The People’s Republic of China now has a 20-year history of digital computation. The initiation of a computer development program in China was motivated by the belief that digital computers would be essential for the development of a modern, industrialized nation. China’s program has been strongly influenced by concepts in computer design from Russia and the West, and computer developments from abroad appear to have been carefully studied and evaluated in the context of China’s needs. However, though the Chinese have learned from others, their primary objective has been to establish a self-sufficient industry providing adequate computing power. None of the events since the death of Mao and the installation of Hua as premier in 1976 indicates a change in this objective.

One cannot discuss the history of Chinese affairs between 1958 and 1978 without noting the decade encompassing the Cultural Revolution (1966-1976) and the activities attributed to the “Gang of Four.” Available information is not adequate to allow us to determine the effects of the strife and change of this period on the development and use of computers. It is clear, however, that some development and construction continued in spite of the difficulties. One obvious product of this period is the neighborhood factory. The “Door Handle Factory” (where the C-2 and 709 computers were built) and the “Torch Semiconductor Factory” (where ICs are built) are examples. These will be discussed later.

Chinese universities are returning to normal operations, but the loss of a decade of technical and scientific university-trained graduates must have a serious, detrimental effect on research, development, and application of computers.

The development of computers and computation in China has been uneven. One cannot say, “The state of computing in China corresponds to the situation that existed in the US in 19xy.” There are three main reasons for this:

1. The US experienced a computer explosion beginning about 1962, when an ample number of computers were available and high-level languages made computation available to people who were not computer specialists. Subsequent developments in languages, operating systems, and architecture have been motivated by user needs. Such an explosion has not yet occurred in China. Two reasons for this could be the small number of computers available and a shortage of trained computer personnel. A larger user community can be expected to make demands for features requiring sophisticated operating systems, virtual memories, and machines.

2. China has had the opportunity to study computing in the outside world and to select the concepts and techniques most relevant to the improvement of computing in China.

3. There is ample evidence that the Chinese have an excellent understanding of computer technology. The research-laboratory state of the art is, in general, quite advanced. However, the transfer of the state of the art from the research laboratory to the factory appears to be a serious problem. Manufacturing methodology, quality control, and testing are probably the most critical items in the whole program.

Third-generation Chinese computer architecture and performance corresponds to that of early-60’s, second-generation machines in the US. The third-
generation Chinese machines use logic corresponding to 1970 American IC technology. Operating systems are not advanced, but considerable effort, both practical and theoretical, is now being given to this subject. Rapid progress in operating-system design and implementation is expected for the systems now under development. Numerous high-level languages are common, but the effective, efficient application of computers is limited by the state of systems programming technology and programming methodology.

Evidence indicates a limited production of 1-MIPS general-purpose digital computers (the TQ-6 model) at 2 to 5 units per year. Production of minicomputers in the DJS-100 series appears to be significantly greater. The new DJS-200 series computers are expected to become the standard general-purpose computers for performance in the 0.1 to 1-MIPS range. Demand for computers appears to exceed the supply. Also, applications exist for supercomputers such as the CDC Cyber, now on order.

Computer Society delegation initiates technical interchange

A delegation consisting of IEEE Computer Society members and their spouses visited the People's Republic of China (PRC) in response to an invitation by the Chinese Electronics Society, a government sponsored group founded in 1962. The CES is concerned with the application of new technology and is responsible for technical exchanges between China and other countries and for the convening of technical conferences.

The IEEE-CES delegation visited universities, computing centers, factories, and cultural sites. The delegates presented technical papers and had numerous informal discussions concerning both technical and cultural topics. The visit began on September 29, 1978, and included the cities of Peking, Nanking, Wuhsi, Hangchow, Shanghai, and Canton. The specific itinerary was presented by the CES after the delegation arrived in Peking, although there had been preliminary discussions prior to arrival.

Within China the delegation was accompanied by members of the CES. VIP treatment and the best accommodations available were provided, and our hosts took care of all the required customs and currency forms, greatly expediting our journey.

Travel between cities was mostly by train or plane; short trips were made in chauffeured automobiles of Chinese manufacture or in minibuses. The Chinese national airline, CAAC, uses Viscount, Trident, Boeing 707-320, and Ilyushin 62 aircraft for passenger service. Five Boeing 747s were ordered in December 1978 for future transoceanic service.

