been responsible for the incredible development of the field. Starting with the invention of the transistor at Bell Laboratories (in 1947), followed by the development at Fairchild (in 1958) of a planar silicon transistor utilizing silicon dioxide as insulator, and the inclusion in 1959 of two transistors on the same silicon substrate (at Texas Instruments and at Fairchild), the density of devices on each crystal chip has increased systematically. In 1976, Intel already announced the production of an eight bit computer with twenty thousand transistors on the same chip. The development in 1960 of the field effect, or unipolar transistor (whose basic principle of operation had been introduced in 1927), as well as the development of new types of integrated devices (MOS, CMOS, NMOS, CCD's and others) have added to the variety of circuits that can be implemented on a single chip. The development of the Metal Oxide Semiconductor field effect transistor (MOS or insulated gate transistor) was particularly important for the achievement of higher possible device densities per chip, due to the lower power consumption for this type of devices. Of course in order to reduce the size of the device the resolution of the litographical process required in the definition of the device on the silicon substrate had to be improved. This improvement was such that starting with linewidths of the order of 6 microns in 1972, by 1981 linewidths of 2.5 microns were achieved, and it is estimated that by 1988 one micron linewidths will be common. The limit in linewidth for the insulaed gate field effect transistors is expected to reach the value of 0.25 microns by the year 2000.

According to the number of components that carry out a determined logic function in each chip, different scales of integrations have been defined [2]:

SSI-Small Scale Integration (2 to 64 components)

MSI-Medium Scale Integration (64 to 2048 components)

LSI-Large Scale Integration (2048 to 65536 components)

VLSI-Very Large Scale Integration, (65536 to 2097152)

The development of the larger scale integration techniques allowed the development of the microprocessor, which is a single chip containing all the central processing unit (CPU) of a computer. Early microprocessor chips were developed towards the end of the 1960's with 500 to 1000 components per chip. Since then there has been an approximate doubling of components per chip every two years. By 1981 the number of components reached 64000 and by 1988 the number of components per chip should reach one million [2].

The rapid time evolution of the production of integrated circuits can be appreciated by quoting J.Allen, director of the Research Laboratory of Electronics at the Massachusetts Institute of Technology [3]:

"Memory capacity--that is the number of bits that we can put on an integrated circuit--is growing at the rate of 70% a year (even though we know that memory chips are going up by a factor of 4 per year and most of us are awaiting the 256K variety right now). Logic density--the amount of logic that we can put in a given space is increasing by 25% a year. Integrated circuit area--or the area of the chip--is going up by 20% a year.....A figure of merit that is often used to describe circuit performance--the power-delay product--is decreasing by a factor of two every year"

Allen expects that by the year 1990, chip sizes of 600 square millimiters will be available, obtained with standard lithographic dimensions under a micron, and one million bits of memory per chip. Considering this prospective development, it becomes obvious that the quality of the silicon single crystal substrates will be a critical factor for the production of the chips to be economically feasible.

The fact that most of the world production of low power integrated circuits is concentrated in a relatively small number of very large companies clearly indicates that this production is subject to major international competition, requiring large investments and huge human resources.

This fact has been certainly stressed by the decision of the Japanese government (through its Ministry for International Trade and Industry - MITI) together with major Japanese electronic companies, to support high risk joint research efforts in VLSI circuits and other high technology areas. More that four years ago MITI began the effort to determine the status of the society of the 1990's and the computers required for the expected developments. MITI proposed the creation of a specialized institute dedicated to the creation of the new technology, thus in 1982 Japan's Institute for New Generation Computer Technology (ICOT) was inaugurated. The money for the new institute was contributed by the following companies: Fujitsu Ltd., Hitachi Ltd., Matsushita Electric Industrial Ca., Mitsubishi Electric Co., NEC Corporation, Oki Electric Industry Co., Sharp Co., and Toshiba Corp. These companies share the costs of running ICOT equally and they expect equal shares of the results achieved by the institute [4].

Similar efforts have been made in the United States, where the Semiconductor Research Corporation (formed in 1982 by a dozen electronic firms) is now considering the development of a 4 million bit random access memory at a cost of some 100 million dollars [4]. The US governement is also sponsoring VLSI research centers at major universities, to be accessible to major industries in the field. The Stanford University Center for Integrated Systems in Palo Alto is a joint venture research center for VLSI, which is supported by 19 corporations at a cost of some 15 million US dollars. Additionally the Microelectronics Center of North Carolina combines the resources of five universities, a research institute and a 30 million dollars industrial research facility. The center has been assigned a budget of 50 million dollars for the years 1981-85.

The Microelectronic and Computer Technology Corporation (MCC) has been established in Austin (Texas) in the summer of 1983, and is similar in structure and purpose to the MITI sponsored Japanese efforts. MCC is dedicated to research and development for the production of the next generation of computers. It is sponsored by 13 companies which contributed funds and personnel, with a budget of 50 million dollars for the first year of operation.

Similar structures are under discussion in Western Europe, where the European Strategic Programme on Resarch in Information Technology (Esprit) was formed under the auspices of the European Common Market organization. Esprit is formed by some twelve companies, research laboratories and government agencies of the different members. The budget planned for the next five years is of the order of 1.5 billion dollars and the project is undergoing a first year pilot program [4].

These corporate approaches to modern integrated circuit design and production clearly limits the scope that most Third Word countries can expect to achieve individually in this field.

In spite of this fact, all countries should study and consider seriously the possible production of integrated semiconductor components. Developing countries realize in general that their future development will depend significantly on the unrestricted availability of these components and systems. All developing countries should carefully evaluate the technological and financial difficulties involved in the development and production of integrated circuits, weighting these difficulties against the gains to be obtained. Third Word countries might find it to their great interest to think about the possibility of reducing the individual difficulties through international cooperation in this field.

2.2 Hybrid circuit technology

A hybrid integrated circuit is a microcircuit which includes thick or thin film paths and circuit elements on a supporting insulating substrate, to which active or passive microdevice elements are attached either prepackaged or in an uncased form as chips, usually all enclosed in a suitable hermetic or epoxy type package. The nature of this type of circuits is such that their manufacture requires less stringent production facilities than those needed for integrated circuit production. Among other things modest quality clean room facilities are necessary.

Thick films hybrid circuits refer to conductive, resistive, or capacitive networks which are defined on the insulating substrate by serigraphic techniques. Conductive, resistive or capacitive pastes are then forced through the mask defined on a screen structure. In the thin film version of a hybrid circuit the same networks are deposited by means of thin film techniques either by evaporation or r-f sputtering techniques through suitable masks [5-6].

Hybrid technology represents an intermediate miniaturization step between printed and integrated circuits. It represents a most interesting technological alternative for Third World countries in view of the simpler technology involved and the smaller investments required.

2.3 Microwave integrated circuits

Historically microwave devices have been the primary driving forces in the development of micron and submicron lithography, since the search for devices with higher frequency reponse is equivalent to the search for a logical device with the shortest possible transition time [7]. With the advent of the

Gunn diode in 1965, and the IMPATT diode a few years later two-terminal devices played a very important initial role in the development of high frequency structures. In the early 1970's the Gallium Arsenide field effect transistor became a prime contender in the development of high frequency devices (up to 25 GHz). This planar device is deposited on insulating substrates, a technique which allows the construction of both passive (microstrip impedance couplers) and active (GaAs FET's transistors) components. These integrated devices, either encapsulated or in chip form, can be added to microstrip line circuits for the configuration of high frequency communication circuits. Once again, as in the case of the hybrid circuits discussed above, the incorporation of commercial active devices to locally designed passive circuits represents an economically attractive intermediate technology suitable for Third World countries. The design and the construction of the passive microstrip networks is relatively simple and in some instances designs used during the last thirty years has been rather empirical [8].

2.4 Fiber-Optic components and systems

During the past few years major progress has been made in the design of fiber-optic communication systems. This progress was made possible by a major development which occurred in 1970 when Corning Glass Works manufactured fibers of essentially pure silica (silicon dioxide) which showed attenuation losses inferior to 20 db/Km at optical wavelengths of 0.85 nanometers. The quality of the fibers has been steadily improving since then, and in 1979 attenuation losses of 0.2 db/Km, at wavelengths of 1.55 micrometers [9] were reported. The achievement of these low losses, close to the theoretical loss limit, together with the fiber bandwidth characteristics, are such that the use of fiber optics for local data communication systems implies a thirty-fold improvement over digital radio telecommunication sysytems [10].

The improvement in fiber optic attenuation characteristics, as well as other intrinsic properties of these components (freedom from electromagnetic pulse and other electromagnetic interferences, minimum crosstalk between communication channels, ground loop inmunity, intrinsic small size and weight, and long term cost reduction), coupled with the evolution of microcomputers and their reduction in price, have definitely established the importance of fiber optics communication systems. Their massive use is clearly foreseen whithin the next five years.

For a country like Venezuela, whose actual communication network is limited but will be greatly expanded during the next few years the importance of fiber optic systems is clearly defined. The field is particularly appealing for the country because the technology of fiber manufacturing is not as difficult as that associated to integrated circuit production. Moreover the design of optical communication systems doesnt imply unsurmountable difficulties.

The technology associated with the manufacture of the other components of the optical fiber sysytem, mainly the light sources and the light detectors, is of course rather complicated. Light sources which are actually being used are either gallium arsenide injection lasers, or light emitting diodes. Local production of these items requires careful consideration even though the experience of Brazil in the development of injection lasers has been very positive [11].

The optical detectors are semiconductor PIN diodes (P-type, lightly doped N type, and N-type), and avalanche photodiodes (semiconductor diodes with a high field region where electron multiplication occurs due to impact ionization). Once again, the local production of these devices merits careful discussion in view of the difficulties involved.

