The Turing-850 Project: Developing a Personal Computer in the Early 1980s in Mexico

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***Abstract*— The increasing popularity in the late 1970s of affordable, general-purpose, microprocessor-based personal computers in the US, generated a widespread interest around the world in this technology. During the 1980s, several developed countries attempted to create indigenous personal computer industries, achieving different degrees of success. However, little is known about similar efforts carried out by developing countries during the same period. The main purpose of this paper is to describe a general-purpose personal computer touted as *Turing-850* designed and built in Mexico in the early 1980s and give a detailed account of the historical context within which this machine was conceived. For comparison purposes we briefly describe some other similar computers designed outside the USA during that time. Turing-850 and other Mexican computers developed in the early 1980s showed that Mexico had the technological capabilities to initiate the development of a national computer industry. However, diverse factors prevented this from happening.**

I. Introduction

On June 8th, 1958 the National Autonomous University of Mexico (UNAM after its name in Spanish) bought what appears to be the first computer ever to operate in Mexico [1] (or anywhere else in Latin America for that matter): an IBM-650. To have a proper home for the IBM-650, UNAM's authorities decided to create the *Electronics Computer Center* (CCE), which was located in the heart of its main campus.[1] Soon after its creation, the CCE began disseminating knowledge of the applications for the novel computer technology. For example, an annual workshop under the name "Computers and their Applications" was created. Remarkably, the third edition of the Conference, held in 1961, featured MIT professors John McCarthy, Marvin L. Minsky and Harold V. McIntosh as the keynote speakers [2].

In 1963-1964, an analog computer called *UNIKORNIO* was built at UNAM; the first of its type in Mexico. Shortly after, Dr. Manny Lemman helped UNAM to construct, as an experiment, the digital computer called *MAYA*, based on the design of the Sabre computer at the University of Israel [1].

[1]UNAM's central university city campus known as "C.U.", was officially inaugurated in 1954. On July 2nd, 2007, "C.U." was included in the UNESCO World Heritage list.

Educational programs in computer science and engineering were offered by Mexican universities a few years later. The first Mexican bachelor program in computer engineering was offered as far back as 1965 by the National Polytechnic Institute (IPN) [3], [4] and was soon followed by a few other universities.

In 1970, the Mexican government created the National Council for Science and Technology (CONACyT), the institution responsible for the policies and investment in science and technology. The initial research grants awarded by CONACyT were basically used to support the expansion of higher education in Mexico. As a result, a small community of researchers and scientists was created in the country [5].

By late 1970s active research and development in computer systems was being conducted in a handful of Mexican universities such as UNAM, IPN and the Benemérita Universidad Autónoma de Puebla (BUAP).[2] These efforts, however, were carried out in a rather isolated fashion, without an articulated national strategy [5], [6]. This situation was symptomatic in a country like Mexico, where the investment made by the government in science and technology was well below the international standards of the era [7]. Furthermore, private funding for research and development was very scarce; most Mexican-owned companies were importing all the technology they needed. Lastly, cooperation between industry and academia was practically non-existent [5], [8], [9].

In an effort to create an indigenous information technology industry, the Mexican government decided to launch a *greenhouse* strategy. To this end, on August 1981 the "Promotion Plan for the Electronics and Computing Industry" (PFIEC after its name in Spanish) was announced.[3] The general goal of the PFIEC was to develop a national computer and electronics industry that could help the country reaching a level of autonomy in information technologies [10]. Information technologies were regarded as strategic towards reducing the tremendous technological dependence from abroad. In the specific case of computers, PFIEC imposed the restriction

[2]Formerly called: "Universidad Autónoma de Puebla", (UAP), its name was changed on April first, 1987 to "Benemérita Universidad Autónoma de Puebla", (BUAP).

[3]Plan de Fomento a la Industria Electrónica y de Cómputo, in spanish.

that every computer sold in the country should have a high percentage of components made in Mexico. Later on, this policy was changed to allow companies importing all computer components they wanted under the condition that these companies had at least 51% of Mexican capital. Likewise, the PFIEC mandated multinational companies to invest between 3% and 6% of their gross sales in R&D, as well as to include a fraction of Mexican manufactured components in their systems [2], [7], [10]–[13].

Nevertheless, soon after the announcement of the PFIEC a major Mexican financial crisis was unleashed, causing profound consequences in the economy of the country across the 1980s. ¿From 1981 to 1989, in a high inflation scenario, the Mexican peso exchange rate against the US dollar went from an average of 24.5 pesos per dollar to an average of 2461 pesos per dollar [14].

A second factor that also affected negatively the nationalistic policies promoted by the PFIEC was the introduction of the IBM-PC and its open architecture. This situation ignited the standardization of microcomputers around the IBM architecture, leaving little room for other design alternatives [12].

