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

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In response to the increasing popularity in the late 1970s of affordable, general-purpose, microprocessor-based personal computers in the US, several countries attempted to create indigenous personal computer industries. The Turing-850, a general-purpose PC designed and built in Mexico in the early 1980s, shows that Mexico had the technological capabilities to develop its own such industry, but diverse factors prevented its creation.

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On 8 June 1958, the National Autonomous University of Mexico (UNAM) bought what appears to be the first computer ever to operate in Mexico (or anywhere else in Latin America)—an IBM 650.<sup>1</sup> To have a proper home for the IBM 650, UNAM's authorities created the Electronics Computer Center (CCE), located in the heart of its main campus.<sup>2</sup> Soon after its creation, the CCE began disseminating knowledge about applications for this novel computer technology, including an annual workshop under the name "Computers and Their Applications." Remarkably, the third conference in the series, held in 1961, featured MIT professors John McCarthy, Marvin L. Minsky, and Harold V. McIntosh as the keynote speakers.<sup>3</sup>

In 1963 and 1964, an analog computer called UNIKORNIO was built at UNAM, the first of its type in Mexico. Shortly after as an experiment, Manny Lemman helped UNAM construct the digital computer MAYA, based on the design of the Sabre computer at the University of Israel.<sup>1</sup>

A few years later, Mexican universities began offering educational programs in computer science and engineering. The first Mexican bachelor's program in computer engineering was offered as far back as 1965 by the National Polytechnic Institute (IPN)<sup>4,5</sup> 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 CONACyT awarded were primarily used to help expand higher education in Mexico. As a result, a small community of researchers and scientists was created in the country.<sup>6</sup>

By the 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).<sup>7</sup> These efforts, however, were isolated, without an articulated national strategy.<sup>6,8</sup> This situation was symptomatic in a country like Mexico, where the government's investments in science and technology were well below the era's international standards.<sup>9</sup> Furthermore, private funding for research and development was scarce, and most Mexican-owned companies were importing all the technology they needed. Lastly, cooperation between industry and academia was practically nonexistent.<sup>6,10,11</sup>

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) was announced.<sup>12</sup>

The general goal of the PFIEC was to develop a national computer and electronics industry that could help the country reach a level of autonomy in information technologies.<sup>13</sup> Information technologies were regarded as strategic, helping to reduce the tremendous technological dependence from abroad. In the specific case of computers, PFIEC imposed the restriction 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 to import all computer components they wanted under the condition that these companies had at least 51 percent of Mexican capital. Likewise, the PFIEC mandated multinational companies to invest between 3 and 6 percent of their gross sales in R&D, as well as to include a fraction of Mexican manufactured components in their systems.<sup>3,9,13-16</sup>

Nevertheless, soon after the PFIEC announcement, a major Mexican financial crisis was unleashed, causing profound economic consequences 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 2,461 pesos per dollar.<sup>17</sup>

A second factor that also negatively affected the nationalistic policies promoted by the PFIEC was the introduction of the IBM PC and its open architecture. This event ignited the standardization of microcomputers around the IBM architecture, leaving little room for other design alternatives.<sup>15</sup>

As a consequence of these factors, the Mexican government changed its policy and promoted liberalization instead 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 percent tax on hardware, which fell to 12 percent by 1994 and was definitely removed in 1998 in the context of the North American Free Trade Agreement (NAFTA).<sup>15</sup>

Another consequence of the Mexican financial crisis in the 1980s 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.<sup>1</sup> One of those academic groups, an engineering team working

at BUAP, undertook the project to design and build the Turing-850 personal computer system. The aim was to create state-of-the-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 our knowledge, the first general-purpose, personal computer system entirely designed in Mexico. This article provides a detailed account of the Turing-850 project and gives some insights into the issues commonly confronted by researchers carrying out technological projects in developing countries. 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 US during the same period.

### **Project antecedents**

In 1980, National Cash Register (NCR) created an R&D department at its Puebla manufacturing plant.<sup>18</sup> The goal 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 had graduated from the California Institute of Technology. Nine Mexican engineers—all 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 because of NCR's financial problems.