Hotel accommodations were for the most part comfortable and adequate but not modern. The food ranged from just adequate on a few occasions to very good, and each banquet was a gourmet's delight. During nonscheduled periods, we used taxis or the chauffeured limousines to visit local shops and other places of interest not included in our formal itinerary. Foreigners in China are still not common and are the subject of considerable curiosity and interest, and in public we were accorded much attention and immediate access to facilities of all kinds.

This visit was the second made by an IEEE delegation in response to an invitation by the CES. In September-October 1977 a delegation specializing in communications, led by then IEEE President Robert Saunders, visited China for 21 days. A limited number of other technical interchanges have occurred over the past 10 years, and available trip reports document the considerable changes that have occurred in the PRC during this period. Of particular note is the July 1978 visit by Frank Press, science advisor to President Carter.

We found the Chinese to be quite open and willing to discuss objectively the present and past state of Chinese society. We were told that the policy of the present government encourages frank and honest discussions. We expressed interest in Chinese culture and politics, and we found that interest reciprocated.

China, a nation of almost one billion people, accounts for one-fourth of the population of the world. In 1972 China's population was 80 percent rural, with three-fourths of the population directly employed in food production. The industrial and service sectors are small in comparison with agriculture. The industrial sector is constantly developing, but food supply has been, and continues to be, of prime importance in both politics and overall development.

One cannot help but be aware of China's vast population. The normal modes of transportation are walking and bicycling, and in the cities and countryside alike, pedestrians and bicycles are everywhere. The net work week is six eight-hour days per week. Since there is no religious consideration of Sunday (or of any other day), the day off will vary from group to group, a practice helping to lessen congestion. All the gardens and places of interest we visited were filled with local people. Travel by the average Chinese by train or plane is not common and appears to be reserved for official business. Automobiles are official vehicles reserved for governmental activities. Tourism is limited to major cities and adjacent rural areas, but is scheduled for significant expansion when facilities become available. Tourism will be developed to generate the hard currency needed to import high technology. At present, technical and other invited delegations are given a much higher priority than tourist groups. They are assigned the most competent translators and operate on firm schedules, while tourists may find translating inadequate and itineraries subject to major change on short notice.

The Chinese, it seems, have some disposable income after they pay for the basic necessities. Department stores and neighborhood shops seem to be stocked with a variety of goods. It was not clear to a visitor which of these items might be freely purchased.
Increased computing power is an essential part of the Chinese modernization program. This goal provides a challenge to universities, research institutes, and factories, since modernization, education, and improvements in production methodology are required to produce the needed computers. Perhaps the greatest challenge lies with the government of China, since modernization will succeed only if effective direction, planning, and coordination are provided and national stability is maintained. Long periods of stability in 20th-century China have been rare.

Some items are strictly rationed; others, such as sewing machines, can be purchased only with foreign exchange. Chinese citizens can own such items if they can find a source of foreign money, such as relatives living abroad. TV is available and can be seen in hotel lobbies, although some families own their own sets. The programming includes foreign-language lessons as well as revolutionary drama.

No individual or group can become expert on China or computers in China during a three-week visit; Professor Piang-chuan Feng, our Harvard-and-Cambridge-educated host in Canton, commented that a foreigner who lived in China for 10 years might learn enough about Chinese society and culture to know what questions to ask! The differences between Chinese and American culture and technology are significant, making general comparisons difficult. Our technical discussions usually involved translation, which was normally quite good. However, errors in translation caused considerable confusion on occasion, particularly when technical details were involved. We were fortunate that two members of our delegation spoke fluent Peking Chinese and were also familiar with Chinese computer vocabulary. We also encountered a number of technologists who spoke fluent English and were familiar with Western computing literature. These two groups were essential for the transfer of detailed technical information.

A significant growth in American and Chinese interaction has occurred during the last year. American businessmen have been visiting China—computers and oil-well-drilling equipment have been sold and Pan American Airlines is now under contract to build a chain of resort hotels. Fluor Corporation is developing a copper-mining complex, and Coca Cola will sell and bottle its product in China. Each week one can read Wall Street Journal reports of new contracts between American firms and the PRC.

Numerous PRC technical delegations have visited the United States as well as Europe and Japan. Many students will study at American universities; the first group arrived last November to study engineering at Stanford.

On January 1, 1979, the United States established normal diplomatic relations with the People’s Republic of China. The ultimate effect of this action on world politics is unknown, but our journey shows that one immediate result will be increased technology transfer between the two nations.