As a consequence of the aforementioned factors, the Mexican government changed its greenhouse policy and promoted liberalization instead. This shift in strategy occurred in 1985, when IBM asked for permission to produce PCs in Mexico. After a lengthy negotiation, the permission was finally granted in 1987. The PFIEC was finally abandoned in 1990. That year, the only Mexican market protection that was still in place was a 20% tax in hardware, that fell to 12% by 1994 and was definitely removed in 1998 in the context of NAFTA treaty [12].

A direct effect of the Mexican financial crisis in the 1980s decade was that the few scientists the country had been able to foster started to emigrate. As a result, only a few small groups within academia had enough funding and human resources to continue developing technology [1]. One of those academic groups, an engineering team working at BUAP, undertook the project of designing and building a personal computer system touted as the *Turing-850*. The aim was to create state-of-art indigenous computer technology that could be readily manufactured by the national industry. The project attempted to create a cooperation channel with Mexican-owned companies by transferring the technology to interested parties.

The Turing-850 became, to the best of the authors' knowledge, the first general-purpose, personal computer system entirely designed in Mexico. This paper provides a detailed account of such project and gives some insights into the issues commonly confronted by researchers from a developing country in carrying out technological projects. As part of the historical framework within which the Turing-850 was conceived, we briefly describe other similar computers designed in Mexico and outside the USA during the same period.

The rest of this paper is organized as follows. Section II gives a recount of the Turing-850 project antecedents and provides details on its design and development. Section III briefly describes other similar computer systems that were developed in Mexico and abroad, contrasting them with the Turing-850. Finally, in section IV, some concluding remarks are drawn.

II. The Turing-85 Project

A. Antecedents

In 1980, NCR[4] created a Research and Development department (R&D)[5] at its Puebla manufacturing plant. The goal there was to further the development of the NCR-2140, one of NCR's most popular cash registers at that time. The R&D department was headed by Luis Medina-Vaillard, a Mexican researcher who graduated from California Institute of Technology in USA. Nine Mexican engineers - all of them recent graduates from Mexican universities - were hired by NCR to join its new R&D department. Their first project was to adapt the NCR-2140's hardware and software to control fuel supplies at gas pumping stations. However, just before reaching the first year of operation, the entire R&D department was shut down due to NCR's financial problems.

Luis Rivera-Terrazas, one of the pioneers of modern astronomy in Mexico [15] and President of BUAP from 1975 to 1981, was a committed scientist who understood the importance of computers not only in science and education but also as an effective means of improving the social development of the country. He was a supporter of the consolidation of Mexican science and technology in order to achieve a technological independence from abroad.[6] When NCR closed its R&D operation, Rivera-Terrazas personally offered the entire R&D team to join the Department of Microcomputer Applications at the BUAP (DMA-BUAP).

Shortly after, six members of the original NCR's R&D team submitted the *Turing-85* project to Rivera-Terrazas, who committed BUAP's resources to finance the initial phase of that project, and promised to look for the extra funds necessary to support it, thereafter. The main goals of the Turing 85 project were: 1) to assess the feasibility of creating state-of-the-art computer technology within a Mexican public university; 2) to design a computer system whose technology could be easily transferred to interested Mexican-owned companies for mass production.

Together with Medina-Vaillard (project leader) and the first author of this paper, the other four participants in the Turing-85 project were: Gregorio Arenas-Muñoz, Carlos Blanco-Salinas, Sergio Guevara-Rubalcava, and Francisco Serrano-Osorio.

B. Turing-85 Project Phases

The Turing-85 project's original goal was very ambitious: the design of a 32-bit multi-user minicomputer system. The NS16000 microprocessor, manufactured by National Semiconductors [16], was initially selected as the main processor for this computer. The project contemplated designing most components, from the power supply, motherboard, terminals and I/O interfaces to the operating system and compilers able to support at least two computer languages. To carry out an

[4]NCR stands for the National Cash Register company.

[5]NCR's R&D department in Puebla was one of the first R&D departments ever created by a transnational company within Mexico.

[6]Rivera-Terrazas founded the Department of Semiconductors and the Physics Institute that now carries his name at BUAP.

enterprise of such magnitude, the original project's budget included the hiring of an important number of researchers and engineers from Mexico and abroad. By January 1982 the feasibility study and preliminary specifications of the computer were completed. The detailed specification is contained in [17].

Unfortunately, on February 18, 1982 the Mexican peso was suddenly devalued.[7] That event triggered a financial crisis in the country that virtually canceled the entire original project. Nevertheless, amidst the economic turmoil within Mexico and with a substantially reduced budget, a more modest proposal was promptly specified: the design of a low cost high performance 8-bit personal computer system. Furthermore, due to the limited human resources and budget available, all efforts were concentrated exclusively on designing the hardware. In honor of Alan Turing, the new project was renamed *Turing-85 phase 0* or *Turing-850*. The project was then divided into two phases. In phase 0, an 8-bit machine would be built whereas the target in phase 1 would be the construction of the 32-bit minicomputer system originally planned. In addition, the goal was set to complete the design of the 32-bit machine by the end of 1985, with the hope that by then the Mexican economy would have recovered.