2.5 Power devices

The technology associated with the typical power devices (diodes, transistors, and silicon controlled rectifiers) implies larger lithographically defined devices (several microns) which can be obtained with conventional photolitography. Difficulties arise in the selection of the proper materials to be utilized as contacts as well as in the development of devices that can handle larger voltages and larger currents. It is a field which is less contested internationally, and it is a field which has evolved in time at a slower pace than the case of integrated digital circuits. The positive evolution shown by relatively small European companies (such as the Societa Generale di Semiconduttori-SGS of Milan , Italy) indicates the factibility of such enterprises. The amount of power components whicn are used in Venezuela, both in the automotive industry, as well as in the rectification processes associated with the energy conversion in the aluminum industry, and the general use of power devices in industrial control systems, attests to the potential of a local activity in this area of microelectronics.

2.6 Solar cells

Even though solar cells are essentially power devices, here they are discussed separately from the previous point, since they involve technologies other than silicon. Besides the usual crystalline , policrystalline or amorphous silicon cells which are amply discussed in the technical literature [12] one must necessarily consider the evolution of amorphous chalcogenide solar cells such as those developed by S. Ovshinsky at the Energy Conversion Device Company of Troy (Michigan). These cells have one major advantage, in that their production is obtained by means of a continuous process of vacuum deposition on a metal substrate one foot wide, and a rate of 4 feet per minute. The cost of peak watt power produced by these cells was of 10 dollars in 1982. Ovshinsky's estimated cost for the same cell produced at faster rates on wider substrates is of the order of 1 dollar per peak watt, for 1987 [13]. If this estimate proves to be correct, certainly this type of cells will play a major role in photovoltaic energy conversion.

Although it is clear that the Venezuelan energy requirements for the next decades will be satisfied by conventional power generation (oil and hydroelectric) the fact remains that large portions of nation's territory are scarcely developed. The need for non conventional power sources for remote nor electrified regions exists today, and it will grow in the coming years. Actual examples for such requirements are the power supplies for the network of seismological recording stations which is now being implemented, the power supplies for navigational buoys along several isolated Venezuelan rivers, power supplies for instrumentation packages at remote installations for the oil industry and power supplies for experimental cathodic protection at isolated installations. For these reasons as well as for potential long-term energy production, research and development in photovoltaic solar energy conversion is being seriously considered in Venezuela.

2.7 Computer aided design

This area of knowledge represents one of the major applications of computers. Once again the evolution in the performance and the price of computers during the last decade, has stimulated their application to many fields of design in many medium and small-sized companies. Most of the engineering design firms of Venezuela are heavily involved in many aspects of industrial plant design, most of which are related to the oil industry (refineries, pumping stations, gasducts, pipelines, steam injection stations and petrochemical plants). Most of the work is now carried out without local computer aided design, and it is obvious that a significant development will have to occur in order to achieve a greater degree of automatization. The Venezuelan civil construction industry, which already has been using CAD for building and road construction since 1970, requires more and more technological support in this field.

Additional use of computer aided design will be required in the activities related to the design of masks for integrated and hybrid circuit technologies if these technologies are to be significantly implemented in the country. Computer aided design is also needed in printed circuit manufacturing which is already industrially developed locally.

In Venezuela great amounts of geophysical and geographical data must be converted into graphical form and interpreted, in a process which is essentially the inverse of digital image processing. This is another very important application where computer aided design is of fundamental importance.

2.8 Computer aided manufacture

For countries which produce large quantities of manufactured goods, the area of computer aided manufacturing is turning out to be the key factor in establishing and mantain production leadership. The effectiveness of the use of robots in the Japanes automotive industry has induced the American automotive industry to follow suit in order to remain competitive, as it has been demonstrated by the Chrysler Corporation. Research and development in numerical control machines has also shown their industrial importance.

In the case of a country with limited manufacturing, as in the case of Venezuela, the intensity and extension of efforts that should be dedicated to this field is not readily evident. It certainly appears reasonable that some efforts must be dedicated to the conversion of existing industrial machinery in order to incorporate numerical control facilities in their operation. In this restricted sense the area of computer aided manufacture is of actual inmediate interest in the country.

2.9 Microprocessor applications

Microprocessor applications are already extremely numerous and their number increases every year. The reader is referred to the review article by D.J. David [14] for a partial listing. The reduced cost of these components have made it possible for their application in almost every aspect of human activity. Many possible applications are still unexplored; in essence the range of the applications is limited only by the imagination of the engineers. The flexibility inherent to the use of microprocessors allows their application to problems of a particular country or region. Applications can easily be customized in order to find original solutions to specific local problems.

In the case of Venezuela, the supervisory control of sparse oil wells in regions of very low population, the control of polyducts, as well as the control of remote installations offers the most fertile ground for original microprocessor applications.

In the field of education the microprocessor finds several applications in view of special Venezuelan conditions: the existence of a limited number of technical libraries, a rapidly growing student population at every level, and a sizable percentage of students which require remedial education. These characteristics pose problems whose solutions require effective and inexpensive original local microprocessor applications and designs.

The development of automated office operation in the country will require many special designs for data transmission systems with distributed intelligence, in in accordance to local customs and requirements.

2.10 Software development

In 1950 the cost of software represented 10% of the total cost of a computer, while by 1990 the cost of software will reach 90% of the total [15]. These figures lead us to the following obvious reflection: the local software production will reduce the magnitude the costs associated to the importation of computer goods by one order of magnitude. Any person who has acquired a personal computer can easily experience this reality when he finds that the purchase of a word processor program for his computer will cost almost the same as the computer itself.

If the person described above happens to live in a Third World country, he will additionally find out that his word processor program must be modified to adjust to the peculiar characteristics of his own language (if at all possible). He will also realize, if he is somewhat technically qualified, that the writing of the necessary program is indeed a task that lies within his own capacities (conceptually at least).

The simple example given clearly indicates the importance that must be attached to the local production of software programs specifically designed for regional conditions. The same reasoning also applies to the development of firmware, that is programs that can be directly incorporated in a memory chip to be used together with a microprocessor in the applications described in section 2.9 above.

The international technological perspectives for the different microelectronic areas have been briefly described. In the following section the situation of those areas in Venezuela will be described from the point of view of research and development, professional and educational activities. In order to place some of these activities in a proper perspective in time, a brief historical summary will be included.

3 THE SITUATION OF MICROELECTRONICS IN VENEZUELA

Venezuela is a country of some 16 million inhabitants, with a territorial extension of some nine hundred thousand square kilometers. Its main industry is the production and the refining of oil, with a current production of 1.7 million barrels a day. Additional major industries are based on the production of iron and aluminum since the country possesses important deposits of iron and of bauxite.

Since 1958 the government has been elected through democratic elections. Not coincidentally, since 1958 there has been a substantial educational and scientific development marked by the creation of the School of Sciences at the Central University in Caracas (in 1958), and the creation in 1959 of The Venezuelan Institute for Scientific Research (IVIC). These two institutions have proved to be very significant in the establishment of organized research and development efforts in the basic sciences in the country. Prior to 1958, research efforts were limited to clinical research in medicine, and some R&D activity in civil engineering. This fact is particularly surprising since the major industry in the country, the petroleum industry, has operated in Venezuela since 1920; yet no research and development existed in any of the fields associated with it, until the industry was nationalized in 1976. The American and European oil companies operating in Venezuela were never concerned with local R&D. All their research and development was carried out at their home laboratories.

In order to describe the evolution of electronics in the country, the national characteristics of the professional and industrial activities in this general field will be described first. The history of the research and development activities in electronics will then be described. Finally a detailed description of most of the main research and development projects which are currently being carried out at several national institutes will be given.

3.1 Professional activities

Venezuela has now some 40000 engineers in different areas; some 8000 of them are in the areas of electrical engineering and computer sciences. Engineers are trained in a five-year undergraduate program at 15 major national universities (all but four of these universities have been established since 1958). 3200 engineers are expected to graduate in 1984, one fifth of them being electrical or computer engineers. The number of graduates is now increasing at a rate of 5 % per year. In general the undergraduate education received is of good quality; among other indices this fact is indicated by the positive performance of those Venezuelan students who have registered for graduate work at major foreign universities. The general evolution of higher education in the country has been particularly accelerated during the last twenty years. This fact is evidenced in the short but effective history of the Simon Bolivar University (USB). It was created in 1970, initially accepting 500 students in the fields of electrical, mechanical, and chemical engineering, mathemathics and chemistry. The university now has some 6000 students enrolled, and it has added the fields of physics, biology, materials science, computer science, architecture and urban studies. The professional training that these students receive is one of the best in the country, and many of the USB graduates have been the founders of a number of successful electronic companies.

The intensive scholarship programs that Venezuela has mantained through the years for graduate and undergraduate studies abroad have been the crucial factor in the training of the professors required for the new universities. Under these scholarship programs 6792 graduate scholarships were awarded by the main funding agency (Gran Mariscal de Ayacucho program) between the years 1975 to 1981 [17], together with several thousands undergraduate scholarships. Some additional 500 graduare scholarships are funded every year by other agencies. Approximately a third of all the scholarships are given to students in the different engineering fields.

The number of professional engineers trained in Venezuela and the quality of their training are quite acceptable, thus satisfying a major requirement for the achievment of an autonomous technological development. Unfortunately most of the trained engineers find employment in activities related to management, sales or purchasing, where their engineering skills are used minimally. This situation is not uncommon to many underdeveloped countries and it reflects an immature industrial reality wherein most of the established industries merely assemble products developed and designed elsewhere. Many local technical companies only sell imported products. This is the case for those electronic companies that assemble consumer electronics products.

One significant exception is found in the engineers employed by the ten or so major engineering consulting firms. These consulting companies are dedicated mainly to the design of industrial plants , underwriting joint design partnership agreements with foreign companies (in several instances). These agreements have made it possible for a significant number of Venezuelan engineers to achieve important experience. In the specific case of control system engineering, most of the designs for plant control and supervision are handled locally (even though the hard and software components used in the system are still being purchased from companies like Honeywell or Foxboro).

Other examples of significant local design activity are found in the petroleum industry, and in some of the electronic Venezuelan companies that will be described next.

3.2 Industrial activity in electronics

There are three major cases that must be discussed: a) mixed companies with large state participation (mainly the telephone manufacturing company MAPLATEX), b)the privately owned companies which are associated to foreign firms and which are mainly dedicated to the sale of imported products and the local assembly of consumer electronic products (radio, TV, sound equipment and others), c)the privately owned Venezuelan companies where local design is utilized, here defined as professional electronic companies. Each sector presents quite different characteristics.