University activity

With the removal of the “Gang of Four” in 1976, real recovery from the excesses of the Cultural Revolution could begin. Former sympathizers appear to have been demoted from their positions on the revolutionary committees at the universities, and reassigned elsewhere. Professors and researchers who were sent to the fields or factories are being reinstated and given special considerations in the form of higher pay and a restoring of their once lost prestige.

Elite schools are being established at all levels. They are given the best teachers and facilities. We visited one experimental middle school attached to Peking Teachers University. Here we were told that only children who passed entrance examinations would be admitted, and that they would all be very likely to gain admittance, in turn, to the most prestigious universities.

During the Cultural Revolution, examinations were abolished along with curriculum requirements. In 1978, for the first time, rigorous, uniform examinations were given nationwide for entrance to universities. A score of at least 80 percent was required for entrance to a university, and higher for the best schools since they take the cream of the crop. Some students were also chosen to study abroad.

Recovery will be painfully slow, for China is missing a ten-year link in her chain of education. Reports were brought back several years ago quoting goals of enrollment for various universities. These goals do not seem to be on schedule. One ongoing result of the disruptions—the shortage of senior personnel—will be felt in all scientific endeavors and most certainly in the universities, where some members of the junior faculty, recruited during recent years, have minimal training.

The required course of study to which the universities have returned includes both courses in basic technology and expanded numbers of electives. Computer science departments are being formed and curricula are being developed. There is considerable interest in the IEEE model curriculum. The credit system, once also abolished, is being reinstated.

It would appear from the large ratio of faculty to students that a considerable number of personnel brought in during the Cultural Revolution are still at the universities.

The non-existence of modern Chinese-language textbooks hinders technical education in Chinese universities. The government has recently initiated a textbook development program involving all of the Chinese universities. The faculty at Tsinghua, for example, have been assigned the task of producing texts for computer architecture, microprocessors, and parallel processing.

In education, as well as in computer development, the Chinese seem to be following the US practice of separating hardware and software.

We visited five universities: Tsinghua, Peking, Nanking, Futan, and the South China Institute of Technology.

March 1979
Tsinghua University. This is a renowned institution whose graduates have been noted for their excellence. It is mainly engineering and science oriented. The campus comprises more than 200 hectares (about 500 acres). There are 180 professors and associate professors and nearly 900 lecturers. For the academic year 1980-81, 7000 students will be enrolled at Tsinghua. Three hundred graduate students have been enrolled this year. There are 250 students and eight graduate students enrolled in the computer science program. Computer science is included within the electrical engineering department and reflects an engineering orientation.

The tour here included an integrated circuit laboratory, a computer laboratory, and an optics teaching laboratory containing a fiber-optics demonstration, a three-color laser, a laser interferometer, and a holography demonstration.

Tsinghua is involved in the production of ICs. Within the labs we saw numerous DJS-130 machines. We also saw a CRT graphic display that was developed at Tsinghua and a digitizer, which had just been received. We saw a Bulgarian disk, dismantled in a clean room, connected to a DJS-130. It was obviously being closely examined. We also saw a step-and-repeat laser-positioned camera developed by Tsinghua for IC mask generation. Tsinghua played an active role in the development of the DJS-130 computer and also in the development of LSI PMOS devices. They continue to play an active role in the development of computer graphics and in IC design automation.

The library appeared to be well stocked. The technical periodical room—available only to faculty—contained about 400 journals. Some were original copies and were current, but most (including all of the IEEE publications) were copies produced by the Chinese government. These were less current, since the copying process takes about six months.

Peking University. This is perhaps the most famous university in China. It is located on a 150-hectare site in the suburbs of Peking. There are 22 departments—12 in the natural sciences, seven in the humanities, and three in foreign languages. The present faculty numbers about 2700. There are 8500 students, of which 450 are graduate students.

Engineering technology at one time had been wholly transferred to Tsinghua but has now been reinstated at Peking. In August of 1978 they created a new computer science department. The curriculum is still being developed—the basic courses are the same as those required by the mathematics and physics departments, but courses in computer software, hardware design, and microelectronics are offered.