Luis Rivera-Terrazas, one of the pioneers of modern astronomy in Mexico<sup>19</sup> and president of BUAP from 1975 to 1981, was a committed scientist who understood the importance of computers, both in science and education and as an effective means of improving Mexico's social development. He was a supporter of the consolidation of Mexican science and technology to achieve technological independence from abroad.<sup>20</sup> When NCR closed its R&D operation, Rivera-Terrazas personally offered the entire R&D team a position in 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 project's initial phase and promised to look for the extra funds necessary to support it thereafter. The project's main goals were to assess the feasibility of creating state-of-the-art computer technology within a Mexican public university and to design a computer system using technology that could be easily transferred to interested Mexican-owned companies for mass production.

Together with the project leader Medina-Vaillard, the Turing-85 project participants were Daniel Ortiz-Arroyo (a coauthor on this article), Gregorio Arenas-Muñoz, Carlos Blanco-Salinas, Sergio Guevara-Rubalcava, and Francisco Serrano-Osorio.

### Turing-85 project phases

The Turing-85 project's original goal was ambitious: design a 32-bit multiuser minicomputer system. The NS16000 microprocessor, manufactured by National Semiconductors,<sup>21</sup> was initially selected as the computer's main processor. 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 enterprise of this magnitude, the original project's budget included the hiring of numerous researchers and engineers from Mexico and abroad. The feasibility study and preliminary specifications of the computer were completed by January 1982. (See related work for a detailed specification.<sup>22</sup>)

Unfortunately, the Mexican peso was suddenly devalued on 18 February 1982.<sup>17,23</sup> That event triggered a Mexican financial crisis that virtually canceled the original project. Nevertheless, amid the economic turmoil and with a substantially reduced budget, a more modest proposal was promptly specified: design a low-cost, high-performance 8-bit personal computer system. Furthermore, because of 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 planned to be delivered in two stages. In phase 0, an 8-bit machine would be built; 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 the Mexican economy would have recovered by then.

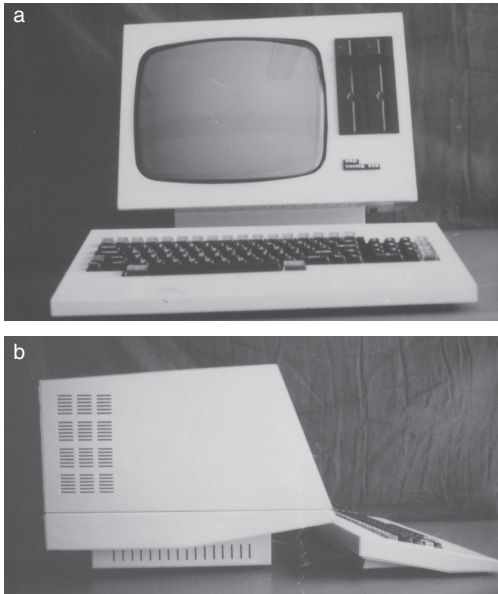
The Mexican commercial and education sectors were the target markets envisioned for the Turing-850. The Turing-850's design was conceived to compete in this market with other similar computers of the era in terms of its features, cost, and performance. The machine was also planned to fulfill BUAP's computing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

### Project development

Phase 0 of the project started in the spring of 1982, with the goal of delivering 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<sup>24</sup> (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 because the personal computer manufacturing sector in the US was growing rapidly. To better maintain 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 for the duration of the project. Additionally, a strict project schedule was set up. However, despite applying all these procedures, the project suffered a series of delays caused by internal and external factors.

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 channels that, on occasion, were slow in processing the purchase orders. The continued depreciation of the Mexican peso against the dollar during those years also caused the project to run out of funds much earlier than anticipated. Ultimately, the computer was only finished thanks to donations obtained from some of



**Figure 1. The Turing-850 (a) frontal and (b) lateral views.**

the companies involved and a contribution of BUAP's Semiconductors Department. Because of these factors, a fully functional Turing-850 computer prototype was not delivered until late 1984.<sup>25</sup>

The estimated project budget for the Turing-850 was approximately \$23,146,000 Mexican pesos—about US\$137,938 at the 1984 exchange rate.<sup>17,26</sup> Out of this budget, 97 percent 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 because 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 64 Kbytes of RAM and no floppy disk units, had an estimated manufacturing cost of approximately US\$941. The typical configuration with one floppy disk unit and the operating system cost approximately US\$1,445. Finally, the fully configured option, which included an extra floppy disk unit and a dot-matrix printer, had an estimated cost of approximately US\$2,047 at 1985 prices.