3.2.1 Telephone manufacture

The MAPLATEX company has an installed production capacity of 250000 telephones a year, whose production reached 180000 units in 1982. MAPLATEX is largely owned (45%) by CANTV, the national telephone company. MAPLATEX began producing regular dial telephones under license agreement with Ericson. The agreement expired in 1979, and now the company is technologically independent, producing some 88% of the telephone parts in the country. Only four engineers out of a total of 300 employees are dedicated to development work related to pushbutton telephones and other more complicated phones with additional local intelligence. In order to achieve these goals in a competitive manner, the management of the company is undersigning agreements with local R&D organizations. The MAPLATEX production market is mainly oriented to fullfilling the internal requirements posed by the installation of some 250000 new telephone lines every year by the CANTV. The importation of telephones into Venezuela is not restricted, so that the operation of MAPLATEX is indeed competitive in quality and price.

3.2.2 Electronic consumer goods

Many foreign based companies operate in Venezuela. Their listing, and the volume of their sales is beyond the scope of this study. However we will mention some significant facts concerning some of them and their operations.

1) IBM of Venezuela is completely dedicated to the sale and the servicing of their products. No local assembly or design is carried out. However, this company has created a Scientific Center dedicated to digital image processing and personal computer applications, and it supports local R&D efforts at other centers.

2) Industrias Philips de Venezuela is mostly dedicated to the sale of Philips products and to the local assembly of TV sets and sound equipment. High-level executives of this company recognizes that no element of local is used in the assembly procedure. Fortunately this company is beginning to support local R&D institutions through equipment donations.

3) Siemens de Venezuela is mostly dedicated to the sale of Siemens equipment but the company is considering the possibility of local assembly of digital telephone exchanges.

4) Hewlett Packard de Venezuela is dedicated only to the sale of Hewlett Packard products. No local design is undertaken but at least a very efficient local maintenance group has been established. Most of the equipment sold is thus supported by the activities of a significant group of Venezuelan tecnicians and engineers.

Due to the reduction of the international price of oil and the strict currency control applied by the Venezuelan government since February 1983, most of these companies are re-evaluating their activities and their rolè in Venezuela. They realize that the level of manufactured goods imported annually will have to decrease drastically and that many products will have to be manufactured locally. For many of the companies mentioned above, all of which have large organizations in the country, the new conditions established mean that they will have to restructure their local operations. Some of them might consider as a reasonable change in activity the local manufacturing of some of their products. The occurrence and extent of the new activities is by no means certain or predictable.

3.2.3 Professional electronics companies

During the last decade a group of entirely Venezuelan electronic companies have been established, and they are now dedicated to the production of capital goods in the areas of telephony, electricity, control and instrumentation. These companies are inherently innovative and their physical and human resources structure has been established so that they can have a high degree of adaptability to market changes. A significant number of their founders have received state support in the form of scholarships during their graduate studies, and most of them have been associated for some years to state supported R&D organizations or to local universities.

The description that follows will rely heavily on the article of C. Perez et al [18], which describes these promising enterprises. The main Venezuelan companies that produced products based on local design are the following:

AETI C.A.	Data adquisition systems for supervisory control. Microprocessor systems for real time operations.
AVTEK C.A.	Voltage regulators with microprocessor control. Ininterruptible Power Supplies. Power line insulators.

DISTELCA C.A.	Telex-Computer interfaces. Software for Office Automatization.
EyT. C.A.	Digital telephone dialers. Adaptive control system for traffic control. Telemetry systems for data adquisition.
FONOLAB C.A.	Telephone exchange interfaces and adaptations. Communication consoles. In-dialing equipment. Software for telephone exchanges.
INTERBA C.A.	Microprocessor based electronic taxi meter. Electronic velocity control system for motor vehicles.
MICROTEL C.A.	Electronic telephone translators. Telephone exchanges (120 and 1000 line PBAX's). Telephone customer identification system. Elevator control systems.
CIRCUITEL C.A.	Printed circuit production for most of the country.
TECHNIELCA C.A.	Electrical motor overload protectors.
VOLTEK C.A.	Electronic sport tabulators and displays. Electronic public display systems. Electronic display clocks and centralized time systems.

SOVICA C.A. Building security and alarm systems.

Available information for the five major companies above indicates the following:

a) Total personnel is of the order of 200 employees, 60% of them are university graduates, and 33% of the total are engineers.

b) Total assets of these five companies is of the order of 4.5 million US dollars.

c) Their total sales for 1983 amounted to 11 million US dollars.

d) Sales have increased 20% from 1980 to 1981, 50% from 1981 to 1982, and 66% from 1982 to 1983.

Even if the numbers are relatively low, the economic projection for these companies is very healthy. These firms certainly represent a very significant first step in the autonomous electronic industry of the country. A new company recently founded in 1983 will produce a 16 bit personal computer for the Venezuelan market, incorporating considerable local design and importing all of the electronic basic components. The estimated marketing date is set for early 1985.

The reality for the electronic industry in Venezuela can thus be summarized in the following manner: the effect of private professional companies with strong local design activities, as well as the activities of the government related telephone company have been very useful in aiding Venezuela's technological development. The role of both these groups will increase with time. On the other hand the role played so far by the larger foreign based companies, has been indifferent at best; whether these companies will play a significant role in the development of the country will depend on the evolution of their activities in the future.

3.3 Research and Development in Electronics

The current research and development activities in microelectronics in the country will be presented in accordance with the following scheme: the brief history of Venezuelan R&D since 1958 will be reviewed first, then the present R&D microelectronics projects will be discussed, and finally, the projection of these activities for the next few years will be presented.

3.3.1 History of electronic R&D in Venezuela

Prior to 1938 almost no R&D activities existed in the country in any engineering field. In 1956 a Neurological Research Institute (IVNIC) was founded under the auspices of the military goverment that was then in power. This institute was directed by Dr. Humberto Fernandez Moran (now a divisional professor in biophysics at the University of Chicago). Since the main activity of IVNIC was oriented towards biophysical research, equipment for studies in nuclear magnetic resonance, electron paramagnetic resonance, thin film evaporation, and low temperature production facilities (liquid helium and liquid nitrogen), were purchased as research support tools. Plans were also made for the purchase of a 3 megawatt water cooled research nuclear reactor. By 1958 when the government was replaced by the present democratic system, the staff of the institute had only one Venezuelan researcher (the director) and 18 foreign researchers. Despite this unfortunate situation, a significant physical plant had nevertheless been provided and the need for a research institute had been established in the public opinion. Among other scientific achievements, Dr. Fernandez Moran developed a diamond knife, mainly for use in microtomes for the preparation of samples for transmission electron microscopy. Many years later this knife would find quite different applications in the preparation of submicron structures for Josephson Junction studies in the Engineering Research Foundation - FII (later described in this report).

When the new democratic government took office, Dr. Marcel Roche was named director of IVNIC, with the mandate to change the structure of the institute in order to incorporate more Venezuelan researchers as well as to increase the fields of research covered. As a result of these efforts the Venezuelan Institute for Scientific Research (IVIC) was created in 1959 on the same site as the previous institute. The initial research fields were dictated by the availability of qualified Venezuelan scientists. These fields initially included: biology, medicine, chemistry and anthropology. The decision to purchase the reactor was mantained and it was decided to open a physics section oriented towards experimental solid state research (in view of the equipment that was already available). It was also decided that the reactor should be operated by Venezuelan engineers. Since no specialized personnel for these fields was then available, an intensive recruiting of recently graduated electrical engineers was undertaken by IVIC. The students were sent abroad for graduate training in three main areas: nuclear engineering for the reactor operation (at the Master of Science level), solid state physics for research in this area (at PhD level), and electronic engineering (at the Master of Science level) for the maintenance and development of reactor electronics . A group of some 15 students left the country around 1959-1960 and the reactor was closed pending their return [19].

After successfully completing their studies, the two groups trained at the masters level were the first to return to the country (1962). After spending one year working with the reactor electronic sysytems, the electronic engineers diversified their activity creating two separated groups: one to be dedicated to electronic maintenance and development (for the whole institute), and the other to develop electronic instrumentation for the researchers of the physics section. The activity of these two groups represented the initial steps for electronic design in the country. They established the first printed circuit facilities and designed quite a number of instruments and apparatus, from simple power supplies and transistor testers, to more complicated pulse generators, digital word generators, and quite a variety of specialized electronic equipment designed for support of IVIC researchers in other fields. Furthermore these engineers carried out intensive recruiting among electronic technicians (trained at local technical high schools) and other electrical engineers. Significantly, one of these recruited engineers would later be the owner-founder of the company CIRCUITEL (described above) the manufacturer of most of the printed circuits used in the country today.

After working for a certain number of years at IVIC, the technicians were sent to the United Kingdom for three years' additional training, in a program equivalent to an undergraduate Bachelor of Science degree.

The group of students trained for research in the pnysics section, started returning to Venezuela around 1964, after completing their PhD education. Some received their graduate degrees in electrical engineering, others in physics or materials science. By 1967 the physics section numbered ten active Venezuelan researchers. By 1968 one of those researchers (trained as an electrical engineer) indicated the need to include engineering as a major research activity at IVIC. He also detected the extremely limited number of engineers that dedicated most of their efforts to research activities in Venezuela. An intensive campaign was organized in order to influence undergraduate engineering teaching at local universities so as to increase the numbers of students that would be willing to continue their studies at a doctoral level abroad. At the same time, the creation of a technological institute to be concerned with all fields of engineering was suggested [20]. As a result of these efforts IVIC implemented the following fundamental policy measures:

1-The inclusion of engineering among the fields to be covered at the institute.

2-A massive PhD level scholarship program in engineering.

3-The creation of a technological center at IVIC, where the activities of the research groups more oriented towards engineering would coexist harmoniously with those of the design and development engineering groups that were formed around the nuclear reactor.

4-The hiring of a limited number of foreign researchers in areas not active in Venezuela (such as mechanical engineering and metallurgy). These foreign researchers were to be hired with the clear understanding that they were expected to carry out research as well as intensive training of Venezuelan students in the new fields.

