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Scientific development in biological, physical and engineering sciences in Brazil

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SCIENTIFIC DEVELOPMENT IN BIOLOGICAL, PHISICAL ENGENEERING SCIENCES IN BRAZIL (GENETICS, INFORMATICS, ELETRONICS AND SPACE INDUSTRY)

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ABSTRACT

This paper gives an overview of scientific and technical development in the areas of genetics, informatics, electronics and space industry. Within these areas emphasis is given to research which has impact on economical and industrial development. Future perspectives are discussed.

I - Introduction

Scientific, technical and industrial development in Brazil has to be focused taking into account macro economical data: (1)

1 – Country Area: 1.3 million square kilometers

2 – Population: 145 millions (74% urban and 26% rural)

3 – Economically Active Population: 55 millions

4 – GNP: US$ 350 billions

5 – Per Capita Annual Income: US$ 2,400

6 – Avarage Life Expectancy: 63 years

7 – Foreign Trade:

7.1 – Total sales: US$ 33 billions

7.2 – Trade balance: US$ 19.7 billions

8 – Main Commercial Partners:

USA (31,5%, EEC (28,7%), LAT. AMERICA (11,6%)

JAPAN (7,2%) OTHERS (21%)

9 – Science and Technology

9.1 – Number of Universities: 64

9.2 – Number of higher education institutions: 600

9.3 – Number of students in higher education: 1.8 million

9.4 – Number of MSc and PhD:

35000 (1984) – 50000 (estimated 1988)

9.5 – Annual investment in Science and Technology: US$ 2 billion

Statistical data are from 1988 unless otherwise stated. For comparison in 1960 the population was 70 millions (45% urban and 55% rural) with 23 million economically active. (1)

Brazil is a large country, plentiful of natural resources and a significant internal market. Although the average per capita income is low, there are regions where it approaches that of developed nations along with others where a significant part of the population toils outside the money economy.

The total number of scientists and engineers involved with R&D represent one per 2900 inhabitants, while in US, Japan and the most developed countries this ratio is one order of magnitude higher. Again if we only consider the highly industrialized regions, where per capita income approaches that of developed countries, than the number of scientist and engineers involved in R&D is about half of that corresponding to those countries.

Scientific activity is supported mostly by public funding, which accounts for 75% of the total expenditure in R&D. Industrial spending, which was negligible in the early seventies, amounted to US$ 0.5 billion in 1988 and tends to grow with the debut of high tech companies.

Research founding is low as a percentage of GNP (0,8%). Studies carried out by the State Secretary for Science and Technology show that the country should spend at least US$ 3.5 billions (1% of GNP) in order to fully use its already existing man power capability and also increase significantly its scientific training. Further increase will be needed to achieve the high tech transformation of its industrial park in the next two decades.

It is in this context that an overview of the Brazilian scientific development is presented, focusing the areas of Genetics, Informatics, Electronics and Space Industry.

II – Scientific development

Biological research was the first area of science implanted in Brazil, having from the outset a strong liaison to agriculture and public health. Brazilian health research became world famous for its work in tropical medicine. Certainly the study of Chagas disease (South American Trypanosomiasis) is one example of its impressive success.

At the beginning of this century, Brazilian Science resided exclusively in isolated research institutions. Only in the thirties was active research established in São Paulo and Rio de Janeiro universities.

The academic science was expanded in numbers and quality in the late sixties. The country shows today the largest scientific production in Latin America. USP (University of São Paulo) contributes with 40% of the country's technical and scientific publications. In 1988 its academic staff (5000) published about 16000 papers.

Still nowadays, Biology related sciences represent about half of the research activities in terms of publications and engaged personnel.

III – Genetics

Although the field of genetics involves human, plant, animal, microbial and more recently molecular genetics, the initial priority was plant genetics, because of its relevance to agriculture. At the beginning of the century IAC (Agricultural Institute of Campinas) played an important role applying genetic techniques to upgrade and develop new varieties of coffee resistant to diseases that might occur in our environment. Nearly all varieties of coffee used nowadays in our agriculture were developed at IAC.