Figure 1 shows frontal and lateral views of the Turing-850.

Because one of the main project goals 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 essential components such as the keyboard and floppy disk units that represented a large percentage of the total system cost had to be imported. To complicate things even further, because of 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.

In its final design, approximately 65 percent of the Turing-850's parts were from Mexican providers. This percentage of component integration from national providers was achieved in some cases with significant difficulty. For instance, 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 produced numerous errors in the first versions of the motherboard that were difficult to find and fix.

The 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 the Turing-850 were a dual 5-1/4-inch 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 Winchester technology.

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

The Turing-850's design was organized into six main modules: the software (mainly the basic input/output system, or BIOS), motherboard, motherboard's printed circuit layout, case, power supply, and video monitor. The design of each module was assigned to a single developer. However, the team discussed the design options proposed for each module, 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.

### **Turing-850 motherboard and BIOS**

The Turing-850's architecture consisted of two Z80 processors interconnected in a master-slave configuration. 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, because networks of personal computers were becoming more popular, it was planned to use the slave processor to manage the network functions in future models. An evaluation of the trade-off 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. However, the dual-processor architecture required a more complex motherboard layout with a design that required laborious, manual work because there were no automated tools available for the task.

The 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 and user programs and manage the hard/floppy disk drives. The design also included a direct memory access (DMA) channel to enable mass storage devices' direct access to memory without requiring the central processor to intervene. The main memory system designed for the central processor consisted of 64 Kbytes of DRAM.

A slower slave Z80A processor running at 4 MHz managed the rest of the I/O devices. This peripheral processor (PP) was also used to control the serial and parallel I/O ports and the computer terminal.<sup>25</sup>

The communication between the central and peripheral processors was implemented with a special parallel interprocessor 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 PP. All operations corresponding to the serial/parallel port or the video terminal were sent to the PP by writing the request into the intercommunication port, an event that

simultaneously generated an interrupt signal to the PP. In turn, the PP received the interrupt, performed the indicated I/O operation, and once it was completed, generated a new interrupt signal back to the CP by writing the result into the interprocessor communication port. The PP employed 24 Kbytes of static RAM to store its internal data.

Figure 2 shows a block diagram of the main components in the Turing-850's architecture.

The Rainbow 100 personal computer from Digital Equipment had a similar architecture as the Turing-850, with two processors interconnected in master-slave fashion.<sup>27</sup> The main differences were that the Rainbow 100 model employed a Z80 processor together with an Intel 8088. This architecture let the computer execute either an enhanced version of MS-DOS or CPM-86/80. Additionally, contrary to the Turing-850, interprocessor communication in the Rainbow 100 was implemented through shared memory using an arbitration mechanism built into the hardware. (A detailed description of the Rainbow 100 model was published in 1984.<sup>27</sup>)

The Turing-850's design enabled the possible connection of extra peripheral devices through the peripheral bus in the motherboard. The bus was made accessible by using a special external connector designed for that purpose. Finally, the parallel and serial port designs were compatible with the Centronics and RS-232 standards. Figure 3 shows the 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 the CP/M OS with all the user applications. Additionally, diagnostics routines were written to test the memory and I/O system during initialization. Because no microprocessor development system was available, a special monitor program was written to facilitate program debugging. The BIOS was written directly in the Z80 assembly language.

### **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 Mexico at the time. Therefore, the most viable option was to employ a monochromatic CRT fabricated by one of the local TV set manufacturing companies, such as Admiral or RCA.

