GENERATIONS OF SCIENTISTS AND ENGINEERS: Origins of the Computer Industry in Brazil*

Erick D. Langer
Carnegie Mellon University

Brazil today constitutes one of the major manufacturers of microcomputers in the world, a seemingly surprising feat for a country that many view as part of the Third World. How was it possible for a developing nation like Brazil to create a high-technology industry and join the exclusive club of highly industrialized countries like the United States, Japan, and Germany as one of the major manufacturers of computers?[1] Many political scientists, economists, and sociologists have tried to explain this exceptional phenomenon in primarily political terms. Most have studied the rise of nationalistic technocrats who began in the mid-1970s to implement a series of regulations that made it possible for Brazilian manufacturers to monopolize the domestic markets for minicomputers and microcomputers.[2]

This approach has been extremely fruitful, particularly because the amount of protection to be accorded to the computer industry remains a hotly debated topic in the political arena. But this approach has largely ignored the question of how and why Brazil developed the technical expertise in the first place that made possible the domestic manufacture of microcomputers. At best, studies have only briefly touched on the experience of the group in the Escola Politécnica of the Universidade de São Paulo, which won the national competition in the mid-1970s to build a computer prototype that could be manufactured domestically. Although this accomplishment was undoubtedly important, the history of the development of the computer industry actually goes back much further, to the end of World War II, and it did not proceed in a linear fashion. Numerous fits and starts and dead-ends involving at least three generations of scientists and engineers laid the basis for Brazil's present-day success in the field. In a real sense, the success of the

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computer industry grew out of a series of failures in other high-technology projects during the 1950s and 1960s. These setbacks led a small group of highly nationalistic individuals in key positions in academe and state agencies to coalesce, and only in the 1970s were they able to take advantage of a juncture of developments in computer technology and Brazilian politics to bring about a domestic informatics industry. Thus while political circumstances during the 1970s proved crucial, research emphasizing this late period and politics cannot explain how the idea of building computers in Brazil and creating a domestic high-tech industry originated and was transformed into a possibility. To answer these questions, one must examine the development of the scientific community that became involved with computers in the era following World War II.

Looking to the Future: Physics in the 1950s

Physicists proved to be extremely important to the creation of a national computer industry in Brazil. Although a number of physicists played key roles in constructing the first Brazilian computers in the 1960s and 1970s, even more important was their having provided the first coherent vision of Brazil's technological future. Unlike other relatively technologically advanced Latin American countries that have emphasized agriculture, law, and medicine, Brazil has fostered development in the field of physics. According to one observer, in terms of the relative efforts devoted to the various sciences, physics led the group, followed by life sciences, mathematics, chemistry, and earth sciences. By the 1950s, several Brazilian physicists had become internationally known in their field. By 1960 Brazilian federal and state government expenditures for basic and applied scientific research totaled fifteen million dollars, the largest effort by any Latin American country.[3]

After World War II, Brazilian scientists concluded that nuclear physics held the key to the future. Many believed that "a new industrial age" based on discoveries in nuclear physics was about to dawn. Perceiving their mission as aiding national economic development, many Brazilian physicists became involved in politics to obtain sufficient funding from the state. Harnessing nuclear power became a priority particularly after the debate over nationalizing the oil industry made it apparent that Brazil lacked efficient energy sources, especially in view of the prevailing opinion that sources of hydroelectric power were too far from population centers to be economically feasible.[4]

A minority of scientists believed that a similar promise was held by computer technology. Mário Schenberg, one of Brazil's most promising physicists who had studied in Italy under Enrico Fermi and elsewhere in Europe, realized that research in solid-state physics constituted an important aspect of computer technology, and he decided to establish a laboratory of solid-state physics at the Universidade de São Paulo (USP). Having also collaborated on nuclear research while studying particle physics, Schenberg bought an IBM 305 minicomputer to do many of the necessary calculations for his research into computers.[5]

The dream of building a computer intended primarily for scientific purposes continued to drive Schenberg. To this end, he initiated contact in the late 1950s with Israeli scientists from the Weizman Institute to establish a joint project for building a mainframe computer. The Brazilians possessed greater expertise in solid-state physics while the Israelis had superior technical knowledge, a complementarity that made a collaborative project attractive to both parties. The project continued under Schenberg's energetic direction into the 1960s, despite political uncertainty in Brazil.