5-The re-orientation of some members of the chemistry center of the institute towards more applied research topics (oil and petrochemistry).

As a result of these policies IVIC had two additional centers in 1974: the Engineering Center and the Petroleum and Chemistry Center. By that time some twenty engineering PhD students were studying abroad under IVIC scholarships.

These actions are considered fundamental for the evolution of the research and development in the years that followed.

After the nationalization of the oil industry which occurred in 1976, the government founded a specialized research and development institute for petroleum, INTEVEP , which started operations in 1977. Its technical personnel was drawn from the personnel of the Petroleum and Chemistry Center of IVIC, as well as from the roster of engineers employed untill then by the different oil companies. This institute now has 1100 employees, and it is funded at a level of 100 million US dollars per year. The organization of INTEVEP is such that both technical personnel from the institute and representatives of the oil industry share its management. This essential link between an R&D organization and its users is thus clearly established.

In 1979, a new research and development institute for those engineering areas other than petroleum was proposed to the government, and in 1982 the new institute, the Foundation for Engineering Research and Development (FII), began operations, starting with most of the technical personnel of the Engineering Center at IVIC. The organizational structure of the FII is such that several of the largest state owned corporations have acted as founders, and their representatives are members of the board of directors of the foundation, thus establishing a close tie between an R&D center and the productive sector. INTEVEP has established that R&D projects in electronics, control, instrumentation and telecommunications, related to the oil industry are to be carried out by the FII.

The governmental structure of Venezuelan science and technology and the different funding organizations for R&D projects will be discussed next. Since 1979 the country has had a

State Minister for Science and Technology, who acts as adviser to the president of the country on related matters, and as such is present at Cabinet meetings. In principle at least, the State Minister is able to influence policy of the different ministries; in practice, the day to day problems faced by the other ministers limits their understanding of the long-term planning which is required in order to effectively incorporate the science and technology variable into the economic life of the nation. Of course these difficulties are common to many developing countries as well as to some developed ones.

In addition to the State Minister, the National Council for Science and Technology, CONICIT , bears the responsibility for science and technology policy planning (CONICIT was founded in 1967 when the government accepted and supported the initiative proposed by a group of scientists). The Council started operations in 1969. Most of the academic and R&D institutions, both private and official, are represented in the directive board of CONICIT. This institution operates mainly as a funding agency, directly supporting R&D projects with an assigned budget of 20 million dollars (US) for 1983. The First Congress on Science and Technology was organized by CONICIT in July 1975, and represented a first major scientific policy meeting which counted with the massive participation of scientists, industrialists, government representatives, and academic institutions. One of the major recommendation referred to the establishment of tax directed at the national industry for the support of science and technology R&D. Unfortunately this recommendation was not accepted at the time by the government.

3.3.2 Actual R&D in microelectronics

The different R&D projects in microelectronics which are now under way at different national institutions will be described in this section. In each case the structure of the various institutions where the projects are carried out and the technical qualifications of the personnel involved will be included. Those projects that are considered to be particularly significant for the technological development of microelectronics in the country, will be described in detail.

3.3.2.1 IVIC

IVIC has 1100 employees, 110 of them being researchers (PhD level) and 140 are research assistants (Master or professional degrees). The are dedicated to research in the following fields: medicine, biophysics and biochemistry, cellular biology and virology, ecology, chemistry, physics, mathematics, and engineering. The engineering group is composed of those researchers which were not transferred to the Engineering Research Foundation. Among them, only researcher is dedicated to microelectronics; he is a Belgian engineer who, after spending one year at the Foundation, has opted to return to full time basic research at IVIC. The work which he has carried out is mainly concerned with theoretical aspects of the operation of integrated devices: the nature of the numerical solutions that apply to a semiconductor when the exact conduction equations are considered, not neglecting diffusion currents, and fully solving Poisson's equation. This work follows the pioneer work of H.K. Henisch and co-workers [21]. Additional work is related to the structure proposed for a novel field effect transistor, the accumulation mosfet. The probable evolution of microelectronics at IVIC will continue to be oriented towards theoretical analysis of existing and new semiconductor devices.

The experimental facilities which were developed at IVIC by members of the FII are now being used by the Foundation under a rental agreement.

3.3.2.2 CANTV-CET Laboratory

The National Telephone Company operates a training center for telecommunication technicians (Centro de Entrenamiento Tecnico - CET). This center has been concerned with significant development work related to the telephone industry. Specialized electronic instruments for the measurement of telephonic traffic have been designod and built at the center, as well as several microprocessor applications for automatic speech recognition and other equipment.

The technical training level of the engineers employed at the center is mostly that of first degree engineers although some of the members of the group have been trained at the master of science level. Since most of their work is related to the development of systems associated with the normal operation of the telephone company, they have shown little interest towards publishing original research activities.

3.3.2.3 Engineering Research Foundation-FII

As mentioned before, most of the members of the engineering center at IVIC, moved to this new institution early in 1982. FII now has some seventy engineers and physicists dedicated to research, development and professional activities. The technical level of the personnel is evenly distributed: one third have been trained at doctoral level, one third have master's degrees, and the remaining third are first degree engineeers. During the next five years the rate of personnel growth is expected to be such that by 1988, the Foundation will have 200 engineers. FII now has five centers: electrical and electronic engineering, metallurgy, mechanical engineering, system engineering and digital image processing. This latter center represents a joint-venture between IBM of Venezuela, IVIC, the Central Office for Statistics and

Informatics, and the Foundation. The FII bears the technical responsibility for the operation of the center. The following technical units exist in the different centers:

ELECTRICAL ENGINEERING:

Instrumentation and microprocessors

Telecommunications

Hybrids and cryogenics

Microelectronics

METALLURGY:

Physical metallurgy

Chemical metallurgy

MECHANICAL ENGINEERING:

Thermal

Fluid mechanics

SYSTEM ENGINEERING:

Information and control

Systems

DIGITAL IMAGE PROCESSING:

Projects

Digital processing

From the 14th to the 16th of December 1983, the Foundation held an internal technical meeting in Caracas; 60% of the papers presented by the technical personnel of the FII were related to fields of microelectronics [22], out of a total of 53 papers. The specific topics were the following:

1) GENERALIZED CONTROL MODULE: this modular intelligent system is based on the central components of a Zilog Z-80 8 bit system, additionally incorporating a D/A conversor to the microprocessor bus. The following programs are stored in the ROM: coaxial cable communication program, and optional programs for local or distributed control. The module has the following I/O characteristics: a coaxial cable input for sequential communication at a rate of 4600 bits/second, 8 digital bits inputs and outputs, 8 A/D channels (8 bits), and two channels for standard RS-232 communication.

2) LOCAL MULTIPROCESSOR NETWORK: the system described refers to the interconnection of several Apple II computers to a PDP11-60 system. The connection is made by coaxial cable and the communication protocol is based on the RAMA (Red de Arbitraje Multiple y Aleatorio) system. All participants in the network can conmunicate with eachother.

3) COMPUTER NETWORKS IN THE CONTROL OF INDUSTRIAL PLANTS: a prototype for a control system with computer networks is described. The system comprises two generalized control modules and three APPLE II minicomputers, connected along a length of 800 meters of coaxial cable. The APPLE can act as a display unit, as an actuator, or as a supervisory unit.

4) HI-SPEED COMPUTER NETWORKS: this paper describes the design of a 2 Megabaud computer network developed at FII.

5) MICRUPROGRAMMED CONTROLLER DESIGN: design techniques which improve the operation of microprogrammed controllers using PROM's, EPROM's or EEPROM's, are discussed.

6) MICROCOMPUTER COMMUNICATION PROTOCOL: the interconnection of the different computers which operate at each subway station in the Caracas rapid transit system is described.

7) FREQUENCY CODER-DECODER: in order to obtain maximum rate of data transmission for a given band width, a novel coding scheme is discussed.

8) REMOTE HEXADECIMAL KEYBOARD LECTURE: a system for the lecture of several hexadecimal keyboards at a distance from a microcomputer, is described. The system is so designed so as to minimize the number of interconnecting lines, it is based on the use of an analog voltage signal (instead of the usual sweep) which is then decoded at the processor unit. This system is to be used in the automatization of part of an aluminum producing plant.

9) DATA ADQUISITION AND ANALYISIS SYSTEM: an 8 channel data adquisition system has been developed for specialized underground applications, together with the required firmware for data analysis at the surface.

10) MULTISERVICE FIBER-OPTIC TRANSMISSION NETWORK: a 3.7 Km fiber-optic system for the transmission of video, telephony, sound and data is described. All the components required (modulators, demodulators, concentrators , etc) have been built. All the signals travel through one fiber, using LED's as optical sources and avalanche diodes as detectors. One TV channel is transmitted, together with 32 telephone channels, one audio channel and data at a rate of 4.8 Kbits/sec. The system will provide supervisory control, videoconference facilities , telephone and computer interconnections at three different locations. Network control is possible equally from each of the nodes. The computers to be interconnected include a VAX system, an IBM 370-145, a PDP 11-60, and several personal computers.

11) CONTROL UNIT FOR A FIBER-OPTIC NETWORK: the detailed design of a control unit based on a Commodore 64 computer and a color monitor is presented. A special circuit is incorporated for the control of the cameras, microphones, speakers, alarms, and the flow of the input and output PCM signals.

12) ANALOG FIBER-OPTIC TV MODULATION SYSTEM: the circuit for modulation and demodulation of the different signals for the fiber-optic network is described. The bandwidth for the LED source is 20 MHz, and the optical power modulation index is 0.2. The APD detector is used with a transimpedance preamplifier followed by a video amplifier with gain up to 45 db.

13) DIGITAL FIBER-OPTIC CODER: a full-duplex 2 megabits/sec system is described where syncronizing signal, clock and data are transmitted along the same channel. The system was achieved implementing data coded in the Manchester code. Error rates were measured to be less than 10 to the minus 12, and jitter rates obtained were of the order of 6%. The system was particularly designed for economy.