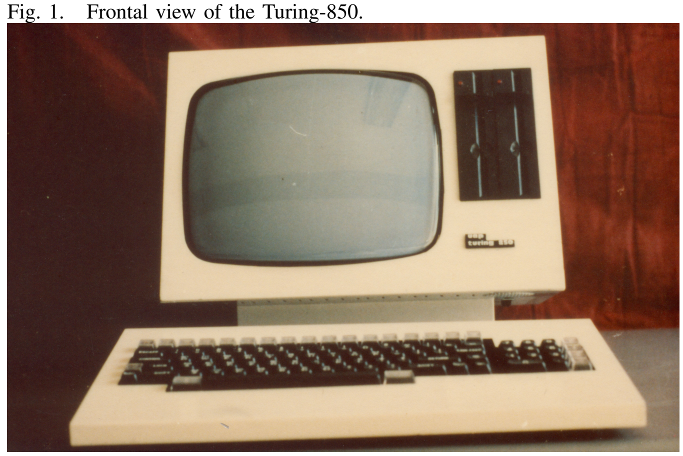
The target market envisioned for the Turing-850 was the Mexican commercial and education sectors. Turing-850's design was conceived to compete in this market with other similar computers of the era in terms of its features, cost and performance. The machine was also planned to fulfill BUAP's needs of computing equipment towards a sustainable self-production of microcomputers.

C. The Development of the Turing-850

Phase 0 of the project started in the spring of 1982, having as one of its goals to deliver a fully-functional 8-bit personal computer system by late 1983.

The restrictions imposed by the government through PFIEC, together with the high retail cost of the original IBM-PC[8] (and other computers manufactured abroad), had created good market opportunities for low cost personal computers fabricated in Mexico. However, to ensure the Turing-850 a share in the incipient Mexican market for personal computers, it was critical to deliver it on time, as the personal computer manufacturing sector in the USA was showing a rapid growth. For this reason, to have a better control of the project, the design team enacted and enforced policies to write, discuss, and get approval for the functional specifications of each subsystem. Design inspections were carried out and periodic individual progress revision evaluations were performed during the entire duration of the project. Additionally, a strict project schedule was set up. However, in spite of applying all these procedures, the project suffered a series of delays caused by internal and external factors.

Fig. 1. Frontal view of the Turing-850.



On the one hand, the local industry had no experience in supporting the development of technological projects. Some reluctant providers were convinced to participate in the project only when it was promised they would supply the components to mass manufacture the computer. Moreover, all imported parts had to be acquired through the appropriate University's channels that, on occasion, were very slow in processing the purchase orders. The continued depreciation of the Mexican peso against the dollar during those years, caused the project to ran out of funds much earlier than was anticipated. The computer could finally be finished only thanks to donations obtained from some of the companies involved and a contribution of BUAP's Semiconductors Department. All these factors caused that a fully-functional prototype of the Turing-850 computer was not delivered until late 1984 [18].

The estimated project budget for the Turing-850 was about \$23,146,000 Mexican Pesos, some \$137,938 US dollars at 1984 exchange rate.[9] Out of this budget, 97% was spent on salaries and the rest on materials and other expenses. The limited budget forced the development team to look carefully at the design options, as there was no room for experimentation.

The original plan designed to advertise the Turing-850 within the national industry, included three configurations as possible selling options to the public. The basic configuration, with 64KB RAM and no floppy disk units had an estimated manufacturing cost of about \$941 US dollars. The typical configuration with one floppy disk unit and the operating system had a cost of about \$1,445 US dollars. Finally, the fully-configured option, which included one extra floppy disk unit and a dot matrix printer, had an estimated cost of about \$2,047 US Dollars at 1985 prices.

Figures 1 and 2 show a frontal and a lateral view, respectively, of the Turing-850.

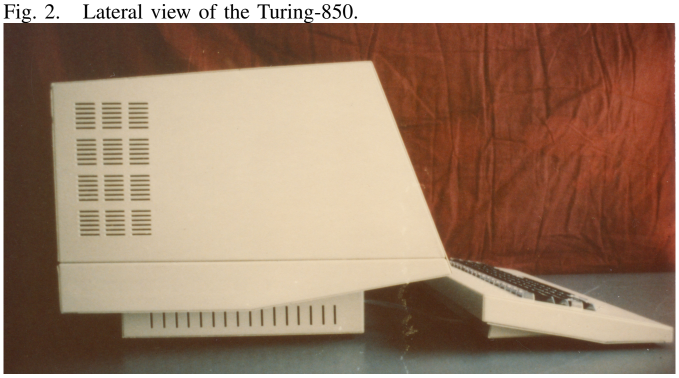
As one of the main goals of the project was to ease the manufacturing of the computer in Mexico, the mechanical and electrical designs had to use components manufactured in the country or otherwise easily obtained from abroad. Some

[7]On February 18, 1982, the Mexican government announced an official devaluation of the Mexican peso from 28.50 to 46 per dollar. The exchange rate of the Mexican currency reached 80 pesos per dollar by the end of that year [14].