The Kubitschek administration also became interested in computers, perhaps because of Schenberg, who was serving as a deputy in the Brazilian Congress at the time. The aims of President Juscelino Kubitschek differed considerably, however. Concerned with national development strategies rather than scientific research, Kubitschek created in 1959 a special agency concerned with computers under the jurisdiction of the Navy's development council, the Grupo Executivo para Aplicação de Computadores Electrônicos (GEACE). Creating a special agency for this purpose showed that Kubitschek was not simply indulging in rhetoric. His seriousness was also reflected in selecting the Brazilian Navy as GEACE's main institutional support. As the service branch with the most sophisticated engineering capabilities, the Navy could provide the best expertise within the Brazilian context. The developmentalist nature of the new agency was explicit, as GEACE Executive Secretary Captain José Cruz Santos explained: "We believe that this initiative will bring immense benefits to a country with a continental destiny such as ours. More modern and quicker processes for the study of its problems, for better comprehension of the interdependency of factors of production in its economic development, for the planning of complex operations today all necessitate millions of calculations."[6] As was often the case in Brazil, nuclear and computer technologies were mentioned in the same breath, as when *O Globo* raved about "the marvelous machines that make more than 1,500,000 calculations per minute, whose advent is considered as important as the utilization of nuclear energy."[7]

Although Kubitschek envisioned establishing a domestic computer industry in late 1959, the head of GEACE (who was responsible for implementing the president's decree) felt that this timetable was premature. Consequently, GEACE became involved instead in simply providing favorable terms for importing foreign computers.[8] In any case, the agency disappeared sometime thereafter during the turmoil of the Quadros and Goulart administrations. Thus a potentially promising start toward promoting and planning the development of the computer industry did not take root. If the pronouncements of GEACE's directors reflected the government's plans, the Kubitschek administration envisioned computers as only a partial means to the larger end of economic development, a component that in all probability could not have competed with the seemingly far greater promise of nuclear physics. Nevertheless, a few important precedents were set during this early, albeit ultimately unsuccessful, phase: an interest in computers was sustained in the universities via research into solid-state physics; and the Brazilian Navy took over the leadership in developing computers through a federal agency established to regulate import of foreign computers and promote creation of a domestic industry.

The Instituto Tecnológico da Aeronáutica and the Coup of 1964

The early 1960s witnessed a precocious development of expertise in building computers that was unfortunately truncated by the military coup of 1964. In addition to the lab at the Universidade de São Paulo, a solid-state physics lab was being run in Rio de Janeiro by Bernardo Gross, a former refugee from Germany, and another had been founded at the Instituto Tecnológico da Aeronáutica (ITA) in São José dos Campos, now an industrial suburb of São Paulo about an hour's drive along the road to Rio de Janeiro. Founded in 1947, the Instituto Tecnológico became the training ground for an entire generation of physicists and engineers who later became principal actors in the sequence of events that enabled Brazil to become a major manufacturer of microcomputers. Much like the Army's Escola Superior de Guerra, the Instituto Tecnológico was open to civilians as well as Air Force officers. Because the school enjoyed a reputation as one of the best engineering schools in the country, competition for entrance among civilian students was fierce. Instructors were drawn mostly from the civilian sector, and the institute fostered an academic climate with few indications of its military sponsorship. Unlike most institutions of higher education, the faculty was employed full-time and included a number of foreign instructors with doctoral degrees from some of the best universities in the United States and Europe. The Instituto's curriculum emphasized electronics, making it the first institution in Brazil to offer such courses. It also boasted a research and development lab, the Instituto de Pesquisas de Desenvolvimento, which carried out projects in aircraft development, electronics, and other areas. This lab also provided the means for an easy exchange between academia and industry based on the U.S. model, a feat rarely duplicated elsewhere. As a result of this exceptionally favorable research climate, many of the best research-oriented electronic engineers found employment at the Instituto Tecnológico.[9]

As part of one class project, a small group of engineering students built the first Brazilian "computer" at the Instituto Tecnológico in 1961. Named after José Ripper, one of its creators, the Zezinho was more like an adding machine than a computer, being composed of transistors and functioning only with difficulty. The machine was never commercialized, being cannibalized instead by subsequent classes for parts in different projects. The creators apparently intended to set an example for the electronics industry in Brazil, to show that Brazilians were capable of developing their own technology.[10] In any case, progress made in computer development at the Instituto Tecnológico and other Brazilian labs soon ground to a halt with the military coup of March 1964.

One of the disastrous consequences of the coup for early attempts at building domestic computers was the dramatic change in the atmosphere at the Instituto Tecnológico, which caused the nucleus of distinguished faculty and students to disintegrate. According to one former student, the atmosphere at the ITA became extremely repressive and the school began to be run like a military camp. Moreover, many students were arbitrarily expelled, and a new campus administration watched over faculty and student activities carefully for leftist ideological contamination. As a result, many of the brightest students and most of the civilian faculty found it impossible to work under these conditions. By 1965 many had left São José dos Campos, and the Instituto Tecnológico never recovered its distinguished academic reputation.[11]

Many faculty members went to work elsewhere, often in foreign countries. Luis Valente Boffi and Sérgio Telles Ribeiro came to the United States and found positions in industry or academia. Students, however, found it more difficult to the leave the country, and many scattered from the Instituto Tecnológico to other Brazilian institutions, where they continued to make their marks. A significant proportion went to the Universidade de São Paulo, joining its physics department and Schenberg's solid-state lab, attracted by the less-regimented life and the strong research group in nuclear and solid-state physics. But repression also hit the university in 1964 when Mário Schenberg, a member of the Communist party, was imprisoned for two months and prohibited from teaching at the university. Because Schenberg was the main Brazilian liaison, the joint project to build a computer with the Weizman Institute in Israel fell apart. The Israelis went ahead with the project and eventually built their own mainframe without Brazilian help.[12]