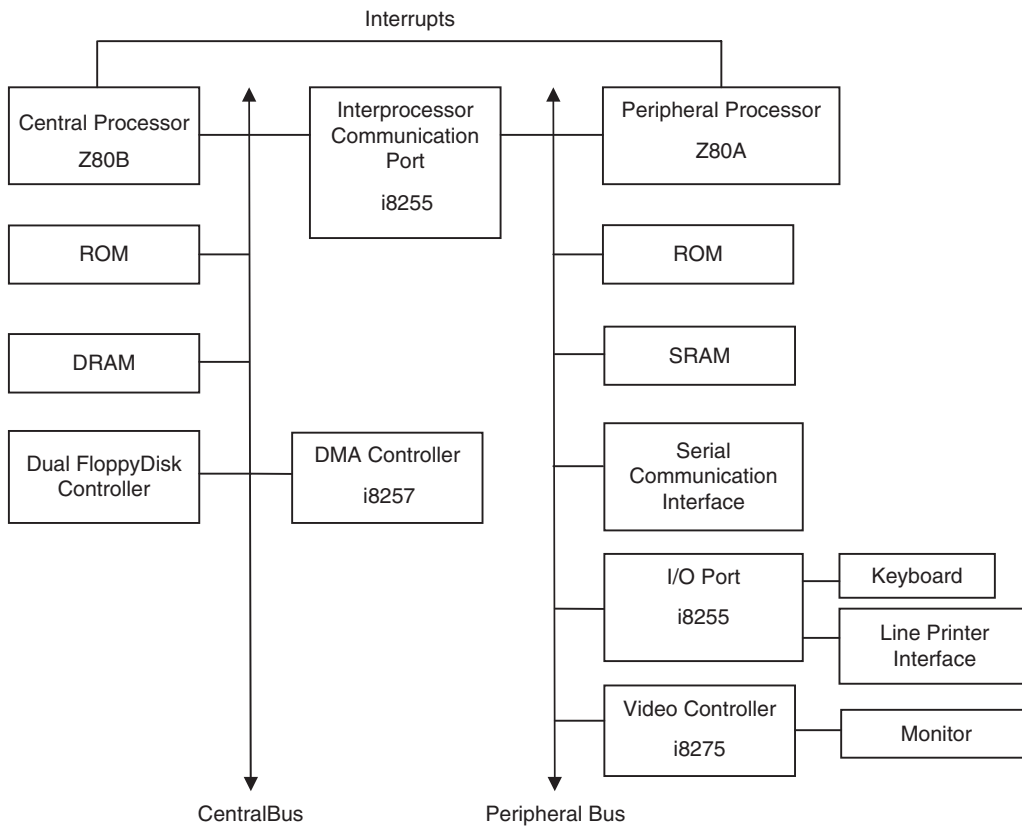


Figure 2. A block diagram of the Turing-850's architecture. On top, the i8255 was used as the parallel interprocessor communication port between the central and peripheral processors.

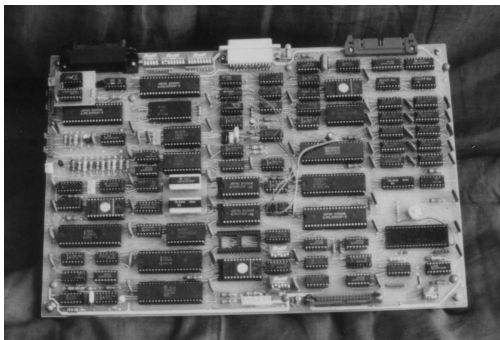


Figure 3. The Turing-850's motherboard. The image shows the central and peripheral processors and the rest of the circuitry.

However, to control the CRT, special amplifiers had to be designed to fulfill the more demanding specifications, in terms of bandwidth, compared to the ones required by TV sets. Designing the control circuitry for the CRT took a considerable amount of time given the system's nonlinear characteristics.

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 it necessary to use costly external AC voltage regulators to protect all the electronic equipment. To cope with this situation, the team 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, because the local industry lacked the technology needed to manufacture specialized high-frequency magnetic components, designing a switching-mode power supply was not a feasible option. Instead, the 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.<sup>28</sup> The switching feedback circuit controlled the power supplied to the voltage regulator in the transformer's secondary winding with a thyristor placed in the AC input line. The power supply design for the Turing-850 could tolerate variations of  $\pm 25$  percent in

voltage (90–150 VAC) operating at 45°C without requiring any external voltage regulator.

The mechanical design of the Turing-850's case 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 Organization for Standardization (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 because it was difficult to design and assemble the mold required for a lighter plastic case at a reasonable cost. Several case prototypes were constructed in wood and metal sheets to test the physical layout of all the boards and the monitor.

### Similar computers of the era

Some other computer systems designed and built outside the US during the early 1980s had capabilities similar to those of the Turing-850. Although we do not intend to provide an exhaustive list of such computers, these examples help illustrate similarities and differences.