14) LOCAL OSCILLATOR FOR A DIGITAL RADIO: the design for a dielectric resonator oscllator system is discussed, with the resonator section located at the input of the active device.

15) MICROSTRIP LINE WITH THREE OR MORE DIELECTRICS: the characteristic impedance and the effective dielectric constant for a planar microstrip line with three (as in the case of microstrip with overlay) or more dielectrics was derived. The calculation is based on the exact determination of the curve which separates the different dielectrics in a plane transformed by two successive Schwarz-Christoffel transformations. The capacitance of the transformed plane geometry is then obtained by numerical finite elements procedures.

16) SUPER-SEMI-SUPERCONDUCTOR JOSEPHSON JUNCTIONS: this paper presents a new procedure for the reproducible fabrication of these types of Josephson juctions which are manufactured with a novel geometry utilizing conventional integrated circuit fabrication procedures. The advantages achieved in the

structures obtained are due to the geometry (negligible capacitances, better film separation control, better union cooling properties and simpler fabrication procedure), and to the semiconductor silicon substrate (relatively high normal-state resistances, controlled electrical properties as functions of doping, coherence lengths below one thousand Angstroms, and IC compatible fabrication techniques). The structures have lead films deposited on a crystalline silicon (N+) substrate on which a step of controlled height is achieved by ion milling.

17) Pb-Te-Pb JOSEPHSON JUCTION FABRICATION, CARACTERISTICS AND CHAOTIC BEHAVIOR: the chaotic behavior of these Josephson junctions under variable microwave irradiation is measured. The junctions were fabricated by high vacuum deposition on sapphire substrates, and then irradieted at variable power levels with 35 GHz microwaves. The effect of chaotic behavior on the Shapiro steps of the devices' IV characteristics was measured. It was confirmed to be related to chaos by means of noise measurements in the 100 KHz range. These noise measurements indicated device temperatures of the order of 10000 K, which is a characteristic of chaotic phenomena.

18) COMPUTER SIMULATION OF IV CHARACTERISTICS FOR TUNNEL SUPERCONDUCTING STRUCTURES: using the RSJ model with quasiparticle resistance curves, varying the parasitic current below the gap energy, and varying the union capacitance, the

behavior of a tunnel type Josephson Juction is simulated in a computer. The IV characteristics are calculated under the presence of irradiated microwave, thermal noise, shot noise, and in the absence of noise.

19) SOLID DIFFUSION AMORPHOUS SILICON DOPING: as a first step towards the production of an amorphoys silicon solar cell of the PIN type, this project has dealt with the RF sputtered evaporation of: 1- amorphous silicon, 2-antimony, and 3- amorphous silicon in an hydrogenated atmosphere. The evaporation is followed by a thermal treatment. The material produced presented resistivities of the order of 0.02 ohm-cm which are comparable with other amorphous silicon doping procedures.

20) HYBRID THIN AND THICK CIRCUITS: several circuits produced mainly by thick film techniques are described. The circuits refer to systems developed under contract with several local companies under propietary no disclusion agreements.

21) POWER INTEGRATED DIODES: the production of power diodes of the abrupt juction n+p and p+n types with protective rings and the electrical characteristics of the devices produced in the FII laboratories are described. The analysis of the additional equipment which is required for the production of diodes with higher breakdown voltages is included.

22) **AUTONOMOUS POWER SUPPLY SYSTEMS:** the production of crystalline silicon solar cells of the type MIS with natural inversion layer, of the type P+/N3, and of the type P+/N/P+ and N+/P/N+, are described. Also described are the electrical characteristics of the cells obtained, as well as the control circuits required for the charging of batteries, and the different techniques for solar panel interconnection and encapsulation. One of the Venezuelan application for the panels produced refers to the power supply for remote stations to be used in the national seismographical network.

23) **DESIGN OF A NAVIGATIONAL SOLAR RIVER BUOY:** the discovery of commmercial deposits of bauxite at the Piriguao mountains, some 700 kilometers up the Orinoco river from the aluminum producing plants of ALCASA and VENALUM, requires the transportation of the raw materialby barges. This procedure implies river navigation aided by a system of luminous buoys to be powered by solar energy. In this project the electrical and mechanical requirements for the control system of each buoy are discussed. A system based on locally produced solar panels is discussed and evaluated.

24) **MAINTENANCE OF THE ELECTRONIC CONTROL OF THE CATATUMBO DREDGE:** the access channel to the major Venezuelan oil fields in the Maracaibo lake must be permanently dredged. The newest and largest dredger, the ship Catatumbo, possesses a rather complex system of sluices which are electronically controlled in order

to mantain a proper ship balance. The project described refers to the redesign of most of the ship electronics which never operated properly since the purchase of the unit.

25) REAL TIME ADAPTABLE DIRECT CONTROL ALGORITHM: some of the details for a novel control adaptable algorithm for systems with delay is described. It is an adaptable proportional-integrating control whose object is the maintenance of the system output near a set point in spite of variations of the operating point and in the presence of constant perturbations. In order to avoid the problems associated with the lack of a positive covariance and the divergence of the identifying filter, the algorithms are modified with alternate numerical mehods which tend to cancel the residue correlation and improve the convergence.

26) ELECTRICAL GENERATION AND DISTRIBUTION SYSTEM: the need of supplying electrical power to an instrumentation platform in the lake of Maracaibo has motivated the present project under contact from INTEVEP.

27) DEVELOPMENT OF A BASIC GRAPHIC COMPUTATION PACKAGE: within the framework of the development of a graphic computation package, to be useful in the area of computer aided design, a group of subroutines have been developed. They are capable of executing translations, rotations, scaling, parallel or perspective projections, and the elimitation of hidden lines in polyhedra.

28) CLASSIFICATION OF NATURAL RESOURCES: the objective of this project is the classification of available natural resources (water and vegetation) utilizing the information derived from remote sensors. The techniques utilized are based on the digital processing of images and photointerpretation. The area considered has an extension of 800 square kilometers in the Sucre state. The results obtained are presented as maps showing the different classified areas together with their boundaries, their perimeters and areas.

29) ALGORITHM FOR THE FOLLOWING OF BORDERS AND FOR THE VECTORING OF LINES: from the digitalized satellite image a second two-toned image (black and white) is obtained; the white regions are assigned to the levels of gray which correspond to the regions whose definition is required in the original image. A vectorying algorithm for closed contours is also presented. The joint application of these techniques to digitalized images allows the definition of information which is not perceivable by the human eye. The application of these techniques to metallurgy (optical and electron microscope images), to medicine (X-ray and microscope images), and to automatized cartography is extremely important. Several practical examples are discussed.

30) SEMI-AUTOMATIC DIGITALIZING OF DRAWINGS: the digitalization of cartographic maps (or any civil engineering drawing), for their inclusion in a data bank is normally carried out through a

manual process which uses a digitizing tablet. This type of manual process requires lengthy procedures where the operators must dedicate large amounts of time to the point by point following of a given contour (or in more modern systems, to the identification of the end poits of a given straight line or arc). A time saving semi-automatic technique for the processing of the images mentioned is presented.

In addition to the several projects reported in the Proceedings of the First Technical Meeting, numerous other projects are being developed at FII under contract agreements with strict confidentiality requirements. One of these projects refers to the design and construction of an automatic machine voting system to be ready at the time of the next scheduled national elections which are going to be held in december 1989. Some thirty thousand units of the basic system will be required. This project will be handled by the FII together with the major professional electronic companies of the country.

3.3.2.4 UNIVERSITY OF CARABOBO

This university is located in Valencia, in the central part of Venezuela. The technical activity related to microelectronic R&D is rather limited since only five professors are dedicated to it. It is however very significant because in 1977-78 one of the first microprocessor applications was developed at this university, in the design of a taxi meter. Not only was this microprocessor application original, but the prototype which was developed is currently industrialized in the country and it is used in Venezuelan taxis.

Current projects underway at the university of Carabobo are:

1) A microprocessor based ultrasonic fetal diagnostic unit, designed specifically for the detection of medical anomalies specifically found in the country.

2) A microprocessor data acquisition unit for the characterization of the transient response of the respiratory system.

3) A microprocessor control unit for professional U-Matic video tapes.

4) A microcomputer for microprocessor developing systems.

3.3.2.5 SIMON BOLIVAR UNIVERSITY

Three major departments are related to microelectronic activities: the computer science department, the systems department, and the electronics and circuits department. The fist two groups are mostly dedicated to the design and implementation of new algorithms and general software, while the electronic and circuit group deals with the design and construction of hardware units and some R&D work related to solar cells (in collaboration with the physics department). The current projects in the electronic and circuit unit are:

1) Thin-film solar cells production by serigraphy and pyrolitic pulverization.

2) Compound semiconductor thin-film structures.

3) Design and construction of signal generators by means of additive synthesis.

4) Design and construction of directive microstrip couplers with stepped impedance lines.

5) Wide band microstrip coupler analysis.

6) Dynamical optimization of multidimensional filters.

7) Linear prediction for the detection of plane waves.

8) Detection and burst error correction in receivers.

9) Image coding by means of linear spectral prediction from the Fourier transforms.

10) Class E amplifier design with unipolar transistors.

11) Robotic arm design.

12) Real time EEG data acquisition and processing.

13) Data acquisition system for the detection of waves in the cardiac cycle.

14) Fetal monitoring system.

Due to teaching duties the staff at the Simon Bolivar University dedicates only part of their time to the R&D activities described. Most of the emphasis is dedicated to development or design work. A great deal of work is carried out by the students in their fifth year thesis project.

Microelectronic R&D at other Venezuelan academic institutions is mainly concerned with microprocessor applications (at the University of Oriente, at the Universidad Central de Venezuela, and at the Instituto Universitario de Tecnologia - Region Capital), and software development for microstrip systems design (Instituto Universitario de Tecnologia - Cumana). As evidenced by the papers presented at the last meeting of the Venezuelan Society for the Advancement of Science [23], the activity of these institutions is limited and it should be increased in the future.