[8]The original IBM PC had a retail cost in USA of around \$3,000 USD with 64 KB of RAM and one 5 1/4" floppy disk.

[9]The exchange rate average value for year 1984, was of \$167.8 Mexican pesos for \$1 US dollar [14].

Fig. 2. Lateral view of the Turing-850.



essential components such as the keyboard and the floppy disk units that represented a large percentage of the total system cost had to be imported. To complicate things even further, due to the financial crisis, special import permits, only allowed for academic institutions and a few public and private companies, had to be obtained from the government.

Turing-850's final design employed approximately 65% of its parts from Mexican providers. This percentage of component integration from national providers was achieved in some cases with significant difficulties. For instance, very few Mexican companies owned the technology to manufacture double-layer printed circuit boards. This technology was largely unknown in Mexico, yet was essential in the design of the complex layout of the Turing 850's motherboard containing two processors. At that time, the Mexican company that manufactured Turing-850's motherboard was still testing and adjusting its manufacturing process to produce double-layer printed circuit boards. This situation provoked numerous errors in the first versions of the motherboard that were difficult to find and fix.

Turing-850's design featured a high performance architecture based on a dual processor organization, and a light pen input system that enabled free drawing on the computer screen. Other more standard features of Turing-850 were: a dual 5 1/4" floppy system; one parallel port based on the Centronics standard and one RS-232C serial port. The Turing-850 also included support in hardware and software to connect a hard disk drive compatible with the Winchester technology.

CP/M was the only operating system that was widely available in Mexico at that time. For this reason, the Z80 microprocessor manufactured by Zilog Inc., was chosen for Turing-850's design, not only because of its compatibility with CP/M, but also for its low cost and wide availability within Mexico.

Turing-850s design was organized into six main modules: the software (mainly the BIOS), motherboard, motherboard's printed circuit layout, case, power supply, and the video monitor. The design of each module was assigned to a single developer. However, the design options proposed by the responsible of a module were discussed within the team, generally reaching consensus on the diverse design alternatives selected. This practice had the beneficial effect of making all participants knowledgeable of and committed to the project.

The following subsections briefly describe the main modules of the Turing-850's design.

D. The Turing-850's Motherboard and BIOS

Turing-850's architecture contained two Z-80 processors interconnected in a master-slave fashion. The goal of this architecture was to create a high performance computer by splitting the I/O tasks and statically assigning them to each processor. Additionally, as networks of personal computers were becoming more popular, it was planned to use the slave processor for managing the network functions in future models of the computer. An evaluation of the tradeoff between cost, performance and ease of design convinced the design team that this architecture was the most effective option, given the relatively low cost of the processors employed. However, the dual-processor architecture required a more complex motherboard's layout that was a particularly laborious manual work, as there were no automated tools available for the task.

Turing-850's master or *central processor* (CP) was a high-speed 6 MHz Z80B microprocessor. This processor was assigned to execute the operating system, user programs and the hard/floppy disk drives. A Direct Memory Access (DMA) channel was also included in the design to enable mass storage devices direct access to memory without requiring the intervention of the processor. The main memory system designed for the *central processor* consisted of 64KB of DRAM.

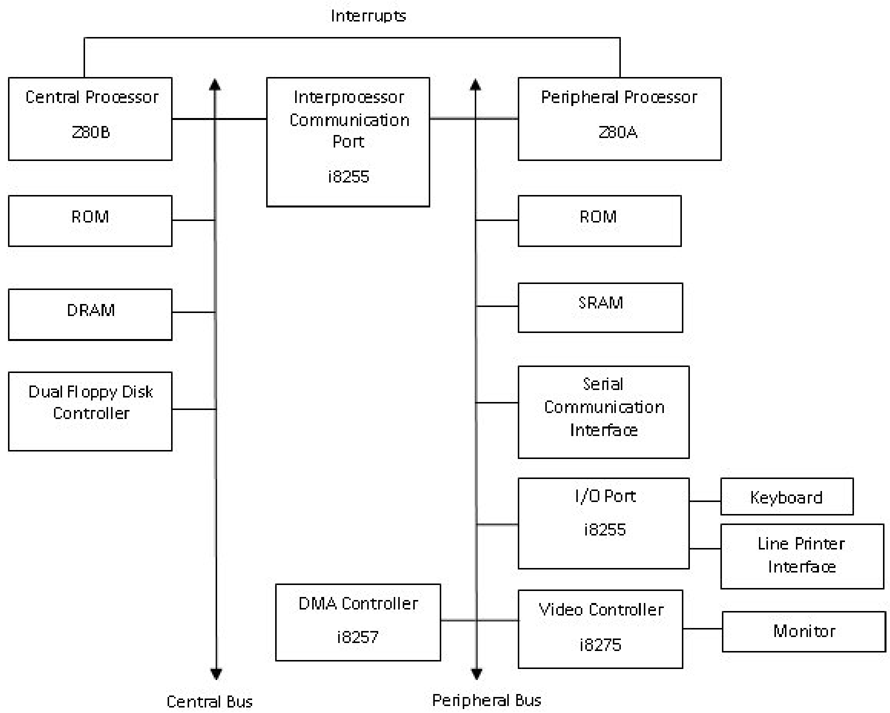
A slower slave Z80A processor running at 4 MHz managed the rest of the I/O devices. This processor, called the *peripheral processor* (PP), was also used to control the serial and parallel I/O ports and the computer terminal [18].