Meanwhile, the Brazilian military regime followed a policy much more favorable to foreign enterprises than had previous regimes, at least in the first years after the coup. This policy made the military government initially unsympathetic to domestic manufacturers of relatively sophisticated technology, an environment that would have made it difficult to develop a Brazilian computer industry even without the repression. One outcome of this policy was the demise of the television-manufacturing industry, which has been located primarily in the São Paulo region. As part of the strategy to attract foreign capital and as a means of developing the poverty-stricken Amazon region, the new regime set up a duty-free zone in Manaus, the capital of the state of Amazonas, where foreign corporations were encouraged to invest in assembly plants that would provide goods for the Brazilian market. One major successful effort included bringing television manufacturers to Manaus. Stripped of protective tariffs and unable to compete with the favored corporations based in Manaus, São Paulo television manufacturers went bankrupt within a short time.

On balance, the 1964 coup "had a negative influence on the development of informatics" in Brazil, as one participant phrased it.[13] The country's most promising institution, the Instituto Tecnológico da Aeronáutica, was emasculated as a result of the repression. This loss made it impossible in the short run for engineering students to continue experimenting with building computers after they and the faculty scattered throughout Brazil and the world. Repression also cut short the joint Brazilian-Israeli project, an effort with important institutional backing and great potential for the development of computer manufacturing in Brazil. Yet despite these major setbacks, the period from 1964 to 1969 also witnessed a realignment in the relative strengths of research institutions in Brazil into the pattern that continues today. The primary Brazilian beneficiary of the demise of the Instituto Tecnológico da Aeronáutica was the Universidade de São Paulo, although universities in Rio de Janeiro, such as the Pontifícia Universidade Católica (PUC), also benefited from the influx of ITA students and graduates. The result was that the most important institutions in developing computer technology in Brazil turned out to be the Pontifícia Universidade Católica, the Universidade Federal do Rio de Janeiro, the Universidade de São Paulo, and a newcomer, the Universidade Estadual de Campinas (UEC, now known as UNICAMP).

Revival of the Computer Idea: The Navy and the National Economic Development Bank

One favorable consequence of the scattering of scientists and engineers interested in computer development was the diffusion throughout Brazil of the idea of building an indigenous high-technology sector and enthusiasm for such a project. This trend led to what one author has called the formation in important government institutions of a cadre of "pragmatic antidependency guerrillas" who pushed through nationalistic measures designed to create and then protect a Brazilian computer industry.[14] As stated before, this aspect is one of the most studied facets of the development of Brazilian computers. This aspect, however, has been emphasized at the expense of the research infrastructure that made building a computer industry feasible in the first place.

In the late 1960s, the Brazilian Navy became interested in developing a domestic capability for building and servicing computers because the Navy had purchased British frigates using Ferranti computers. The primary motivations for this course of action were national security concerns that foreign computer specialists or a domestic computer manufacturing base would be unavailable in case of war, combined with an awareness of the limitations on importing expensive foreign goods.[15] In a joint project with the Banco Nacional de Desenvolvimento Econômico (BNDE), the Navy in 1968 hired Katuchi Techima, an ITA graduate and a professor at the Universidade de Brasília, to determine the possibilities of creating a native computer industry. Techima traveled to major research centers in Brasília, Minas Gerais, São Paulo, and Rio de Janeiro to discuss the plans of the Navy and the BNDE with interested physicists and electrical engineers at these institutions. The resulting report made it clear that while considerable enthusiasm existed for such a project, only a few institutions possessed the necessary trained personnel and infrastructure. These included the Pontifícia Universidade Católica in Rio, the physics department at the University de São Paulo, and the electrical engineering department of the Escola Politécnica, also at USP.[16]

But the report went beyond merely evaluating the state of high-technology research in Brazil to define the problems within research institutions, and it severely criticized Brazil's dependence on imported technology. For example, the report cited the laments of researchers at the Escola Politécnica regarding administrative problems and a lack of financial support that precluded teaching applied courses regularly. According to those interviewed, salaries were low and research money virtually nonexistent. Also indicted was the lack of integration between research and applications in industry, which rendered many of the advances in research irrelevant. Only through greater financial support, integration between instruction and research, and a structure encouraging the use of research results in industry could Brazil break the stranglehold of imported technology.[17]