4 FUTURE PERSPECTIVES FOR LOCAL MICROELECTRONIC ACTIVITY

On december 4th, 1983, a new administration was elected in Venezuela. One of the expected measures to be taken by the new government will be the devaluation of the national currency unit sometimes in the first half of 1984. The current foreign currency exchange controls are also expected to be continued. If so, the situation will be such that the amounts of foreign imports will be greatly reduced, and local industrial production will be strenghtened in order to cover the needs of the local market as well as for possible exports.

Under this scheme, the circunstances will be optimal for an increase in the industrial activity related to microelectronics and the corresponding required increase in the local R&D and design efforts. It it important to estimate the range of activities that can be reasonably developed in view of the actual situation, with the existing human and material resources for the different micrelectronic fields.

The analysis to be presented is derived from the discussion and the results of a wokshop financed by CONICIT and organized by the FII, held in Caracas during the days from June 31, to July 2nd 1983 [24]. This workshop benefited from the participation of most of the Venezuelan researchers in the field, representatives for most of the professional electronic companies, representatives of

CONICIT and representatives of the Ministry for Industrial Development (Ministerio de Fomento). The objectives of the meeting were the following: a) an evaluation of all of the microelectronic past activities in the country, b) an evaluation of the possible future activities in microelectronics during the next five years, and c) a summary of possible governmental recommendation for the definition of a real policy for the accelerated development of the field.

4.1 Pespectives in IC development

Future development in this area is particularly difficult to estimate. Not only is the international development of low power analog and digital integrated circuits, a process which is highly accelerated and highly competed, but also it requires major financial and human resources. Only one IC laboratory exists in Venezuela at present (with available resolution of 5 microns in silicon technology), with a total of some ten engineers with PhD training in the field. Major steps must obviously be taken if IC manufacturing is to be accomplished in the country. The level of expenditure required for the conversion of the existing laboratory facilities to an industrial scale operation is certainly of the order of several million dollars, if improved circuital resolution is to be achieved. This fact together with the limited trained manpower, implies that significant development will occur only through major government sponsored action or through major international agreements. These possibilities will be considered further in the following sections.

Probable developments which will occur independently of major initiatives, will be related to the local production of photodetectors (with silicon technology) and the creation of a gallium arsenide research and development laboratory. The probable evolution of silicon power device production is decribed separately.

4.2 Hybrid circuit perspectives

This sector of microelectronics offers one of the best perspectives for its massive development in Venezuela within the next few years. The country has decided on an intensive expansion in its communication system (telephony, data, etc.) so that the application of hybrid circuitry is assured. The technology required for hybrid circuits is relatively simple and the level of required investments is more accessible for the country (one or two million dollars).

Several professional electronic companies have established their interest in producing hybrid circuits, both thick and thin films. There is a significant local effort in R&D (at FII) and this effort will be increased. A consortium formed by several electronic companies and the FII, for the manufacturing of hybrid circuits is being considered at present. The role of the FII will be concentrated in R&D. Most of the hybrids currently imported will be produced locally. This is certainly the case of those required by the telephone industry.

The experience obtained by Venezuela during the last fifteen years of production of printed circuits (mainly by Circuitel), establishes an excellent base for the definition of those circuits that should be hybridized.

Even the local production of pastes is now being considered together with the economics of the process.

4.3 Microwave IC perspectives

A significant increase in local R&D activities will also occur in this field together with some limited manufacturing efforts in near future. Passive microstrip elements will certainly be produced, incorporating imported active devices. Local designs for telecommunication networks will also increase.

Local R&D efforts in gallium arsenide technology will be developed in relation to studies concerning high frecuency active devices. The results of these studies will determine the possibility of future industrial future development.

4.4 Perspectives in fiber-optic systems and components

There is no doubt that optical communication system design will strongly increase for large and small scale applications. Optical buses incorporated to telephone automatic exchanges are being designed now, and supervisory control sysytems for hostile environments (refineries and other industrial plants) will be completed soon.

Several cable manufacturing firms are now evaluating the economics for the local production of fibers, in view of the plans of the telephone company regarding extended use of optical communication links in the country.

Local R&D concerning detectors and light sources will increase. Efforts are being made in order to re-orient the activity of physics researchers who are now involved with studies on ternary and cuaternary semiconductor materials, towards gallium arsenide technology.

4.5 Power device perspectives

The local production of power diodes, transistors and silicon controlled rectifiers is deemed possible in view of the large device areas involved, and in view of the potential markets for the local automotive industry, the local electronic industry and the aluminum industry. A major increase in the actual R&D efforts must be developed in order to be able to have a better industrial perspective particularly in the case of SCR's production. Power diode prototypes have already been developed, and significant research in metal to silicon contacts for high current levels has been carried out.

The development of this area will require some sort of international collaboration scheme, either with established foreign companies who might wish to carry out local construction under joint-venture schemes, or through the support of international development agencies.

4.6 Solar cells perspectives

As indicated earlier in section 2.6, the major application of solar cells in the country will not be dedicated to massive energy conversion schemes in view of the available oil and hydroelectric energy potential. On the other hand, a potential market of some 4 million dollars is currently estimated for solar cell remote areas applications. The production of solar panels using imported cells is under way now, together with some limited local production of crystalline silicon solar cells. Possible international joint R&D activities in amorphous cells are being considerd in projects with the company Energy Conversion Devices.

4.7 CAD perspectives

Local computer aided design will grow without any doubt in the next decade. The country has already a significant infrastructure of computers, as well as a sufficient pool of human resources in the area. Furthemore, national industrialization plans will grow, and they will require continuos growth in CAD, particularly in the oil industry.

The largest engineering private companies in the country are aware of the need for expanded CAD activity, if they want to be competitive with foreign firms. These engineering firms are presently discussing interactive schemes with local R&D organization for the optimization of human and financial national resources.

A modified CAD application, of great importance for Venezuela, is the development of strong groups in digital image processing with two purposes: a) the evaluation of the resources of the national territory, and b) the production of maps from digital data banks mostly related to geographical and geophysical data. The personnel employed in actual groups in this field are expected to grow an order of magnitude (from 15 to 150) within the next five years.

4.8 CAM perspectives

The automotive industry is the major national industry which could require comouter assisted manufacturing. However the nature of this industry in Venezuela, is based on the assembly of imported parts. If this industry were to install robots in their production line they would in all probability purchase the automatic systems abroad. A local activity in computer aided manufacturing, including supported R&D activities, would require a major change in the attitude of the industry. This major change is hard to predict, and very hard to induce since this national industry is still strongly tied to foreign car manufacturers.

In the case of smaller manufacturing industries the gradual modification of existing machinery, so as to increse their numerical control and automatic features, represents a development which is totally feasible. This development will certainly occur and the design and production of the required electronic systems will be local.

4.9 Microprocessor application perspectives

We have already discussed that the development of this area is almost infinite, being bounded only by the ingenuity of the designers. Special regional conditions might induce a local development of microprocessor applications in those areas where international systems are unavailable or when the available systems require major modifications.

The technology involved in microprocessor applications is directly available to all countries with a reasonably good engineering or scientific training. This is certainly the case of Venezuela, where all of the major academic institutions offer microprocessor courses in the regular electrical engineering study programs.

The major specific fields of microprocessors applications in Venezuela are related to the oil industry, and to the communications industry. Supervisory control and automatic operation of oil fields, pumping stations, oil and gas pipelines, refineries,and processing plants offer a wealth of examples. Furtnemore if one considers that the international oil industry is undergoing a modernization process at present, one realizes that the technological gap between developed and underdeveloped countries is still not too great in this area. A reasonable chance exists for the establishment of local designs which can compete economically and technically with those designs originating from the more industrialized countries. The technological revolution occurring in the telecommunication industry in the industrialized world, has shown a tendency towards systems with more distributed and local intelligence, and it points out to a potential window for designs produced in accordance to local needs and specifications.

Another example of specific microprocessor local application in telecommunications, is represented by the design of an automatic voting network for Venezuela. If the network were to be used only for voting, then its cost will probably be the major factor against its implementation. On the other hand the additional facilities that can be incorporated into such a network (seismic data network, hydrological data network, library interconnection system, medical data network, etc.), indicate that a special design incorporating local conditions would be of great use for Venezuela, or for countries similar to it.

Additional microprocessor applications which require local designs are obviously required in the field of automated office operation, and in education. It is particularly in the field of education where the different local conditions must weight heavily on the systems used.

4.10 Perspectives in software development

As in the case of microprocessor applications, software development is well suited for local activities, due mainly to these reasons: a) the financial resources required for the establishment of a software company are much more accessible to Third World countries than in the case of hardware companies, b) software production is a labor intensive activity, c) most of the technological knowledge required is easily accessible, and d) programs developed for one specific application are seldom directly transferable to other cases.

The problem of software development in developing countries is described in detail in reference [25], where it is stated that:

"UNIDO's preliminary investigation has shown that in the developing countries such as Argentina, Brazil, China, Egypt, India, Malasia, Mexico, Republic of Korea and a few others, the potential for the development of a computer software industry exists."

This is also the case for Venezuela, where trained human resources are available in sufficient numbers and where the industrial development plans currently under way require more and more special programs for specific local applications. The relative size of the computing centers and computer sections in the various nationalized oil companies clearly points out the importance of this type of activity in the petroleum industry.

5 COOPERATIVE EFFORTS

The maxim of strength through union is certainly an old and proven concept which also applies to the technological development of one or more countries. If the available national resources, both human and financial are scarce, it is obvious that their optimal utilization will require a concerted national action, avoiding the duplication of efforts, and with maximal agreement between the different entities involved: the state, the R&D community and the local industry. This first step depends on the national will of each country and each country alone, and it represents a minimal first effort that must be achieved if a faster rate of technological development is desired.

The same principle that applies to the different groups within a given country should of course also apply to different countries. Agreement should be achieved in order to rationalize individual efforts, to avoid unnecessary competition (if at all possible), or to reduce it through common agreements. Common fronts should be established towards more industrialized nations (as in case of OPEC), as well as towards less industrialized nations (as in the case of the agreement undersigned by Mexico and Venezuela for the supply of oil at better rates for Caribbean and Central American countries).