The Peking University Computation Center has a DJS-18 computer. This is a 48-bit word, 150-KIPS, general-purpose machine with a main memory of 64K in core. A number of standard peripherals are available, including an electrostatic printer, an x-y plotter, magnetic tape units, and paper-tape readout/punch equipment. The machine was constructed in 1971 and is said to be in use 20 hours per day.

New research projects involve Chinese character processing for typesetting newspapers and books, microprocessors, microprogramming, software theory, operating system methodology, and LSI circuits.

The Peking University library is reported to contain 3,100,000 books, some 400,000 of which are in English.

Nanking University. Nanking University consists of five social science departments and 14 natural science departments. There are 3500 undergraduate, 45 foreign, and 180 graduate students. Of the 1600 faculty members, half are devoted to research since enrollment is still low. The other half spends 30 percent of its time on research. Research priorities are set by the country’s needs, the province’s needs, and the university’s needs. Present research activities include hardware and software projects for the DJS-200 series. Pascal-like programming languages are under development and work on the Nanking-designed DJS-200 operating system continues. The university is also developing Cobol for the 200 series, and a project for designing a display for Chinese characters is underway.

The Computer Science Department is new; it used to be part of the Mathematics Department. In addition to basic required courses, faculty-specified electives are divided into two groups—software and hardware. General electives are also divided along these lines. Our contact was with the software faculty. This group was impressive—well-read and conversant with the state of software theory and practice in the US.

Students attend classes approximately 20 hours per week. Fifty percent of that time is devoted to computer science subjects. The department has 160 undergraduate students and two graduate students. (One hundred additional students were due to arrive in October.) Of the 57 faculty members, about 10 percent were female. The percentage of female students has dropped since the installation of the entrance exams. No one volunteered the present percentage.

A new library is under construction and will house 2,500,000 volumes.

Futan University. At Futan there are 14 departments, evenly split between humanities and natural sciences, as well as four research institutes. There are 3600 undergraduates at the university, all resident students, and 300 graduate students. The faculty numbers 2000.

The Department of Computer Science has four areas of specialization: software, hardware, information processing, and automation. A teaching-research section is responsible for each specialty. The department has 499 students and 150 teachers.

We visited seven labs at Futan. Three were concerned with the production of ICs. The fourth contained a Model 719 computer, built from 1971-73. This machine has an Algol 60 compiler and is scheduled for replacement, since they are now teaching Basic and Fortran IV. The fifth lab contained a
tunable dye laser with a nominal output of 50 millijoules. The remaining labs were concerned with holographic storage and character recognition. In general, the equipment was made in-house and was somewhat out-of-date when matched against present Chinese production.

South China Institute of Technology, SCIT has 6300 students. Fifty graduate students were admitted in 1978. The 1985 goal is 15,000 students, including 2000 graduate students. There are 2030 teachers, of whom 93 are professors and 208 assistant professors.

SCIT is presently setting up a software specialty. The computing center has a Model 441B3 computer manufactured in Tientsin in 1968 and received by the institute in 1975. Every student learns Fortran. A DJS-120 and a DJS-130, both minicomputers, are available.

Computer development, 1958-1978

The number of general-purpose computers in China in 1976 was estimated at 1000. The typical Chinese computer in current production is a third-generation machine employing magnetic core memory and paper-tape I/O. The fastest machine developed in China to date is the Model 013, rated at 2 MIPS. The fastest in regular production is the TQ-6, rated at 1 MIPS. Production can be divided into machines having the characteristics of a minicomputer and those having the characteristics of a large, general-purpose mainframe computer.

Table 1 lists some of the known Chinese computers. Basic characteristics are listed as well as the source of the information. This information has been compiled from previous literature and from information gained during our visit. No attempt is made here to present the complete history and genealogy of computers in China. Their development has involved many institutions, and the information available to outsiders is incomplete. It is likely that insufficient knowledge of the details of computer development exists even in China. If the history is to be written, it will have to be written by the Chinese, and they have more pressing problems at present. Identification of computers is confused by different national and factory designations for the same computer. The national DJS designation derives from Dainzi Jisuanji Shuzi, the Pinyin transliteration of the Hanzi characters for "direct computer numeric." The national designation for analog computers is DMJ.