According to the report, "the Escola Politécnica [at USP] represents perhaps the major technical potential of Brazil, thanks to the number of its faculty and its structure for teaching engineering."[18] In fact, the Escola Politécnica was to prove crucial in developing the first commercial computer in Brazil, particularly the Laboratório de Sistemas Digitais (LSD), founded by Antônio Hélio Vieira Guerra in 1966 and made operational in 1968. Like the research and development lab at the Instituto Tecnológico, the LSD enjoyed a good working relationship with industry. The director of the Escola Politécnica, Fadigas Fontes Torres, provided needed funding for the LSD lab and its equipment. At first Vieira envisioned building a research lab for telecommunications equipment using the new digital technology. He had worked primarily with television technology until the demise of the São Paulo industry forced him to look elsewhere. In the short run, telecommunications appeared to be the most promising field. But Vieira had also worked earlier with Schenberg on the joint Brazilian-Israeli computer project and had maintained an active interest in computers as well.[19] Perhaps because of the report, Vieira encouraged students at the LSD to work on computer peripherals, using an IBM 1130 acquired in 1969. More importantly, Vieira hired a number of U.S. professors to come to São Paulo and offer intensive computer science courses.[20]

Another important institution within the Escola Politécnica was the Laboratório de Microeletrônica (LME), which had been established in 1968 by Carlos Américo Morato de Andrade, who had earned a master's degree from Syracuse University. Morato's advisor at Syracuse, Richard Anderson, provided much of the initial know-how and built the first semiconductor at the LME. By 1970 Morato de Andrade and his associates were beginning to produce custom-made semiconductors, despite initial problems in establishing sufficient quality control. This accomplishment was an important first step because general opinion at the time held that Brazilians would never be able to build their own computers without knowing how to manufacture chips. This point had been the thrust of research efforts by physicists like Mário Schenberg since World War II.[21]

The Guaranys Project: The Cisne Branco and the Patinho Feio

In 1971 the Navy and the BNDE, after lengthy consultations, created a special commission called the Grupo de Trabalho Especial (GTE) FUNTEC 111. Its tasks were to supervise construction of a minicomputer for Navy use and to create a machine for the domestic market. The head of the project was Captain José Luis Guaranys, one of Vieira's students in 1961 who had subsequently taken electrical engineering courses at Syracuse.[22] Guaranys had been particularly impressed by Jean-Jacques Servan-Schreiber's book entitled *The American Challenge*, which he cited repeatedly in press interviews. The Navy captain apparently agreed with Servan-Schreiber's contention that Brazil would be left behind if it did not begin to build its own computers.[23] The commission planned to award four million dollars to the institution that created the most viable model within four years' time.

At first glance, the distribution of scientific and engineering resources throughout the country appeared to guarantee that either an institution in Rio de Janeiro or the numerous and talented groups in USP's physics department or Escola Politécnica would get the award. Certainly, the Universidade de São Paulo had a clear advantage at the outset due to the experience gained at the Instituto Tecnológico da Aeronáutica, research in microelectronics at the LME, and the work done on computer peripherals at the LSD.

A surprise competitor appeared, however, when the recently established Universidade Estadual de Campinas (UNICAMP) entered the race. Located in a city one hundred miles north of São Paulo, the university was so new that it had not even been included in the 1969 BNDE report. The rector at Campinas presumably thought that winning the computer contract would quickly establish the Campinas campus as a major force in the Brazilian academic community. To this end, he hired a graduate of the Instituto Tecnológico da Aeronáutica, Sérgio Telles Ribeiro, to head the development effort. After leaving the Instituto Tecnológico in the mid-sixties, Telles had worked for the U.S. National Research Council in Illinois and with National Semiconductor in California. Another Brazilian electrical engineer, Manoel Sobral Junior, also an ITA graduate, returned from the United States to join the effort at Campinas. The university administration wanted Telles to create by 1972 a computer engineering course whose main object would be to construct a computer prototype that could be manufactured locally. Telles proposed to create a medium-sized minicomputer like the IBM 1130, with a number of more advanced features. The Brazilian version was to be faster than the IBM and have a twenty-four-bit, rather than a sixteen-bit, processor. Telles estimated that the new computer would cost between twenty-five and thirty thousand dollars when available to the Brazilian consumer. The group at Campinas gave its project the rather grandiose name of "Cisne Branco" (white swan). The choice was probably politically motivated by the fact that "Cisne Branco" is also the title of the anthem of the Brazilian Navy.[24]

The São Paulo newspapers reported at length on the Campinas project, while the institutions in São Paulo and Rio de Janeiro disappeared from view. This focus appeared to be justified, as was explained in *O Estado de São Paulo*: "There are many other developed research and technology centers [in the country], but it is almost certain that the Campinas team will get the work contract. There are only three computer engineers in the country. And two of them are at UEC [UNICAMP]."[25] Although the Campinas group asserted that "their preoccupation was not with constructing a computer in Brazil but a Brazilian computer with its own characteristics," they thought it necessary to contract with a number of U.S. technicians, "people who already know how to do a number of things" and who "could not be found in Brazil."[26] Nevertheless, the Universidade Estadual de Campinas was betting on a certain development model that was probably unrealistic in a number of respects. Although supervised by Brazilian engineers, the Cisne Branco project envisioned a highly sophisticated, state-of-the-art machine that, at least initially, would be partially constructed by foreign technicians. Not only would the cost be high (although less expensive than the IBM model), but the project was also expected to take about four years to complete.