Technological agreements for the accelerated development of microelectronic or other advanced technologies, should be possible for countries with similar development levels and similar problems. Within the Latin American scene, possible similar partners could be Brazil, Mexico and Venezuela which were identified as "middle-tier developing countries" by a study carried out by the U.S. House of Representatives in November 1980 [26]. Considering the development undergone by Argentina since then, this country should also be considered under similar conditions.

Efforts should always be continued in order to achieve truly effective agreements between industrialized and less developed countries, even though the number of examples of effective technology transferences are not abundant. In fact in most instances of technical relations between countries of different technological levels, the label of "technology transfer" is really applied to the process of mere technology sale (at high levels of profit).

There are no examples of technological Marshall plans designed for the achievement of reasonable technological development of a given country or countries. If these plans were to exist, a more balanceddistribution of technology in the world and correspondinly a more stable world balance, would also exist.

This fact comes as no surprise since very large proportions of high technology products produced in industrial countries are now marketed and sold in less advanced countries. Major changes in this situation are obviously conditioned by the existence of the established vested interests.

In the telecommunications industry alone there is a perspective 88 billion dollar market within the next five years. Although a significant percentage will be spent by Third World countries, no Third World manufacturers are to be found among the leading group of Western Electric, ITT, Siemens, Ericsson, GTE, Northern Telecom, NEC, GEC, Thomson CSF, and Philips.

While pointing out some drawbacks in the relationship between developed and less developed countries, one should never fail to point out one of the most positive aspect in these relationships, that is, the open accessibility of Third World students, professors and researchers to most of the academic institutions in the more advanced developed countries. This aspect of true technological transfer must be recognized and properly valued since it represents one of the most effective factors for change in less developed regions. Some institutions in some industrial countries are particularly excellent and open to foreign participation, and in this sense it is pertinent to quote Dr. Paul E. Gray, the president of the Massachussetts Institute of Technology on the subject of scientific and technical information transfer among countries [27]:

"My own view is that while there is a legitimate concern about the transfer of scientific and technical information to countries which would use it to their military and strategic advantage, there is far less understanding of the degree to which quality and progress in science depend on openess and sharing of information within the educational and research communities. The research universities of this country are, already, international communities of students, faculty, and research staff who are selected on the basis of ability and promise -- not on national origin."

It is obvious that the free accessibility to institutions of great academic standards in developed countries, has been a strong factor for the technological improvement of many countries. If the different industrial establishments of the more advanced countries were to follow a more concerted and open action with respect to their operations in less developed countries, the technological world situation would suffer major changes. It is of course rather utopian to expect these changes to take place spontaneosly, but Third World governments should be aware of the range of possible technological agreements that could be induced through trade agreements, political treaties, and natural resources supply contracts.

International organizations have played and must continue to play a significant role in order to achieve a more balanced technological distribution. These organizations face the difficult task of achieving agreement among several countries, and the degree of difficulty increases as the number of countries involved increases. On the other hand they can count on the concerted support of many Third Word countries which are united in their intention of achieving a higher technological level in spite of national differences of economies and tyoes of governments. In the case of microelectronics, and in particular in the case of the production of integrated devices and circuits, the corporate nature of modern efforts for the production of these items clearly points out to the desirability of a concerted action on the part of Third World countries.

5.1 Cooperative efforts in Venezuela

Three major areas of internal cooperation should be stronly increased: cooperation among the local professional electronic companies, cooperation among the R&D community and these companies, and cooperation among the government, the R&D community and industry.

5.1.1 Cooperation among companies

As we have described above most of the major electronic companies which develop local design in electronics are dealing with similar tasks where there exists a certain degree of local competition. Although these elements of competition are highly desirable for a healthy industrial development, the companies should develop common strategies for handling major national electronic production goals. A positive development along these lines seems to exist in the case of the proposal for the production of automatic voting machines, which is to be handled by a consortium of the different companies. To the extent that this joint mechanism will be succesfull, the strength and visibility of the local electronic industry will be enhanced. Other projects that might be handled jointly by the companies is related to the production of basic telecommunication equipment, basic microprocessor control modules and the local fabrication of electronic components.

5.1.2 Cooperation between R&D units and industry

The size of the different professional electronic companies in Venezuela is still rather reduced, and most of their effort is dedicated to design, marketing and sales. Their R&D efforts are reduced, and they are limited to the products which are manufactured. The major state controlled telephone and telephone manufacturing companies have little development and no research. On the other hand the major R&D state sponsored organizations have invested substantial amounts of money in personnel training and for the purchase of specialized equipment. It is rather obvious that the interaction of the different sectors should be increased for the common good. The R&D groups must prove to the satisfaction of the companies, that they can handle different projects with total confidentiality, and with total impartiality. One major step along the line of increased cooperation will be taken with the establishment of a joint venture between FII and two electronic companies for the production of hybrid circuits. Equally important cooperative programs might be developed in the production of optical fibers, in the manufacturing of solar cell panels and in the development of microprocessor applications. In all of these fields the R&D groups would concentrate on the designs and their constant improvement, while the companies would concentrate on the manufacturing.

5.1.3 Government, Industry and R&D Centers

Government has a major role to play in inducing the desired interaction, since it controls several large companies while at the same time it regulates the operation of all the private companies as well as the operation of most R&D orgnizations. Government also regulates most of the goods and services which are used in the country every year; it also authorizes the importation of those goods and services that are purchased abroad. A clear governmental policy for microelectronic development, based on objective technical analysis, would greatly help change the technological situation of Venezuela in a relatively short time.

During the last thirty years the Venezuelan government has certainly supported the establishment of local R&D institutions, as well as the founding of several universities, and a central policy and financing institution (CONICIT). No specific policy concerning the establishment of priorities among the different technical and scientific fields was ever implemented until 1979 when the Petroleum Technological Institute (INTEVEP) was created with the mandate to carry out research and development in the areas directly related to the petroleum industry. The level of financing for this new institute was definitely higher (for salaries for the personnel as well as for the purchase of laboratory equipment and materials), than in the case of other R&D institutes. The government clearly indicated that it considered petroleum related research as fundamental for the development of the country. No other fields have been declared as having special priorities up to the present time. Research and development projects supported by CONICIT are judged on the bases of their technical quality, and the funds are apportioned equitably among the different fields.

Every five years the platforms of the major political parties have reflected several suggestions for science and technology programs. Up to the last election, these suggestions referred mainly to different organizational schemes for the sector of science and technology [28]. In the last election (December 1983), the programs of the major political groups established some priority guidelines for those topics that should be developed nationally with greater intensity. Significantly enough, all parties coincided on the importance of modern electronics for the national development. In some of the programs, reference was made to the electronic complex (electronics, telecommunications and informatics), while other programs stressed the importance of electronics or that of microlectronics. No detailed plans were presented regarding the procedure to be followed for achieving the desired accelerated microelectronics development. In order to reach this goal the government must establish a clear and coherent policy, which could be based on the following actions:

1) An official declaration defining microelectronics as a priority area.

2) An official definition of a major goal to be achieved in electronics (i.e. the reduction of foreign microelectronic imports by 50% in five years).

3) The establishment of a national microelectronics commission formed with government representatives, representatives from industry, and from the R&D community. The main objective of the group would consist in the tentative definition of a detailed policy for the accelerated expansion of microelectronics in the country. This tentative policy would later be ratified officially by the government.

4) The inclusion of R&D personnel in the boards of directors of the major state owned or mixed industries, where most of the more important decisions concerned with the purchasing of equipment and technical services are made.

As a matter of fact, during the last three years of the previous government the last recommendation concerning the inclusion of R&D personnel in the directive boards of major industries or state corporations, was implemented in four instances. Researchers were appointed to the Telephone Company (CANTV), to the Public Utility Company (CADAFE), to the telephone manufacturing company (MAPLATEX), and to the board of a major company for the production of seamless steel pipes for the oil industry. As a direct result of these appointments, several decisions were influenced by scientific and technological criteria, and projects which would have been designed outside the country were developed locally.

All the recent Venezuelan administrations have been in fact aware of the need for an industrial policy aimed at the substitution of imports. The level of global imports has been 10 billion US dollars yearly, during the years 1977 until 1980. An additional 8 billion dollars has been spent in the same four year period in technology contracts[29]. With this spending profile it is obvious that the government should encourage local production by all means. One of the measures taken by the government along these lines has been the Decree 1234 of the 8th of October of 1981 [30]. The whole document is directed towards limiting the purchase of foreign goods and services, as clearly shown by the text of the first article:

"The different Ministers will not be able to authorize the purchase of foreign goods (either consumer, intermediate or capital goods), nor the approval of consulting contracts, or the construction of different public or industrial works, or the hiring of technical personnel outisde of the country, when there exists a national offer with adequate conditions of quality, opportunity, and cost, regardless of whether the purchase is direct, or whether it is carried out through a private or public bidding process."

This decree certainly establishes strong legal bases for the development of local technical activities, although its effective application depends on the intelligent evaluation of the phrase "... adequate conditions of ...".

The administration which has recently been inaugurated (February 2nd 1984) has taken some additional positive steps that will also tend to increase the local technological effort:

1) The office of the State Minister for Science and Technology has been mantained. The new minister is an ex-director of IVIC, and he has announced plans to convert CONICIT into a formal Science and Technology Ministry.

2) The new minister has named a highly trained engineer (PhD in computer sciences and director of one of the major professional electronic companies), as a liason officer between the ministry and the productive sector.

3) Conversations are under way in the new government for the establishment of a tax aimed at the productive sector, to be directed toward the financing of local R&D activities. Should this measure be implemented it will represent a major significant step in the country's development.

4) The new minister for the Environment and the Natural Non-Renewable Resources (MARN), is also a qualified scientist whose activity will help in establishing closer ties between the R&D community and the government.

Some researchers (in biology and ecology) have been named to the new boards of directors of some of the state owned or mixed companies, it is hoped that this very effective measure will be extended in the near future so as to include researchers in more technical fields related to the basic national industries.