Others institutions, working with plant breeding and improvement, developed crop varieties adequate to our climate, which are resistant to local diseases and insects, produce higher yields and are of better quality. In horticulture, about half of the crops presently cultivated in the country were developed at ESALQ (USP School of Agriculture) and IAC. Important results in plant breeding and improvement has also been achieved by EMBRAPA (Brazilian Institution for Agricultural Research) which has several research centers throughout the country and UFV (Federal University of Viçosa). EMBRAPA has carried out research with a large variety of crops (tropical fruits, maize, cotton, sugar cane, etc.) and UFV most outstanding achievement was a variety of soybean with improved quality and higher yield. Several other universities also contributed (UFRS – Federal University of Rio Grande do Sul, UFMG – Federal University of Minas Gerais, UNICAMP – State University of Campinas, UFSC – Federal University of Santa Catarina, UFPR – Federal University of Paraná)

An example of the international success of Brazilian research in plan crossbreeding and improvement is the study being undertaken by biologists from Cornell University on the Brazilian tomato Alcobaca. This variety is being investigated because it tastes better than other varieties and can be kept in stock for 12 days, while others last for only 5 days [2].

Today, nearly all agricultural crops produced in different regions of the globe can be grown in Brazil. Most of the research that allowed this development and diversity in our agriculture was carried out at Brazilian institutions.

Genetics has also played an important role in animal husbandry, contributing to the country large activity with livestock for production of meat and dairy products. In this field, the most important research centers for cattle breeding are those from EMBRAPA, along with research at universities (USP, UFRS and UFMG).

In genetic improvement for pig breeding and production of sires most of the research is being developed at EMBRAPA – Research Center in Concordia (Santa Catarina State) and at UFV. These institutions and ESALQ are also involved in genetic improvement of poultry, including the production of sires.

In human genetics, most of the research in centered in the study of populations and clinical cases (60% of published papers).

A significant part of the outcome of Brazilian Journal of Genetics, published in English and indexed in all international abstracts.

In classical biotechnology the country achieved a good development both in academic research and in industrial applications. This includes technology based manipulation of natural properties of existing organisms for industrial purposes, like fermentation technology, industrial animal and plant genetics (e.g. hybrid seeds), vaccines and blood by-products, natural products fine chemistry, biomass industrial technology, microbiological applications to soil management, mining and oil fields.

An important success of Brazilian technology is the work carried out for sugar cane genetic improvement which coupled with developments in fermentation technology turned alcohol fuel economically competitive with gasoline in Brazil. The alcohol fuel agro industrial sector employs about one million people and has achieved an annual production of 13 billion liters. In 1988, from the total vehicles produced by the automobile industry in Brazil, 90% were for running on alcohol fuel and the remaining 10% for a mixture of 20% alcohol and 80% gasoline.

Alcohol is an automotive fuel which presents environmental advantages since it produces less air pollution then gasoline. Furthermore, the amount of CO_2 produced in sugar cane processing and alcohol combustion is absorbed back from the atmosphere by sugar cane plantations.

With the advent of molecular biology, the country which was well acquainted with "classical genetics", fell behind of the research carried out in developed countries. There are few research groups in molecular biology and genetic engineering. USP has a four years program financed by the Interamerican Bank for Development, with molecular biology being one of the priority areas for investment, both in equipment and training of the research staff.

In advanced, "modern" biotechnology there are research groups in EMBRAPA's centers, and several Federal and State Universities. The output of academic work that has already been transferred to industry is restricted to plant micro propagation by tissue culture and related cell manipulation, and diagnostic kits.

Apart from these, research is active in Brazilian Universities and public research centers, on engineered organisms and their industrial use, on novel non-physiological uses of cells and tissues, on technology of recombinant organisms and cell fusion products, animal and plant cell manipulations (e.g. artificial seeds, "in vitro" plant chemistry, animal egg. cell and embryo technology) and cellular/molecular immunology. However, most of these research groups do not detain a critical mass of people capable of working effectively in these frontier lines and transfer new developed technologies to industry. Brazil has not yet marketed a single product of recombinant technology or hybridoma culture.

In 1988, total sales from biotech industrial activity yielded US$ 10.5 billions, from which US$ 9 billions are from energy/biomass. The remaining US$ 1.5 billions are distributed in the following industrial activities: (3)

ACTIVITY	**US$ MILLIONS**	**PERCENTAGE**
Human Health	555	37.0
Agriculture	562	37.5
Food	266	17.7
Animal	52	3.5
Environment	33	2.2
Other	32	2.1

Data for the biotech industrial activity are from ABRABI data base. (3). ABRABI is an association of companies particularly active in the more advanced aspects of biotech R&D and in university-industry relations. It has 36 members from which, 33 are biotech companies interested in different sectors of biotechnology and 3 are financial and risk capital companies.