As it turned out, the Campinas group's confidence in the success of their project was misplaced. A different model of prototype development prevailed instead, one emphasizing a more practical approach that was quicker, "dirtier," and much less costly. This ultimately successful approach was utilized by Hélio Vieira and the Laboratório de Sistemas Digitais. As noted, shortly after the LSD was established, Vieira hired a few U.S. academics to teach intensive computer science courses that provided the theoretical basis for development. Perhaps more significantly, Vieira also arranged for Glen Langdon, a Syracuse Ph.D. working for IBM, to begin teaching in early 1971 a three-semester sequence of courses that would lead to the construction of a computer. According to one participant in the course, Langdon was "the most important person in [the development of] the Brazilian computer industry" because after the first semester, when the computer was designed, he served as an advisor rather than building the computer himself.[27] Langdon found that individuals at the LSD were willing and enthusiastic about building the internal computer architecture. At first, the course participants included not only students of the Escola Politécnica but a select number from the physics department. These courses gave the students confidence as well as proficiency in mastering the problems of computer design for themselves.

In actuality, a number of students at the LSD already possessed some significant experience with computers, although not in building a central processing unit and other internal architecture. Since the foundation of the LSD, Vieira had encouraged his students to work on peripherals. Students had written theses on building modems and computer terminals, creating software, and the like.[28] But when they attempted to obtain employment as electrical engineers in the large multinational corporations dominating the Brazilian computer market, such as Burroughs and IBM, they found themselves relegated to irrelevant tasks that neither tapped their knowledge of computers nor helped them continue to develop their expertise. In response, some formed small companies where they did consulting work and tinkered with various electronic gadgets, as did Edson Fregni, Joséf Manasterski, and Célio Ikeda.[29] The Brazilian-trained engineers felt their being excluded from their areas of expertise in the multinational companies acutely, and their alienation undoubtedly led to a general disillusionment with the prospect of finding work among existing companies. It also fostered a sense of nationalism.

In July of 1972, a new computer developed at the LSD was presented to Brazilian officialdom, one based on a standard Phillips (4096-word, 8-bit per word) magnetic memory core. Named the Patinho Feio (ugly duckling) in counterdistinction to the ambitious Cisne Branco, the computer had a much smaller memory and was more primitive than the one envisioned by the Campinas group. With only eight-bit words and a memory capacity of only four kilobytes, its programming was relatively laborious. In fact, the computer was accidentally unplugged during the demonstration, although these problems were promptly fixed.[30] Despite all, the construction of the machine by the LSD group (and perhaps their impromptu display of technical know-how during the demonstration) impressed the Navy and the BNDE, especially because the way it had been constructed showed that the participants had mastered computer design and were competent to build these machines inexpensively and with minimal infrastructure. As a result, the LSD group received the contract to build a computer for scientific use, which became known as the G–10. Expertise gained from this model eventually led to building the initial models of the Cobra line of computers, with the participation of Ferranti, the British computer manufacturer.[31]

Meanwhile, the students from the physics department who had participated in Langdon's course during the first semester did not continue in the construction phase. Instead, they built their own computer, which they employed to analyze statistical results of the department's particle accelerator.[32] Thus the physicists finally succeeded in building their long-anticipated scientific computer, the dream kept alive by Mário Schenberg for many decades.

Many of the engineers involved in the USP project became entrepreneurs and helped fuel the explosion of small Brazilian computer companies. Between 1975 and 1985, the number of computer-related companies jumped from four to more than a hundred. In 1984 these companies produced a thousand computers and seventy thousand microcomputers as well as twenty-five thousand printers, forty thousand terminals, and many other peripherals. In 1984 the computer industry directly generated more than twenty-one thousand jobs, nearly one-third of them requiring college-level skills.[33] Part of the proliferation of new Brazilian companies can be traced to the economic nationalism engendered in many trained Brazilians after their experiences with the large multinationals taught them that they would be unable to find suitable jobs if they did not help create their own companies. Although many engineers at first made clones of Timex Sinclair and Apple computers, they also created original designs that met with varying degrees of commercial success on the Brazilian market.[34]

Yet Brazil could not have taken advantage of this series of fortuitous events had not three generations of scientists and engineers since World War II fostered the idea of building their own computer and created the necessary academic infrastructure to be able finally to do so in the 1970s. By this time, the country boasted a significant scientific community that was increasing in size and world importance. Between 1967 and 1974, Brazil's production of scientific articles in international journals quadrupled; during the same period, its share of the world's scientific production doubled to over 3 percent. The Brazilian government also continued to expand and improve university education, as in 1975, when it approved the second basic plan for scientific and technological development allocating increased amounts for scientific and applied research projects.[35] This plan helped assure the training of enough engineers and support personnel to foster continued growth in the computer industry.