The communication between the *central* and the *peripheral processors* was implemented with a special parallel inter-processor communication port that enabled the processors to exchange data and control signals. The coordination of the two processors was established through a handshaking protocol. The *central processor* fetched a program's instruction stream from memory and determined which operations would be either executed locally or sent directly to the *peripheral processor*. All operations corresponding to the serial/parallel port or the video terminal were sent to the *peripheral processor* by writing the request into the intercommunication port, an event that simultaneously generated an interrupt signal to the *peripheral processor*. In turn, the *peripheral processor* received the interrupt, performed the indicated I/O operation and once it was completed, generated a new interrupt signal back to the *central processor* by writing the result into the inter-processor communication port. The *peripheral processor* employed 24 KB of static RAM to store its internal data.

Figure 3 shows a block diagram of the main components in Turing-850's architecture. The diagram depicts on top the i8255 used as the parallel interprocessor communication port between the *central* and the *peripheral* processors.

The Turing-850's design enabled the possible connection of extra peripheral devices through the *peripheral processor* bus in the motherboard. The bus was made accessible by using a special external connector designed for that purpose. Finally,

Fig. 3. A block diagram of Turing-850's architecture.

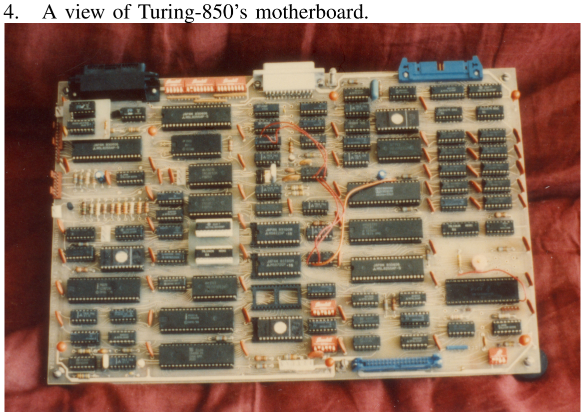


the parallel and serial port designs were compatible with the Centronics and RS-232 standards.

It must be remarked that the Rainbow 100+ personal computer [19] from Digital Equipment Corporation had a similar architecture to the Turing-850, with two processors interconnected in master-slave fashion. The main differences were that the Rainbow 100+ model employed a Z80 processor together with an Intel 8088. This architecture allowed the computer to execute either an enhanced version of MS-DOS or CPM-86/80. Additionally, interprocessor communication in the Rainbow computer was implemented through shared memory using an arbitration mechanism in hardware. A detailed description of the Rainbow 100+ model was published in 1984 [19].

A view of Turing-850's motherboard containing the two processors and the rest of the circuitry is shown in Figure 4.

Fig. 4. A view of Turing-850's motherboard.



The firmware written for the Turing-850 consisted of an interface layer in the BIOS that enabled the Turing-850 to boot and execute CP/M OS with all the user applications. Additionally, diagnostics routines were written to test the memory and I/O system during initialization. As no microprocessor development system was available, a special monitor program was written to facilitate program debugging. The BIOS was written directly in the assembly language of the Z80.

E. The Computer Monitor, Power Supply and Case

Designing the monitor for the Turing-850 represented a challenge because there were no specialized companies capable of manufacturing computer monitors in the country. Therefore, the most viable option was to employ a monochromatic CRT fabricated by one of the local manufacturing companies of TV sets such as Admiral or RCA. However, to control the CRT, special amplifiers had to be designed to fulfill the more demanding specifications, in terms of bandwidth, of a computer terminal compared to the ones required by TV sets. Designing the control circuitry for the CRT took a considerable amount of time given the non-linear characteristics of the system.