The Fourth Ministry of Machine Building has overall jurisdiction over computer production. Research, development, and production typically involve universities, research institutes, and factories. Proposals for computer development are evaluated by the

<table>
<thead>
<tr>
<th>YEAR</th>
<th>COMPUTER</th>
<th>LOCATION</th>
<th>WORD LENGTH (BITS)</th>
<th>MAX. MEMORY SIZE</th>
<th>RATED OPS. PER SECOND</th>
<th>REFERENCE</th>
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<tbody>
<tr>
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<td>AUGUST 1</td>
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<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<td>1962</td>
<td>DJS-1</td>
<td>PWF</td>
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<td>2K</td>
<td>1800</td>
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<td>3000</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>1966</td>
<td>DJS-6</td>
<td>PWF</td>
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<td>100,000</td>
<td>12</td>
<td></td>
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<tr>
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<td>DJS-21</td>
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<td>8K</td>
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<tr>
<td>1968</td>
<td>MODEL C-2</td>
<td>SICT</td>
<td>128K</td>
<td>180,000</td>
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<td>1970</td>
<td>MODEL 111</td>
<td>PICT</td>
<td>32K</td>
<td>110,000</td>
<td>12,9,12</td>
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<td>32K</td>
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<td></td>
<td>(TQ-16)</td>
<td>SRF#13</td>
<td></td>
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<tr>
<td>1971</td>
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<tr>
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<td>8K</td>
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<tr>
<td>1973</td>
<td>MODEL 719</td>
<td>FUTAN U.</td>
<td>32K</td>
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<td>8K</td>
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<td>1976</td>
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<td>2,8,14</td>
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<tr>
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<td>DJS-5050</td>
<td>ANHWEI RW,</td>
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<tr>
<td>1977</td>
<td>(MICRO)</td>
<td>TSINGHUA U.</td>
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<tr>
<td>1977</td>
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<td>PWF</td>
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<tr>
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<td>1978</td>
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<td>N/A</td>
<td>1,000,000</td>
<td>7</td>
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</table>

Table 1. Chinese computers, 1958-1978.

Unidentified, unverified machines are not included. The first generation was from 1958 to 1965, the second from 1966 to 1968, and the third from 1969 to the present.

March 1979
The New Long March

Mao Tse-tung's Long March from Kiangsi to Shensi in 1934 was a short-term military disaster but a long-term tactical triumph. Encircled by Chiang Kai-shek's forces, Mao's band of 100,000 abandoned their domain in Kiangsi's mountains and crossed some 6000 miles of the world's most difficult terrain in search of a territorial base. They reached their destination over a year later, a meagre 30,000 strong. The poetic achievement of that group has entered the legends of the people. The fact of the accomplishment, achieved against great odds, gave Mao undisputed leadership of the Communist movement and contributed to his "mandate from heaven"—that element so necessary to the successful takeover of the country's government.

China is now engaged in a national effort to attain technical equality with the West by the year 2000. Signs and slogans proclaiming this objective inundate the populace. The goal is the subject of dramas, dances, and the lyrics of children's songs. Even candy wrappers exhort the people to show great zeal in straying toward this goal. The effort has been called "The New Long March," a name particularly appropriate because, like its namesake, it will be made against tremendous odds and will irrevocably alter Chinese life.

The movement's namers were also wise in making an oblique reference to the late leader of the Communist Party, for in doing so they seem to be both giving credit for his accomplishments and offering an unstated apology for digressing from his path. Technological advancement in China calls for a break from the self-reliant policies of Mao and a new dependency on other nations, particularly in the West. As one American China-watcher put it, "Mao must be turning upside down in his mausoleum."

In 1978 Teng Hsiao-p'ing signed commitments to purchase $27 billion in technological equipment and supplies from Japan, Western Europe, and the United States. Japan has obtained the majority of this business and recently signed a $20 billion long-term trade agreement with China. Under this agreement, China will provide oil to Japan, and Japan will provide steel and steel mills to China. France and China have a $13.5 billion trade agreement involving telecommunications satellites, TV broadcasting, modernization of a steel complex and construction of a magnesium plant and two 900-megawatt nuclear power plants.

At present, the United States is in third place in the trade race. The actual trade between the United States and China for 1979 is estimated at $1.3 to $2.2 billion, of which more than half consists of China's agricultural imports. No matter what the level of technology transfer from the West, China's importation of food is expected to increase substantially—although technological development is now a first priority, in the long run it is the problem of feeding its population that will determine the nature of China's dealings with outside powers.