A number of other factors also contributed to the success of the domestic computer industry. In line with the scientists' tradition of maintaining extensive political involvement in government to gain needed advantages from the all-important state, the Brazilian engineers and physicists involved in the computers both in academia and industry pressured the government to protect the native minicomputer and microcomputer industry. As Emanuel Adler has shown, this campaign occurred in 1975, very early in the production cycle, partly because of the military's interest in maintaining such an industry for national security purposes.[36] In addition, the proliferation of cheap computer chips, stimulated by the microcomputer revolution in the United States, created what one author has called a "technological window" that made it possible for Brazilian companies to manufacture computers inexpensively.[37] Access to inexpensive chips might help explain why in the early 1980s, many Brazilian firms such as Scopus switched from emphasizing peripherals to building microcomputers themselves. Although this kind of competition meant that the potential inherent in the microelectronics labs of USP and other institutions was never fully realized, it created a boomlet in the number of domestic computer companies that began producing for the Brazilian market.

Conclusion

How does the development process for computers in Brazil illuminate the potential for such feats in other countries? Two interrelated issues in particular appear to have special relevance. One concerns the manner in which the Brazilian computer industry finally succeeded. The other relates to the way in which the Patinho Feio group at the Escola Politécnica managed to beat the competition from Campinas. These issues highlight unique aspects of this particular case study as well as general lessons that can be drawn from the Brazilian experience and applied elsewhere.

It is important to note that the idea of domestic computer construction, based on local talent, existed for decades before the actual development of a commercially viable computer. The path taken by this development was tortuous at best, especially because technology, potential markets, and world market conditions were constantly changing. No one in the 1950s in Brazil (or probably anywhere else) envisioned the development of tiny, inexpensive mass-produced microchips that would make the microcomputer possible and provide independent computing power for much of the general public. While it is not unusual for few, if any, to foresee where technological developments will lead, this lack of foresight has particular significance in Brazil and other Third World countries. Although the concern with nuclear and solid-state physics and the related concern with microelectronics were vital to the eventual development of a native computer industry in Brazil, these research and development programs failed to produce their own breakthroughs. The computer development program was actually a fortuitous by-product of numerous failures of other, more concerted long-term efforts such as the nuclear energy program. Thus those who view the Brazilian computer industry as a success story are only partially correct at best. The establishment of the Laboratório de Sistemas Digitais in São Paulo and the effort in Campinas were built upon the ruins of failed programs in nuclear physics, the bankrupted industrial production of television sets, and the virtual dismantling of the Instituto Tecnológico da Aeronáutica. Other areas, like solid-state physics and microelectronics, failed to keep up with advances in their fields when financial support and (in the case of microelectronics) commercial success eluded them. Consequently, scholars who pick up the story only in the 1970s cannot discern these failures, which are essential for understanding the development of the computer industry in Brazil.

This development process, with fits and starts and partial setbacks that sometimes turn out to be fortuitous, actually seems to be the usual pattern for technological development.[38] Given this tendency, it appears that few countries outside the highly industrialized minority

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can "afford" to spend much of their scarce resources on programs that in all likelihood will not work out. In other words, the road to success for the Brazilian computer industry was littered with many costly failures, which made it impossible to plan in any coherent way for the eventual success (if any) of these programs. How many Third World countries, most of them less-favored than Brazil with a large resource base and an impressive pool of scientific and engineering talent, can afford to embark on these kinds of programs if eventual success is so hard to predict?

Even the Brazilian success entailed political maneuverings to foster the industry that can only be described as extremely fortuitous. The initial thrust of protectionist measures was to safeguard the minicomputer market, which was the only one existing at the time other than the mainframe market. These protectionist measures were implemented just as the microcomputer made its entrance, at a time when large foreign-owned companies like IBM had little interest in this area. By protecting the minicomputers, the Brazilian government also protected the lucrative microcomputer market, which native entrepreneurs were able to enter with relatively little initial capital investment and much lower technological requirements. Thus even the eventual success and proliferation of Brazilian companies specializing in microcomputers was not planned in any coherent fashion and actually occurred completely by accident.

Another very fortunate circumstance was the rapid expansion of mass-manufactured chips on the world market. Although it destroyed Brazilian efforts to build their own semiconductor industry, it gave Brazilian hardware manufacturers access to cheap components for building their own machines. This outcome relates to the second issue, exemplified by the Patinho Feio development model that triumphed in the GTE competition. Instead of attempting an elaborate paper design that would take years to develop, the Patinho Feio group built a workable model in a relatively short time and thus demonstrated their engineering capabilities in a pragmatic way. Although this approach entailed obtaining a foreign-manufactured core memory and initial advice from a number of U.S. engineers and scientists, the LSD group showed that it was possible to achieve a certain measure of technological independence rather quickly.

The Brazilian case also demonstrated a pattern of selective protectionism, based on a pragmatic approach that continues to characterize the Brazilian computer industry. Many Brazilian firms continue to produce clones based on other models that are successful on the world market, such as Apple and IBM. Brazil's importance as an industrial nation, the nationalistic sentiments of its rulers, and its relative independence from outside pressures made it possible to continue to produce these kinds of goods despite concerted pressure by the multinational computer companies. This independence and pragmatism have perhaps ensured the continued success of the domestic industry in that it is probably impossible for relatively small companies with limited resources to engage in the extremely costly research and development funded by computer giants like IBM and other companies in the industrialized world. Moreover, the unlikeliness that many other Third World countries could resist multinational pressures further accentuates the specialness of the Brazilian case. It may also explain why only Brazil has been able to engage in the lengthy and expensive development process of the computer industry and has thus far succeeded in fostering its growth.