During the early 1980s fluctuations in the voltage supplied by the Mexican national power company occurred frequently in many regions of the country. These large variations made necessary the usage of costly external AC voltage regulators to protect all the electronic equipment. To cope with this situation, it was decided to design a special power supply that did not require any external protection equipment. At that time, the technology of switching-mode power supplies was relatively recent. Furthermore, since the local industry lacked the technology needed for manufacturing specialized high frequency magnetic components, designing a switching-mode power supply was not a feasible option. Instead, Turing-850's power supply design employed a conventional linear voltage regulator with a special feedback circuit connected from the secondary to the primary winding of the transformer through opto-couplers [20]. The switching feedback circuit controlled the power supplied to the voltage regulator in the secondary winding of the transformer with a thyristor placed in the AC input line. The power supply design for the Turing-850 was capable of tolerating variations of $\pm 25\%$ in voltage (90-150 VAC) operating at $45\,^{\circ}\mathrm{C}$ without requiring any external voltage regulator.

The mechanical design of the case for the Turing-850 was inspired by some of the computer terminals manufactured by NCR at the time. The design included some of the ergonomic recommendations for computer equipment from the international standards organization (ISO). A thermodynamic analysis of Turing-850's case interior was performed to identify the optimal number and location of the ventilation holes. As a result, an aesthetic slim case was produced containing all the components, except the keyboard. The case was fabricated locally from metallic sheets since it was difficult to design and assemble at a reasonable cost, the mold required for a lighter plastic case. Several prototypes of the case were constructed in wood and metal sheets in order to test the physical layout of all the boards and the monitor.

III. Similar Computers of the Era

In this section, we briefly describe and compare some other computer systems designed and built outside the USA during the early 1980s, that had similar capabilities as those of the Turing-850. We do not intended to provide an exhaustive list of all the computers that were similar to the Turing-850, but rather to illustrate with a few examples their similarities and differences.

A. Some Other Mexican Computers

Arguably the earliest digital computer ever designed in Mexico was the Heterarchical (AHR)[10] parallel-processing machine, which was built at UNAM in 1979-1983 [21]–[25]. The AHR was a special-purpose computer designed for executing LISP natively. The AHR employed a front-end minicomputer, where users could edit and debug the LISP programs while they were being executed by the AHR back-end in parallel. The computer was capable of hosting from 5 to 64 Z-80 microprocessor chips.

The Micro-SEP 1600 computer was designed around 1985 by the Mexican Ministry of Public Education (SEP). This microcomputer was a slightly modified re-design of the Radio Shack TRS-80 color computer containing a Motorola MC6809E microprocessor [8]. Micro-SEP's main purpose was to supply a low-cost computer to public junior-high schools.

[10]The term *Heterarchical* was introduced by the authors of this computer to indicate that all processors in the architecture were organized in a horizontal fashion as opposed to a hierarchical arrangement.

The DMA-BUAP, headed by Harold V. McIntosh [3] was one of the pioneer Mexican centers in the development of computer systems based on microprocessors. At the DMA-BUAP several microprocessor-based computers were designed and built. For example, a multi-user system called SMU based on a S-100 bus design was fully-functional since 1979 until the late 1980s [26]. This system was able to serve up to ten dumb terminals connected to the S-100 bus. Another noticeable example was the CP-UAP, designed with a NEC-V20 microprocessor on a STD-bus [3], [27]. These microcomputer systems were built with two main goals in mind. On the one hand, it was desirable to have a practical platform for executing and hosting the compilers for *REC* and *Convert*, two programming languages based on regular expressions and pattern-matching, respectively, which were designed by DMA-BUAP researchers [3], [28]. On the other hand, these computers were used as tools for teaching programming skills to computer science and engineering students. Given the limited human resources available, the efforts of all these projects were concentrated exclusively on designing the motherboards, whereas the rest of components was imported.

In IPN's "Centro de Investigación Tecnológica en Computación", (CINTEC after its name in Spanish), the first prototype of the computer Almita II was completed on August 1984. The chief designer of Almita II was the Mexican engineer Miguel Lindig-Bos. In its first version, Almita II had 256 KB of RAM memory, two 360KB floppy disk units and an intelligent terminal powered by an Intel 8031 processor. The main processor was a state-of-the-art 16-bit Intel 80186 running at 8 MHz. Reportedly, the processing speed of this microcomputer was 3.4 higher than that of the original IBM-PC [29], [30]. The first prototype of Almita II was a proof of concept, it did not include a case and all boards were assembled using the wire-wrap technique [31].

It was only until July, 1986 that Lindig-Bos managed to receive from the IPN authorities the required budget for building 10 microcomputers. This task was successfully completed in April, 1987 [32]. By that time, the design of those 10 microcomputers had some differences with the original Almita II, being the most important one that the main microprocessor utilized was the INTEL 80188. Partially because of this change, the new design was touted as "IPN E-16" [30]. Furthermore, the IPN authorities launched a mass production program of the IPN E-16 aiming at reaching a sustainable self-production of microcomputers. As of the end of 1993, a total of 1189 IPN E-16 computers and its descendants were operating in most IPN Faculties [33]. The model IPN E-16 is a rare case of relative success in the history of Mexican computers.