5.2 Cooperation between countries

The general lines of interaction between countries in Latin America should be established along the following lines: a) a major joint R&D effort between Argentina, Brazil, Mexico and Venezuela, and b) a major effort in the training of R&D groups of the other countries. The differences in technological level among the four countries might be a limiting factor in the development of joint projects (Brazil is definitely more developed in several of the areas of microelectronics, particularly in integrated circuits). However, a careful selection of topics such that each country is the major responsible for a given area, and the possible organization of companies operating in the four countries might successfully induce the required cooperation. As an additional binding factor, the cooperation might be established under an international organization umbrella as it will be discussed in the next section.

5.3 International cooperation

The subject of international cooperation in the field of microelectronics is not a new topic for the various specialized United Nation agencies. In the particular case of UNIDO, the role of Third World countries in the field of microelectronics has been discussed at several international conferences. It is clear that whatever schemes might be developed, the efforts of several nations must be involved: it is also clear that the rapid evolution of the technical knowledge in the field requires a large component of R&D activities together with the purely commercial or industrial aspects. The design of chips for customized applications has been considered economically and technically feasible in a number of countries [31].

Within the American continental scene, the Organization of American States has supported several collaborative organizations maily dedicated to conventional technologies or to the transfer of information and professional knowledge [32]. No major R&D joint ventures have been established.

The time seems appropiate for the proposal of a major transnational effort in microelectronics to be sponsored through an international organization such as UNIDO, or the OAS. As a matter of fact Venezuela has proposed to UNIDO the establishment of a Regional Center for Applied Microelectronics to be hosted by the Fundacion Instituto de Ingenieria (The Engineering Research Foundation- FII). The activities to be covered at the new center would be the following:

1) Research and development in the following areas: integrated circuits and devices, hybrid circuits, components ans system design for optical fiber communications, solar cells, power devices, and components and systems design for microwave integrated systems. These R&D activities would be directed towards designs and applications particularly suited to the realities of a partially developed country.

2) Technical assistance to Venezuelan and foreign industries in their plans for the establishment of new industries related to the different microelectronic areas. It was felt thet the experience already gathered by the Foundation in its dealings with Venezuelan industries was important, and it could be used by other developing countries, most of which experience similar problems.

3) Technical training at all levels, from that of laboratory technician to the level of a researcher. This activity can be carried out in collaboration with local and foreign universities. These activities are considered fundamental in view of the level of investments required and due to the need for on the job training which is fundamental to microelectronic activities. This type of training is difficult to obtain at established companies both in developed and in underdeveloped countries. The proposed center can be conceived as center for the training of

trainers, that is, those professionals from other countries who will later create other regional centers in their respective nations.

4) An information center for the collection of technical data and technical experiences to be freely available to other groups and nations. This activity should cover from collections of technical books and periodicals, to technical reports, computer programs and video recordings for technical training.

The FII was considered as a suitable base for the proposed Regional Center in view of the substantial investments already carried out both in equipment, buildings and trained personnel. Additionally, the legal structure of the Foundation allows the establishment of a center such as the one envisioned, to be founded by the FII together with an international agency.

The geographical position of Venezuela has influenced its traditional Latin American and Caribbean cooperation role, as evidenced by its actions from the time of the wars for independence to the recent agreements for the supply of hydrocarbons to neighbouring countries. Additional evidence is given by the signing of technical collaborative agreements with: Argentina (1972), Bolivia (1973), Brasil (1973), Ecuador (1973), Mexico (1973), Haiti (1974), Dominican Republic (1974), Guatemala (1976), Peru (1976), and a complementary Science and Technology agreement with Brasil in 1977.

The Regional Center proposed for Venezuela could be one among other Regional Centers to be established in other countries. The various centers would all interact along guidelines established in common accord by the different countries and by the sponsoring international agency. The guidelines would be drawn on the basis of a maximal common good. There is no doubt that the individual countries's activities in microelectronics would be strengthened by this scheme, the collaborative efforts of the different members would increase, and, perhaphs, the structure of a united effort in microelectronics by Third World countries might bring about new avenues of effective collaboration with more advanced countries.

6 CONCLUSIONS AND RECOMMENDATIONS

The description of the reality of microelectronic activity in Venezuela has been the essence of this paper. Although limited at the moment, this activity has a reasonable potential for growth in view of the educational development of the country during the last forty years. The nature of the Venezuelan economy, which is based on the industrial development of natural resources like oil, iron, aluminium, coal etc., implies a need for an active local development of the electronic complex (electronics, telecommunications and informatics). In this sense, even without considering military implications, the strategic development of most of the fields of microelectronics is a national necessity. The task might seem almost impossible in view of the fast rate of evolution of the international knowledge in the field, and in view of the large investments required (both in human and financial resources), and yet the country has no other alternative but to try to achieve reasonable technological autonomy in some of the fields. This autonomy can only be achieved with a strong research and development effort, with a well co-ordinated national effort and with constant improvement in the quality and intensity of the educational standards.

Transnational and international technological agreements will be of great importance in the acceleration of the technical development of the area of microelectronics in the country, and they might prove to be of importance for the collective development of other countries.

The distinguished economist Lester C. Thurow, in discussing the actual technological situation faced by the United States in view of fierce Japanese competition in many high technology fields and the loss of American industrial leadership during the last three decades, states the American situation in the following terms [33]:

"...The problem is not how to get back to the effortless superiority that we had back in the 1950s, but how we run with the leaders of the pack -- behind in some activities, ahead in other activities, but average with respect to the best economies of the world. That should be the goal you think about..."

In the case of Venezuela, as in the case of many other underdeveloped countries, Thurow's statement also applies. The nation must seek to reach a passable international level in some industrial activities, mainly those related to petroleum, iron, and aluminum industries, as well as some of the more strategic areas of microelectronics which nowadays affect the whole spectrum of industrial endeavor.

7 REFERENCES

1- Microelectronics and society, G. Friedrichs and A. Schaff,Editors Pergamon Press, Oxford , 1982.

2- A. Reisman, "Scaling to Micron and Submicron Dimensions", IEEE Proc.,Vol. 71, No. 5, p. 550-565, May 1983.

3- J. Allen, New Perspectives in Electronic Technology, Proceedings of the "Global Technology Change- A strategic assesment Symposium", MIT June 21- 23 (1983), p. 61-85.

4- IEEE Spectrum, November 1983 issue dedicated to the New Computer Generation, and also see: Business Week, August 8, 1983, p.62.

5- W.R. Wisseman et al., "GaAs Microwave Devices and Circuits with Submicron Electron Beam Defined Features", Proc. of the IEEE, Vol. 71, No. 5, May. 83, p. 667-675.

6- J.B. Gunn, "Instabilities of current in III-V semiconductors", IBM J. Res. Develop., vol. 8, p. 141-159, Apr. 1964.

7- R.L. Johnston et al, "A silicon diode microwave oscillator", Bell Syst. Tech. J., vol. 44, p. 369-372, Feb. 1965.

8- R.C. Callarotti and A. Gallo, "On the solution of a microstrip line with two dielectrics", IEEE MTT Trans., April 1984, to be published.

9- T. Miya et al, "Ultimate low-loss single mode fiber at 1.55 microns", Electronic. Letters 15, p. 106, Feb. 1979.

10- D.C. Hanson, "Fiber Optics in Local Area Networks", Vol. 57,. Adv. in Electronics and Electron Physics, Academic Press, p. 145-229, 1981.

11- J. Ripper, Campinas University, Brazil (private communication).

12- S.J. Fonash, Solar Cell Device Physics, Academic Press. New York, 1981.

13- S. Ovshinsky, Energy Conversion Devices, Troy (Michigan), (private communication).

14- D.J. David, "Microprocessor Systems", Adv. in Electronics and Eletron Physics, Vol. 57, p. 411-471, 1981.

15- T.R. Ide, "The Technology", Microelectronics and Society, G. Friedrichs and A. Schaff, Editors, Pergamon Press, Oxford, p. 37-88, 1982.

16- J. Garcia N., "La Investigacion en Venezuela", CONICIT Series Estadisticas, May 1982.

17- Ciencia y Tecnologia en Cifras, Informe Estadistico No. 1, July 1st,p. 46, 1981.

18- C. Perez et al, "Desarrollo Tecnologico Industrial - El caso de las Empresas de Electronica Profesional", Memorias del Congreso Internacional de Sistemas, Caracas, 1983.

19- M. Roche, Bitacora, Ediciones IVIC, Caracas, 1963.

20- R.J. Cardenas, Ciencia y tecnologia, OCI Direccion de Publicaciones, Caracas, 1970.

21- H.K. Henisch, "Space-Charge Controlled Conduction in Thick Metal Insulator Metal Barriers", J. Appl. Phys. 51(7), p.3790-3793, July 1980.

22- Fundacion Instituto de Ingenieria, Memorias de las Primeras Jornadas Tecnicas, J. Aponte Editor, Editorial Arte, Caracas 14-16 December 1983.

23- Acta Cientifica Venezolana, Vol. 34, Suppl. 1 (1983).

24- Taller de Microelectronica, FII, - June 1983, Proc. to be published CONICIT.

25- United Nations Industrial development Organization (UNIDO), "Problems of Software Development in Developing Countries", prepared by UNIDO Secretariat, 1983 (IS.383).

26- U.S. House of Representatives, "Survey of Science and Technology Issues - Present and Future", Staff Report of the Committee of Science and Technology, 97th Congress, p. 329, June 1981.

27- see reference [2], p. 9

28- Ciencia y Tecnologia en programas de Gobierno, CONICIT Direccion de Politica Cientifica y Tecnologica, Serie Cuadernos, Caracas, 1981.

29- Costo de Importacion de Tecnologia 1976-90, CONICIT Direccion de Politica Cientifica y Tecnologica, Serie Cuadernos, Caracas, 1981.

30- Gaceta Oficial de la Republica de Venezuela, No. 32329, October 8, 1981.

31- Prof. Narasimhan, "Proposal to Establish a Silicon Foundry to Service Developing Countries Needs", Tata Institute, Bombay (India), 1983 (unpublished).

32- A. Araoz, "America Latina Planeacion y Desarrollo de la Ciencia y la Tecnologia", Comercio Exterior, Vol. 31, No. 5, (Mexico), p. 540-550, 1981.

33- see reference [2], p. 255.