The internal market for modern biotech products is presently US$ 600 million/year. This figure is expected to increase to US$ 1.5 billion/year in the next decade. (3)

Biotechnology is one of the four areas of scientific and industrial development which has government priority. At the President's Special Secretariat for Science and Technology there is an Associate Secretariat for Biotechnology. Its role is to coordinate investments in R&D and to set out the policy for scientific and industrial biotechnology following societal needs and environmental safety. The other three priority areas are: New Materials, Mechatronics and Fine Chemistry.

In the period 85-88, the global R&D expenditure in biotechnology [3] was US$ 269.2 millions. The funding sources were: Government (65.7%), Industry (32.9%) and Foreign Institutions (1.4%)

The estimated labor force in biotechnology R&D[3] amounts to 3200 scientists and engineers, 1400 graduate and 1800 technicians.

IV. Informatics and electronics

In the early seventies the first laboratory for production of Integrated Circuits (IC) was established at USP in the Department of Electrical Engineering. In this department the first microcomputer was developed and the technology transferred to industry.

Brazilian Government gave priority to the development of Brazilian industries in informatics. Since the local industry could not compete with multinational companies in terms of price for their products, a protection law was decreed 10 years ago forbidding imports of equipment, when there is a similar type produced by Brazilian companies. This protection applies only to small machines, up to 1 MIPS.

With this protection law, the national industry of informatics flourished. From total sales of only US$ 200 millions in 1979, this sector achieved US$3 billion in 1988, which is 66% of total sales. Multinational companies, which sell mainframes and their peripherals, had total sales of US$ 1.5 billions.

Nowadays, the informatics national industry comprises 380 companies, employing 50000 people, one third with a university degree (engineers, physicists and mathematicians). The type of equipment produced is: small mainframes, minicomputers, microcomputers, personal computers (PC, XT and AT), accessories and peripherals for this type of equipment, like video monitors, magnetic tape units, printers, computer terminals, plotters, modems and hardware for local networks and communications.

This year, two companies, Proceda and Villares, are marketing workstations with graphics capability. The system SITIM, already in the market, specializes in image processing and was a spin-off from developments undertaken for satellite image processing at INPE (National Institute for Space Research)

Only a few of the Brazilian companies are investing in R&D of hardware and software and have their own research groups for new developments (e.g. ITAUTEC, ITAUCON, SID INFORMATICA, VERTICE, ELEBRA)

More advanced R&D in informatics is mostly undertaken at Universities and Research Institutes. In Campinas, CTI (Technological Center for Informatics) carries out research in semiconductor materials and devices, design of integrated circuits (IC), instrumentation, software and hardware for industrial processes automation and robotics. Another important research institute in this field is INPE which acquired a solid experience in designing and manufacturing IC's. Its initial motivation was to attend the institution internal demand for products with high reliability and rigid specifications, to be installed in equipment developed for space research. Now, the Institute is able to design and produce IC's for industry according to their requirements. It has been designing IC's for industries in the fields of aerospace, military and informatics, and can produce high density double sided IC's with plated through holes. Regarding materials characteristics and processes, specifications and standards, they can achieve the most strict requirements from class 5 of the standards established by US Institute for Interconnecting and Packaging Electronic Circuits.

Several Universities work in projects of IC's. USP is developing IC's for parallel processing and is building prototypes for a minisupercomputer and a supercomputer. The minisuper is in the assembly stage and its UNIX operational system has been already developed. Graphics workstations with 50 MIPS processing capacity have already been developed and the technology is being transferred to industry. A 32 bit microprocessor using LISP is being developed for applications in Artificial Intelligence. Although USP's laboratory for IC's is not at the scale of producing IC's for industry, it uses techniques for wafer processing, like Rapid Thermal Process, Plasma Etching, Low Pressure Chemical Vapor Deposition. A feature size of 1 micron can be achieved. A Laboratory for MBE (Molecular Beam Epitaxy) is being installed which should allow development of more advanced IC's.

At UNICAMP (State University of Campinas) research is being carried out using lasers and wafers made of GaAs and other composite semiconductors. Involved in research with parallel processing are also UFRS, UFRJ (Federal University of Rio de Janeiro) and UFMG. UFRS works already for some time with ion implantation in semiconductor wafers and UFMG has being using MBE.