Since the Communist takeover, a primary concern has been increasing the productivity of the land. Despite the wholehearted, strenuous efforts of the cheapest labor force in the world, grain productivity has grown only 3 to 3.5 percent a year, barely keeping ahead of the population growth of 1.8 to 2 percent. By the year 2000, China's urban population is estimated to be 300 million and its rural populace a mind-boggling one billion. Even at their hoped-for productivity gain rate of 4.5 percent per year (which no major grain producing nation has ever met), those numbers will mean that a lot of people will go hungry. The realistic policies of Teng are intended not to bring in television sets and automobiles, but to feed the world's largest nation and keep it governed by a unified body. Technological development will serve these objectives.

The financing of technological development is a major undertaking requiring sophisticated planning and management. Exports, tourism, and credit are the sources of the hard currency needed to fund the country's modernization, and the management and development of these sources is a critical and challenging component of the modernization program. China has little debt and an excellent credit rating. In recent months, the Chinese have abandoned their long-held ideological opposition to borrowing money from foreign sources. This action was necessary to fund the initial steps in the modernization drive. Japan and Western Europe have provided low-interest loans. China has natural resources, including oil, that are underdeveloped and can become a major source of revenue. The export of those resources is an essential part of the existing Chinese trade agreements, and will become a factor of great import in its dealings with other nations.

The problem of how to deal with the outside world has confounded China during most of its history. Generally, there have been two schools of thought regarding interaction with the outside world. One faction—conservative, reactionary, idealistic, and xenophobic and including such ideologically diverse groups as the Manchu aristocracy and the Maoist extremists—advocates avoiding all foreign contacts and ignoring the existence of the outside world. The opposite faction, identified as pragmatists or realists, includes the technocrats. This group believes that isolation from the outside world is impossible and that Western technology should be put to the service of "Chinese genius." This group included Chou En-lai, the former Premier who died in 1976, as well as his often purged protege, Teng Hsiao-p'ing.

A reading of Chinese history makes it easy to understand the reasoning of the conservative, reactionary group even if one's natural tendency is to side with the technocrats. This history is dominated by internal strife and famine, conflict with immediate neighbors—particularly Japan and Russia—and nightmashir interaction with colonizing Western powers. Internal control was traditionally held by local warlords. When one clan or family grew strong enough to demand fealty from the others, a dynasty was formed. Dynasties ruled for periods from 100 to 400 years, all eventually weakening into a period of turmoil that proved to be a testing ground for the next power-
to-be. Traditionally, the new ruler was the one with a demonstrated "mandate from heaven," strong evidence of which was the ability to control everybody else and, especially, to protect the Chinese from outside encroachment.

The Manchus, aliens from the north who demonstrated their mandate by displacing the Ming in 1644, had degenerated into a puppet government by the 20th century. By the time their reign ended with the formation of the Republic in 1912, China was little more than a semi-colony with Great Britain controlling the Yangtse Valley, Canton, and Tibet; France dominating the provinces adjacent to Viet Nam; and Germany controlling the province of Shantung. Russia held Outer Mongolia and Sinkiang Province, and Japan controlled Manchuria and Fukien. Shanghai had become an international city with foreign sections and concessions.

The creation of a Chinese Republic in 1912 was evidence of the desire to shake off the "foreign devils," but President Yuan Shih-k'ai proved too weak to unify the country. Internal turmoil continued and external aggression, particularly from Russia and Japan, increased.

Japan took full advantage of the Western powers' preoccupation with World War I to strengthen its claim to Manchuria and Korea. When the Western powers acknowledged Japan's sovereignty over China in the Treaty of Versailles, the reaction in China culminated in a mass movement that called for a wholesale change from a traditional decadent society to a modern progressive state. This reaction, called the "May Fourth Movement of 1919," launched movements towards Westernization that included Marxism. The desire for Westernization, although an apparent paradox, is not a departure from Chinese ideals. It is a manifestation of the pragmatist spirit—the strong, centralized Western-style state merely serves "Chinese genius."

After the first Long March, an alliance between the Nationalists (now under the leadership of Chiang Kai-shek) and the Communists was formed in order to end Japanese expansionism. Japan's World War II defeat and subsequent withdrawal left the two factions free to settle their own civil war, which ended with the withdrawal of Chiang's government to Taiwan and the establishment of the People's Republic with its capital in Peking, in 1949.