It is important to mention that there were a few other computer design efforts going on in Mexico during the 1980s decade. For instance the *Centro de Investigación y Desarrollo de Tecnología Digital*, (CITEDI-IPN), developed in 1984 a multiuser system (up to three users) based on the Z80 processor and a proprietary operating system [31]. Another example was the digital computer "IMPetrón", designed by a team of four engineers in the Mexican Institute of Petroleum (IMP after its name in Spanish). IMPetrón was an 8-bit micro-

TABLE I

COMPARISON OF TURING-850 WITH OTHER SIMILAR COMPUTERS. N/A = DATA NOT AVAILABLE

	Turing-850	**IPN E-16**	**Amstrad PCW 8256**	**Cobra-210**
Operating System	CP/M	MS-DOS	CP/M	Proprietary, compatible CP/M
Main μprocessor	Z-80 @ 6 MHz 64 KB RAM & 8 KB ROM	80188 @ 8 MHz 256KB RAM	Z-80 @ 4 MHz 64-128 KB RAM	Z-80B @ 5.85 MHz 64 KB RAM
Peripheral μprocessor	Z-80B @ 4 MHz 28 KB RAM & 4-8KB ROM DMA channel, Intel 8257	No secondary processor	No secondary processor	An optional floating point processor DMA channel, Intel 8257
Monitor Floppy Disk	B/W, 24 $\times$ 80, 12" two 5 $\frac{1}{4}$-inch units	color (RGB), 640 $\times$ 400, 12" two 5 $\frac{1}{4}$-inch units	Monochromatic Green 32 $\times$ 90, 12" two 3-inch unit	Monochromatic Green 27 $\times$ 80, 12" two 8-inch unit
Serial Port	RS232C	RS232C	N/A	RS232C
Parallel Port	Centronics interface	Centronics interface	Proprietary interface	Proprietary interface
Case	metal, single (CPU,video) + keyboard	metal	plastic, single (CPU,video) + keyboard	plastic, CPU,video + keyboard + floppy disks
Year	1984	1987	1985	1983

computer developed around 1985, whose main application was the simulation of digital control designs [34]. Unfortunately, as little documentation is available on these systems we will not discuss them any further.

B. British Computers

The Amstrad PCW 8256 was a personal computer manufactured by the British company Amstrad [35], which started its commercialization in 1985. The Amstrad PCW 8256 model included a high-resolution monochromatic monitor, 3-inch floppy disk drives and a printer controlled through a proprietary protocol. Its design included an 8-bit Z-80 microprocessor running at 4 MHz. The Z-80 was capable of addressing up to 256 KB of memory using a paging technique. The main application of this computer was to use it as a word processor. However, it was also capable of running CP/M and all its applications.

The BBC Micro was a personal computer built by the British company Accorn in 1982 for the BBC of London. It was a low-cost computer design based on an 8-bit 6502 microprocessor manufactured by MOS Technology running at 2 MHz. The most expensive models of the popular BBC Micro (models B and B+) came with 32KB and 64KB of RAM memory and cost £399 (about 764 USD) and £499 (about 953 USD) in 1982 and 1985, respectively. A PAL RF video modulator inside the computer allowed it to use an external TV. A special interface enabled the BBC Micro to connect an external Z80 microprocessor to execute CP/M. The extra processor cost was £894 (about 1,707 USD). The initial objective of the BBC Micro project was to design a computer which could be used for educating people about computer technology. A special TV show from the BBC called "*Making the Most of the Micro*" promoted the use of this computer within the UK [36].

C. Brazilian Computers

In 1974, the Cobra consortium was formed in Brazil. This consortium was a state-owned company formed with the participation of the British company Ferranti and several Brazilian private companies and public universities [37], [38]. Cobra was funded with the purpose of creating a national company capable of designing computer systems equipped with its own technology. In the early 1980s the company produced the Cobra-210, a personal computer system. Cobra-210's design included an 8-bit Z-80B microprocessor running at 5.85 MHz, 64KB of RAM and two floppy disk units [39]. To control peripherals independently of the main processor, Cobra-210's design included an Intel 8257 DMA controller. Moreover, the machine had the optional capability of including a floating point co-processor to speed up the execution of numerical applications. The Cobra-210 was compatible with the previous models of the computer: the Cobra-300 and Cobra-305.

In 1984, the company Microtec Sistemas brought to the Brazilian market a compatible PC-XT [40]. Thanks to a governmental policy of protecting the national IT industry, by 1986, the Brazilian computer industry was able to supply up to 86% of its internal market [41]. However, in the beginning of the 1990s the Brazilian government changed this policy allowing the importation of computers from abroad. This produced a crisis in the national computer industry, forcing it to look into other market segments where it could be more competitive. The Brazilian computer industry decided to reconfigure their new designs to target the commercial bank and services sectors. It is in this market were Brazilian information technology (IT) companies such as Procomp, SID and Itautec have an important share to present date [42].