The development of Brazilian supercomputers may turn out to be of foremost importance. It does not aim to compete with Japan or USA in this market, but to fulfill its internal needs, since US supercomputers are subjected to case-by-case export restrictions [4]

In all newer computer systems, software plays a key role. It is the enabling factor that makes advanced systems feasible. Progress in software is essential in fully exploiting the opportunities offered by parallel systems. It is an important area of computer technology shaping the development of both new hardware and new computer applications.

There are several Brazilian companies working with commercial software, ranging from genetic applications, support to industry to specific software.

Universities are working with more sophisticated software development like operating systems, applications in industry automation, artificial intelligence and CASE – Computer Aided Software Engineering (USP, UFSC, UFRJ, UFMG, PUC/RJ – Catholic University of Rio de Janeiro).

An area where significant industrial investments are planned for next decade is manufacture and industrial process automation. The most important research centers in this area are CTI and Universities (USP, UFSC, UFRJ). These centers are developing hardware and software for automation in order to transfer the know-how to Brazilian industries. They also have training programs for industries technical staff, in order to adapt them to the new technology. Two years ago, USP has introduced an undergraduate course in Mechatronics to provide the labor market with engineers specialized in automation.

An indication for automation potentialities in Brazil industries is provided by the number of sold computer-numerically controlled (CNC) machines, which presented a five fold increase in the last five years. The number of CNC's acquired by industries in the last 5 years amounts to 4600 units and the market shows a tendency for faster increasing.

A recent study carried out by the Science and Technology Secretariat shows a high demand for automation technologies in Brazilian industries. As an example, pulp and paper industries plan to invest US$ 3 billions, in the next five years, to expand and modernize their plants. About 10% of the investment will be in hardware for process automation.

The petrochemical industry is already investing in automation. In 1988 its expenditure reached US$ 212 millions and there is a planned investment of about US$ 300 millions per year, during next decade, to achieve the planned degree of automation. Textile industry plans to invest US$ 4.2 billions during next decade to improve productivity. From this total, US$ 0.5 billions are for automation equipment.

There is a lot of room for automation in several other areas: automotive industry, sugar and alcohol industries, etc. The above examples show that our industry intends to move to computer integrated manufacturing (CIM) and computer integrated processing (CIP). These technologies encompass hardware, software and systems that support the design and manufacture of mechanical devices and control/monitor processes.

Brazilian industries have already capability for producing part of the required equipment needed for automation, but they cannot attend the total demand. About 50% of the investments in industry automation will probably be spent abroad.

Apart from research in electronics related to informatics and devices to be used in automation, the only other area where there is significative R&D effort in electronics is for telecommunication devices. There is no R&D in the country for electronics of high consumption and domestic use (e.g. TV's, videos, domestic appliances). This market is dominated by multinational companies which have their factories in the country. It is a significative market (e.g. 2.5 millions of color TV's were marketed in 1988.

In the area of telecommunications, Brazil has a modern and efficient system comparable to those existing in developed countries. EMBRATEL, a state company, is responsible for communications via satellites and the support system for digital data communications. Each state has a telephone company in charge of the local communication network.

Equipment for telecommunications is mostly produced in the country by multinational companies, some of which in association with national industries.

The most active research centers are CPQd – Telebras (Telebras R&D Centre) and INPE. The first is concerned with the development of components for telephone exchange, microware transmission and reception, including optical fiber technology. Its objective is technology transfer to industry. INPE develops systems for satellites dedicated to remote sensing.

In Universities research is centered in the development of IC's, using GaAs and other composite semiconductors and microlithography, to speed up signal transmission (UNICAMP, USP), laser diodes and photo detectors (PUC/RJ) and electro-optics (UNICAMP, UFRJ, PUC/RJ). R&D in industry is centered in the area of military applications (ENGESA, AVIBRAS, ORBITA) like guidance of smart weapons, radar systems, etc.

V - Space research and space industry

Space activities in Brazil are coordinated by COBAE (Brazilian Committee for Space Activities). The main civilian organization devoted to space research activities is INPE. Its activities, which cover only peaceful uses of outer space, are in the following areas:

Space and Atmospheric Sciences

Remote Sensing

Space Engineering and Technology

There are 1600people working at INPE, from which 900 has a University degree (150 PhD's and 190 MSc's) and 700 are administrative and technical support staff.