#### *Other Mexican computers*

Arguably the earliest digital computer ever designed in Mexico was the Heterarchical (AHR) parallel-processing machine,<sup>29</sup> which was built at UNAM between 1979 and 1983.<sup>30–34</sup> 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 could host 5 to 64 Z80 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 redesign of the Radio Shack TRS-80 color computer containing a Motorola MC6809E microprocessor. Micro-SEP's main purpose was to supply a low-cost computer to public junior high schools.

The DMA-BUAP, headed by Harold V. McIntosh, was one of the pioneer Mexican centers in the development of computer systems based on microprocessors.<sup>4</sup> Several

microprocessor-based computers were designed and built at the DMA-BUAP. For example, a multiuser system called SMU based on an S-100 bus design was fully functional from 1979 until the late 1980s.<sup>35</sup> This system was able to serve up to 10 dumb terminals connected to the S-100 bus. Another example was the CP-UAP, designed with a NEC-V20 microprocessor on an STD-bus.<sup>4,36</sup> These microcomputer systems were built with two main goals in mind. First, 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, that were designed by DMA-BUAP researchers.<sup>4,37</sup> Second, these computers were used as tools for teaching programming skills to computer science and engineering students. Given the limited human resources available, all these projects concentrated exclusively on designing the motherboards, whereas the rest of the components were imported.

In IPN's Center for Research in Computing Technology (CINTEC), the first prototype of the computer Almita II was completed in August 1984. The Almita II's chief designer was the Mexican engineer Miguel Lindig-Bos. In its first version, Almita II had 256 Kbytes of RAM memory, two 360-Kbyte 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, this microcomputer's processing speed was 3.4 times faster than that of the original IBM PC.<sup>38,39</sup> The first prototype of Almita II was a proof of concept; it did not include a case, and all the boards were assembled using the wire-wrap technique.<sup>40</sup>

Lindig-Bos did not receive the required budget for building 10 microcomputers from the IPN authorities until July 1986. This task was successfully completed in April 1987.<sup>41</sup> By that time, the design of those 10 microcomputers had some differences with the original Almita II, most importantly that the main microprocessor used the Intel 80188. Partially because of this change, the new design was called the IPN E-16.<sup>39</sup> Furthermore, the IPN authorities launched a mass-production program of the IPN E-16 in hopes of reaching a sustainable self-production of microcomputers. By the end of 1993, 1,189 IPN E-16 computers and its descendants were operating in most IPN faculties.<sup>42</sup> The model IPN E-16 is a rare



case of relative success in the history of Mexican computers.

There were a few other computer design efforts going on in Mexico during the 1980s. For example, the Digital Technology Research and Development Center (CITEDI-IPN) developed a multiuser system (up to three users) based on the Z80 processor and a proprietary operating system in 1984.<sup>31</sup> Another example was the digital computer IMPetrón, designed by a team of four engineers in the Mexican Institute of Petroleum (IMP). IMPetrón was an 8-bit microcomputer developed around 1985; its main application was the simulation of digital control designs.<sup>43</sup> Because so little documentation is available on these systems, we will not discuss them any further.

#### *British computers*

The Amstrad PCW 8256 was a personal computer manufactured by the British company Amstrad,<sup>44</sup> 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 Z80 microprocessor running at 4 MHz. The Z-80 was capable of addressing up to 256 Kbytes of memory using a paging technique. This computer was designed as a word processor, but 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 32 and 64 Kbytes of RAM memory and cost £399 (approximately US\$764) and £499 (about US\$953) in 1982 and 1985, respectively. A phase alternate line (PAL) encoding video modulator inside the computer allowed it to use an external TV. A special interface let the BBC Micro connect an external Z80 microprocessor to execute CP/M. The extra processor cost was £894 (approximately US\$1,707). The BBC Micro project's initial objective was to design a computer that could be used to educate 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.<sup>45</sup>

#### *Brazilian computers*

The Cobra consortium was formed in Brazil in 1974. This consortium was a state-owned company formed with the participation of the British company Ferranti and several Brazilian private companies and public universities.<sup>46,47</sup> Cobra's purpose was to help create a national company capable of designing computer systems equipped with its own technology. In the early 1980s, the company produced the Cobra-210 personal computer system. Cobra-210's design included an 8-bit Z-80B microprocessor running at 5.85 MHz, 64 Kbytes of RAM, and two floppy disk units.<sup>48</sup> 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 coprocessor to speed up the execution of numerical applications. The Cobra-210 was compatible with the computer's previous models: the Cobra-300 and Cobra-305.