NOTES

1. As of 1986, Brazil ranked eighth in domestic market size, with a market projected for 1987 of 3.7 billion dollars, and its growth rate of 60 percent is the second-fastest in the world (only China's 80 percent growth rate is higher). See U.S. Department of Commerce, *U.S. Industrial Outlook 1986* (Washington, D.C.: U.S. Government Printing Office, 1985), 287. The only other Third World country with a substantial domestic computer industry is India. On this topic, see Joseph M. Grieco, "Between Dependency and Autonomy: India's Experience with the International Computer Industry," *International Organization* 36, no. 3:609–32; and his book with the same title (Berkeley and Los Angeles: University of California Press, 1984).
2. For example, see Emanuel Adler, *The Power of Ideology: The Quest for Technological Autonomy in Argentina and Brazil* (Berkeley and Los Angeles: University of California Press, 1987). Also representative of this approach is *The Computer Question in Brazil: High Technology in a Developing Society*, edited by Antônio Botelho and Peter H. Smith (Cambridge, Mass.: Center for International Studies, Massachusetts Institute of Technology, 1985).
3. Harold C. Mattraw, "Capabilities for Scientific Research and Engineering in Selected Latin American Countries," *Tempo*, Research Memorandum RM 60TMP–59 (Santa Barbara, Calif.: General Electric Co., 1960), pp. 18, 21–22.
4. Simon Schwartzman, *Science and Higher Education in Brazil: An Historical View* (Washington, D.C.: Wilson Center, 1979), especially pp. 13–17; and interview with Mário Schenberg, São Paulo, 24 May 1985. For an overview of the Brazilian nuclear program, see Joseph A. Camilleri, *The State and Nuclear Power: Conflict and Control in the Western World* (Seattle: University of Washington Press, 1984), 178–85. An excellent analysis of the nationalization of the petroleum industry is included in John D. Wirth, *The Politics of Brazilian Development, 1930–1954* (Stanford, Calif.: Stanford University Press, 1970).
5. Interview with Schenberg. The installation of this new computer was hailed in an article in the *Folha da Tarde*, 8 Aug. 1959. See the archives for the state of São Paulo (in São Paulo), under the section "Computadores."
6. "Quatro Computadores Já com Importação Aprovada," *O Globo*, 2 May 1960.
7. Ibid.
8. Ibid.; also an article in *Folha da Tarde*, 14 Oct. 1959. See the archives for the state of São Paulo (in São Paulo), under the section "Computadores."
9. Interview with Cláudio Mammana, a former engineering student at the ITA now a faculty member of the physics department at the Universidade de São Paulo, in São Paulo, 31 May 1985; interview with Katuchi Techima, an ITA graduate and a professor at the Universidade de Brasília, São Paulo, 22 May 1985; and interview with Carlos Américo Morato de Andrade, São Paulo, 28 May 1985. For a description of

the Instituto Tecnológico da Aeronáutica, see Mattraw, "Capabilities for Scientific Research," 20–21; on the Escola Superior de Guerra, see Alfred Stepan, *The Military in Politics: Changing Patterns in Brazil* (Princeton, N.J.: Princeton University Press, 1971).