D. Comparison

The goals and scope of the Turing-850 project had important differences with the other Mexican computers described in Section III-A. As opposed to the Micro-SEP and the special-purpose, research-oriented AHR, the Turing-850 was an entirely new design; it was general purpose and had a hierarchical dual-processor architecture. Furthermore, contrarily to the rest of DMA-BUAP computers, the project included the design of the entire computer system and not just the motherboard. In comparison, the IPN E-16 employed a single more advanced processor, but was delivered almost three years after the Turing-850. Finally, contrarily to most Mexican computers of the era, special care was given in Turing-850's design to ease its manufacturing and operation within Mexico.

Table I shows a feature comparison between the Turing-850, IPN E-16, the Amstrand PCW 8256, and the Cobra-210.

The Turing-850 and IPN E-16 were developed within academia by a small group of developers with little previous experience in computer design. In contrast, the Amstrand PCW and Cobra-210 were produced by companies with ample experience in computer design. In spite of those limitations,

Table I shows that the Turing-850 was a competitive machine when compared to similar computers of the era.

IV. Conclusions

The Turing-850 was a personal computer system especially designed to be manufactured in Mexico at low cost. To achieve this goal Turing-850's design employed approximately 65% of its components from local providers. The project was inscribed into the nationalist efforts made at that time to create indigenous technology aimed at eventually reaching the technological independence of the country.

Turing-850 and other similar Mexican computers showed that in spite of the limitations faced and the adverse economic conditions prevailing in the country at that time, it was feasible to develop state-of-art technology for personal computers within academia.

After the project was finished, the Turing-850 computer was demonstrated in diverse academic and industrial meetings. Specifically, the project was presented at CONACyT, UNAM, IPN, University of Las Americas and "Arturo Rosenblueth" Foundation [43]. After a CONACyT's initiative, the Turing-850 system was also exhibited in some important industrial expositions. It is worth to mention that CONACyT at the time had created a special fund called "Trust Fund for Shared Risk"[11] with the goal of fostering the cooperation between academy and industry in projects of high technology. Under this scheme, CONACyT provided half of the investment needed to produce the technology developed within academia. In spite of the advantages offered by such initiative, the restrictions imposed by PFIEC to promote the creation of a national computer industry, and all the efforts made to publicize the project, no Mexican company showed interest in producing the Turing-850 nor any other computer designed by Mexican researchers. In late 1985, the next stage of the project, consisting in the design of a 32-bit minicomputer, was definitively canceled and the original design team disbanded. A few years later, some members of the original Turing-850's design team formed a start-up company to design and manufacture electronic devices. The rest pursued academic careers in Mexico and abroad.

The Turing-850 project failed to reach the goal of transferring its technology to a Mexican-owned company for its widespread production. Furthermore, the design of a more ambitious 32 bit computer was canceled prematurely. The causes for the failure were of a diverse nature.

Firstly, the economic and political conditions prevailing in the country when the project was initiated changed drastically during its development. The Mexican government shifted its original policy from a greenhouse scheme to promoting liberalization in the computer sector. Furthermore, government policies on technology failed to establish clear goals and coordination mechanisms at the time when the development of computer technology required of more sophisticated capacities and links between industries, government and universities. Another factor was the lack of development of the few Mexican companies that were manufacturing personal computers at that time. Instead of using the protective mechanisms implemented by the government to develop its own technology or seeking the collaboration of the few research centers existing in the country, those companies decided to acquire the technology from abroad. A representative example of this trend was the Mexican firm *Printaform*. This company acquired the rights from Columbia Data Systems in USA to manufacture and sell, with some success, the personal computer *Columbia Printaform*, which was very similar to the original IBM PC-XT.

Finally, the appearance of the IBM PC-AT in August 1984, together with the success of MS-DOS and the IBM PC-compatible computers, made CP/M-based computers such as the Turing-850 obsolete very quickly.

In contrast with the Mexican case, during the 1980s Brazil, and other countries such as the so called *"Four Asian Tigers"* (Hong Kong, Singapore, South Korea, and Taiwan), were investing heavily in technological development. The case of Brazil is especially significant as it shares with Mexico a similar level of economic and industrial development.

It can be claimed that Brazil achieved a relative success in creating an important computer industry capable of producing its own technology. The success was partially due to the protective mechanisms implemented by the Brazilian government at the right time. This, combined with a crucial support since the early 1970s of both public and private sectors, fostered the development of the computer sector. However, in the Mexican case similar protective mechanisms did not work in the same way as they did in Brazil. A possible explanation for this is that, contrarily to Mexico, the Brazilian banking sector supported the creation of a national computer industry as they foresaw the importance of computers to their business market. Finally, in Brazil multi-national companies were convinced to participate in joint ventures with state-owned companies [12], [38], [44].

Turing-850 and other Mexican computers developed in the early 1980s showed that Mexico had the technological capabilities to initiate the development of a national computer industry. Unfortunately, the financial crisis of the 1980s, together with some of the factors previously mentioned prevented this from happening.

[11] Called "Fideicomiso de Riesgo Compartido" in Spanish.

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