In 1984, Microtec Sistemas brought to the Brazilian market a compatible PC-XT.<sup>49</sup> Thanks to a governmental policy of protecting the national IT industry, by 1986, the Brazilian computer industry was able to supply up to 86 percent of its internal market.<sup>50</sup> 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. Brazilian information technology companies such as Procomp, SID, and Itautec still have an important share in this market today.<sup>51</sup>

#### *Comparison*

The goals and scope of the Turing-850 project had important differences with the other Mexican computers we have described here. 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 high-performance hierarchical dual-processor architecture. Furthermore, contrary to the rest of the DMA-BUAP computers, the project included the design of the entire computer system, not just the motherboard. In comparison, the IPN E-16 employed a single, more advanced processor but was delivered almost

Table 1. Comparison of the Turing-850 with other similar computers.

Feature	Turing-850	IPN E-16	Amstrad PCW 8256	Cobra-210
Operating system	CP/M	MS-DOS	CP/M	Proprietary, compatible CP/M
Central microprocessor	Z80 at 6 MHz 64 Kbytes RAM and 8 Kbytes ROM	80188 at 8 MHz 256 Kbytes RAM	Z80 at 4 MHz 64–128 Kbytes RAM	Z80B at 5.85 MHz 64 Kbytes RAM
Peripheral microprocessor	Z80B at 4 MHz 28 Kbytes RAM and 4–8 Kbytes ROM DMA channel, Intel 8257	No secondary processor	No secondary processor	An optional floating-point processor DMA channel, Intel 8257
Monitor	B/W, 24 × 80, 12"	RGB color, 640 × 400, 12"	Monochromatic green 32 × 90, 12"	Monochromatic green 27 × 80, 12"
Floppy disk	Two 5 1/4-inch units	Two 5 1/4-inch units	Two 3-inch units	Two 8-inch units
Serial port	RS232C	RS232C	*	RS232C
Parallel port	Centronics interface	Centronics interface	Proprietary interface	Proprietary interface
Case	Metal, single (CPU, video) plus keyboard	Metal	Plastic, single (CPU, video) plus keyboard	Plastic, (CPU, video) plus keyboard and floppy disks
Year	1984	1987	1985	1983

\* Data not available.

three years after the Turing-850. Finally, unlike most Mexican computers of the era, special care was given in the Turing-850's design to ease its manufacturing and operation within Mexico.

Table 1 shows a feature comparison between the Turing-850, IPN E-16, the Amstrad 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 Amstrad PCW and Cobra-210 were produced by companies with ample experience. Despite those limitations, Table 1 shows that the Turing-850 was a competitive machine when compared to similar computers of the era.

### Conclusions

The Turing-850 and other similar Mexican computers showed that despite the limitations faced and the adverse economic conditions prevailing in the country at that time, it was feasible to develop state-of-the-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, the University of Las Americas, and the Arturo Rosenblueth Foundation.<sup>52</sup>

After a CONACyT's initiative, the Turing-850 system was also exhibited in some important industrial expositions. At the time, CONACyT had created a special fund called the Trust Fund for Shared Risk<sup>53</sup> to foster cooperation between academia and industry in high-tech projects. Under this scheme, CONACyT provided half of the investment needed to produce the technology developed within academia. Despite the advantages offered by this 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 or 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 the more ambitious 32-bit computer was canceled prematurely. These failures occurred for several reasons.

First, 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 a time when the development of computer technology required 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 their own technology or seeking the collaboration of the few research centers 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 the US to manufacture and sell, with some success, the personal computer Columbia Printaform, which was 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 to Mexico, 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 during the 1980s. Brazil is especially significant because it shares with Mexico a similar level of economic and industrial development.

Brazil achieved relative success in creating an important computer industry capable of producing its own technology, in part due to the protective mechanisms implemented by the Brazilian government at the right time. Combined with crucial support since the early 1970s of both public and private sectors, this fostered the development of the computer sector. However, in Mexico, similar protective mechanisms did not work in the same way. A possible explanation is that, contrary to Mexico, the Brazilian banking sector supported the creation of a national computer industry because it foresaw the importance of computers to their business market. Finally, multinational companies in Brazil were convinced to

participate in joint ventures with state-owned companies.<sup>15,47,54</sup>

The 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 other factors prevented this from happening.

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