10. Interviews with Techima and Mammana; see also J. C. Melo, *A Incrível Política Nacional de Informática* (Rio de Janeiro: n.p., 1982), 17–18. Based on my information, Mário Ripper's reminiscence asserting that the Zezinho was meant to serve as an example to industry (as quoted in Adler) is probably inaccurate and appears retrospectively significant in this respect only because of the success of the Brazilian computer industry during the late 1970s and early 1980s. See Adler, *The Power of Ideology*, 244–45.
11. Interview with Mammana.
12. Interview with Schenberg.
13. Interview with Mammana.
14. Adler, *The Power of Ideology*. Also see Adler's article, "Ideological 'Guerrillas' and the Quest for Technological Autonomy: Brazil's Domestic Computer Industry," *International Organization* 40 (1986):673–705.
15. See Adler, *The Power of Ideology*, 206–7, 245. Also see "Brasil Fará Computador," *Estado de São Paulo*, 29 Oct. 1970.
16. Banco Nacional de Desenvolvimento Econômico (BNDE) and the Universidade de Brasília, "Relatório das Visitas Efectuadas às Instituções de Ensino e Pesquisa," 1969, typescript. My sincere thanks to Katuchi Techima for providing access to this important document.
17. Ibid. Parts of this report are summarized in "Brasil Já Pensa em Computadores," *O Estado de São Paulo*, 20 Mar. 1969.
18. BNDE, "Relatório das Visitas," appendix 1, p. 25.
19. Interview with Edson Fregni, São Paulo, 28 May 1985. A participant in Langdon's course, Fregni went on to found Scopus, a computer manufacturer, and to head the Associação Brasileira de Indústria de Computadores e Periféricos (ABICOMP), a computer industry interest group. Also, interview with Antônio Hélio Guerra Vieira, São Paulo, 31 May 1985.
20. Antônio Hélio Guerra Vieira, "EPUSP/LSD," mimeo, São Paulo, 1971. This document lists five U.S. computer scientists who taught classes at the LSD between 1968 and 1971. Glen Langdon, Jr., also provided information on Vieira's strategy in a telephone interview on 18 April 1985. Work on computer peripherals in the initial stages of the LSD are also well documented by the grants listed in the *Relatórios* of the Fundação de Amparo a Pesquisa do Estado de São Paulo (FAPESP), an important source of funding for engineering and scientific research in São Paulo.
21. BNDE, "Relatório das Visitas"; interviews with Morato de Andrade and Langdon; also see FAPESP's *Relatórios* from 1966 onward.
22. Information on Guaranys's career and education comes from his curriculum vitae, kindly provided by Admiral César Moácir Bastos Cardoso, and from my interview with retired Admiral Roberto de Paula Messiano, a former classmate of Guaranys, who was also involved with GTE after 1973. The interview took place in Rio de Janeiro on 30 May 1985.
23. Jean-Jacques Servan-Schreiber, *The American Challenge* (New York: Atheneum, 1968). The book was cited by Guaranys in an interview with *O Estado de São Paulo* published 23 Mar. 1971 under the title "Computador Une Marinha, Universidade e Indústria."
24. See "Brasil Deve Fazer os Computadores," *O Estado de São Paulo*, 7 Jan. 1971; and "Brazil perto do seu 1a Computador," *O Estado de São Paulo*, 21 Mar. 1971.
25. "Brazil perto do seu 1a Computador," *O Estado de São Paulo*, 21 Mar. 1971.
26. "Podemos Construir um Computador Moderníssimo (Aguardamos Ordem)," *Jornal da Tarde*, 16 June 1971.
27. Interview with Fregni.
28. Masters' theses produced at the LSD include these titles (translated): "System of Graphic Representation on an Oscilloscope Screen," by Francisco J. de Oliveira Dias (1971); "Modem for the Transmission of Data," by Paulo Wanderley Patullo (1971);

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"Terminal for the Transmission of Data," by Lucas Antônio Moscato (1971).

29. Interview with Edson Fregni. He later joined with Manasterski and Ikeda to found Scopus Tecnologia, the largest privately owned manufacturer of microcomputer systems in the country. Also see Peter B. Evans, *State, Capital, and the Transformation of Dependence: The Brazilian Computer Case*, Working Paper no. 6 (Providence, R.I.: Center for the Comparative Study of Development, Brown University, 1985), 5.
30. "Na USP, Computador Brasileiro," *O Estado de São Paulo*, 25 July 1972.
31. Interview with Edith Ranzini, Professor of Electrical Engineering at the LSD, São Paulo, 28 May 1985; and Adler, *The Power of Ideology*, 245.
32. Interviews with Mammana and Fregni.
33. Paulo Bastos Tigre, *Technology and Competition in the Brazilian Computer Industry* (New York: St. Martin's Press, 1983), 110. Cláudio Fritschak, "The Informatics Sector in Brazil: Policies, Institutions, and the Performance of the Computer Industry," paper presented at the National Science Foundation Symposium. "National Policies for Developing High Technology Industries: International Comparisons," Washington, D.C., 12–13 Sept. 1985, p. 41; Associação Brasileira da Indústria de Computadores e Periféricos (ABICOMP), *Catálogo da Indústria Brasileira de Informática 84/85* (Rio de Janeiro: ABICOMP, 1985), 5.
34. Adler, *The Power of Ideology*, 238–79. Also Evans, *State, Capital*; Bastos Tigre, *Technology and Competition*; Botelho and Smith, *The Computer Question*.
35. Regina Lúcia M. Morel and Carlos Médicis Morel, "Um Estudo sobre a Produção Científica Brasileira segundo os Dados do Institute for Scientific Information," *Ciência de Informação* (Rio de Janeiro: n.p., 1978), as cited in Schwartzman, *Science and Higher Education*, p. 33, n. 34. University education is discussed in Fay Haussman and Jerry Haar, *Education in Brazil* (Hamden: Archon Books, 1978), 92–94.
36. Adler, *The Power of Ideology*, 262.
37. Simon Schwartzman, "High Technology or Self-Reliance? Brazil Enters the Computer Age," *The Computer Question*, 29–34.
38. For an elaboration of this idea, see particularly the articles in *Technology and Culture* 17, no. 3 (1976), which deal with definitional problems of the developmental phase of technological change. Also see Raymond H. Isenson et al., *Project Hindsight* (Washington, D.C.: Office of the Director of Defense Research and Engineering, 1969).