INPE develops scientific payloads for stratospheric balloons and sounding rockets. Its Launching Centre can launch balloons with 1.5 tons up to a height of 40 Km, where they can stay for more than 10 hours. Scientific experiments are also carried out using instruments on satellites through international cooperation. The Institute also carries out experiments on the ionosphere, having also an observatory for studies of atmospheric luminescence, geomagnetic stations, a radio observatory, a radar laser and stations for measurements of atmospheric ozone and radon. Their research in aeronomy couples measurements obtained using ground equipment and data obtained with balloons and sounding rockets.

Research is also carried out in fields of high energy astrophysics, using X-rays and gamma rays measurements. Quasars are studied using VLBI (Very Long Base Interferometry). Solar Physics and Radioastronomy are also studied at INPE, with strong cooperation with other international laboratories. There are several other universities with research groups in astrophysics, cosmology and nucleosynthesis, but these activities will not be discussed since these academic groups have little influence upon space industry.

One year after the launching of the first remote sensing satellite (Landsat) INPE installed a network for tracking the satellite, coupled with a system for reception, data processing and image generation.

INPE's remote sensing program uses satellite data as well as data obtained by sensors installed in airplanes and balloons. Its network for satellite imaging covers the whole country and a major portion of South America. It also receives images from the French satellite SPOT.

INPE's activities in remote sensing cover agriculture, forestry, geology, environmental analysis, cartography and basic research on image processing and remote sensing. Because of increasing demand on applications of image processing, from the academic community and private sector, the Institute is establishing joint programs with Universities, providing equipment and personal training.

INPE is also the country's most advanced institution in meteorology, housing the CPTEC (National Centre for Weather Forecast and Climatology). Its research covers interpretation of satellite data, synoptic meteorology, climate modeling, micrometeorology, dynamical and physical oceanography.

In the nineties INPE will launch for satellites. The first two will be used for meteorological data and scientific measurements and the others for remote sensing in the optical region with 200 meters resolution. The launcher for these satellites will be built by

CTA (Aeronautics Technological Centre). The whole system, apart from the launcher, was designed by INPE and parts are being built by industry.

Two other satellites for monitoring natural resources, with 20 meters spatial resolution will be built and launched in a cooperative program with China, using Chinese launchers. INPE is in charge of the satellite structure, energy system, on board computer, communications, sensors and tests, control and tracking.

The Brazilian program is space technology aims to attain autonomy for future space activities. INPE is transferring the technological developments to industry, which is already involved in the satellites projects and associate equipment, like tracking stations, communications, and data processing.

There is also on going research for space stations and platforms, propelling systems (liquid, ionic), microwave powerful generators, materials for space vehicles, atmospheric re-entry and the necessary sensing and communication devices.

CTA is a Centre from the Ministry of Aeronautics. One of its research areas is the development of rockets (sounding, launching) and other developments of space vehicles.

EMBRAER which is now an important airplane manufacturer (Brasilia airplane, AMX fighter) producing also materials and structure foe space applications, is an example of technology transfer from CTA to industry.

CTA and INPE are both located in São José dos Campos city, in the river Paraíba valley (São Paulo State). In this valley, several high tech industries are also located, working with technologies developed at both institutions. Their activities range from military equipment (e.g. missile) to other applications like avionics, radars, controls, guidance devices, communication devices, special materials and structures, automation for space vehicles, radio-meteorology and image processing equipment.

Government contracts are still their main financial resource, but there is already a significant number of civil clients in the areas of telecommunications, image processing and aeronautics.

Conclusions

In the areas discussed, the available R&D capabilities, both in human resources and research facilities, present the possibility of quickly overcoming the existing gap between their developmental stage and the state of the art in most developed countries. To achieve this goal, it is necessary to increase significantly investments in R&D, including a higher participation of the productive sector in funding. Recently Prof. D. Zagottis from USP, who is presently the President's Special Secretary for Science and Technology, has proposed a governmental policy for special tax advantages to stimulate industrial investments in R&D.

Several success cases of technology transfer to industry indicate that strengthening of university-industry relationship will play an important role in future scientific and technological developments.

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He has published many technical papers on nuclear physics and energy in general, four physics textbooks, five books on energy and numerous articles in newspapers related to science, technology and energy problems.

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