Although Mao Tse-tung's mandate was seemingly undisputed—his control of the country's internal problems was the most effective in its history and the expulsion of foreign influences was total—the road to Chinese Communism has been very rough going. One of its most difficult times was the Cultural Revolution, Mao's attempt from 1966-69 to create the most ideologically pure Communist state in the world. During the Cultural Revolution, Mao attempted to reaffirm his tenet of "continuous revolution" to maintain the dictatorship of the people (working class, peasant class, and soldiers) over capitalists and intellectuals who valued specialization and class stratas.

Every organized activity in China was affected. On July 13, 1966, all schools were closed. Secondary schools remained closed for four years. Teachers were vilified and persecuted by activists of the Revolution. Professors were sent to the fields or factories to reform their vision of the world by contact with workers and peasants. Professorial positions, as well as positions in research, were taken over by proletarians. Course content was modified in favor of political teaching. The traditional facilities of universities, such as lecture halls, libraries, and laboratories, were supplemented or even supplanted by workshops, factories, and farms. Admissions to universities were made according to maturity in political and social understanding and dedication to the aims of the Revolution. Practical experience of any kind took precedence over academic achievement. Courses were cut from four or more years to three, and grades were eliminated. Publication of technical journals was abolished. Some campuses became veritable battlegrounds as different factions of revolutionaries fought mini-wars among themselves. Some intellectuals did not survive the transfer to the unwelcoming countryside or the physical demands of their new lives.

Idealistic though the movement was, the scars left by the Cultural Revolution are deep. Since the official end of the movement in 1969, universities and industrial systems have been gradually returning to a bitter normalcy. Those brave enough to voice protest to the movement have been castigated out of respect to the Revolution's mentor, who continues to be revered as a demi-god. However, the direction now being taken towards technological advancement and international involvement indicates that, off the record at least, the Cultural Revolution is recognized as a big mistake.

It is important to note that, disastrous as ideologically pure communism is for the scholar or creative genius, for the rural peasant it was a giant step forward. Literacy was introduced and opportunities to emerge from the peasant way of life became available for the first time in history in parts of China. The danger of introducing Western technology and methods to China, as Mao was well aware, is that the huge rural populace of the country tends to be forgotten.

The current move to Western trade and exterior mutual dependency is a triumph of the realists of the Communist government. China's cheap labor force and natural resources, of which there are an abundance, will in effect be traded for food, of which there is a dangerous scarcity. And to the extent that high technology supports the goals of the pragmatists, it too will be imported and even given the highest priority. But the move is a dangerous one, for if history proves consistent, increasing technological advancement and contact with the West could lead to a new Chinese middle class interested in improving its way of life at a proportionately greater pace than possible for those in the rural areas of the country. And if the food supply and demand ratio continues at its present course, a natural disaster such as drought could be interpreted as loss of mandate. There is no greater spur for revolution than famine. The second Long March will have to be carefully undertaken in order to avoid being the first step to a third.
ministry for appropriateness and consistency with the national program.

The production of electronic equipment, according to a 1978 study by the Joint Congressional Economic Committee, involves 200 major plants employing nearly a half million people, about 500 smaller plants each employing up to 500 people, and perhaps 1500 neighborhood factories. The typical neighborhood factory originated as a producer of non-electronic components such as door handles. The conversion to electronics production, involving training and equipment, was funded by the government.

The application of the Chinese "three-in-one" concept results in considerable interaction among (and in some cases, little separation of) teaching, research, and production. Separation became minimal during the Cultural Revolution, when many university laboratories became factories. On the other hand, the application of the principle of self-reliance, often expounded by Mao, limits interaction on a broader level. This results in a lack of standardization and product interchangeability and in duplicative, uncoordinated efforts.

In the past, a number of universities and research institutes constructed their own computers. In some cases the machines were design prototypes; in others they were constructed to obtain a computational facility. Direct construction of computers by universities for the purpose of computation appears to be on the decline, probably due to increased availability of industrially produced machines. However, the close involvement of universities with production and design continues. At present, research institutes appear to be leading the development of prototype machines.

The most prestigious research institution is the Peking Institute of Computer Technology of the Chinese Academy of Sciences. PICT was established in 1956 as part of the program to achieve the objectives of the 1956 twelve-year plan for the development of science and technology. PICT currently employs about 1000 people involved in research, development, manufacturing, application, and service-bureau activities. The divisions of the institute are administration, manufacturing, circuits and computer architecture, magnetic storage devices, electric power, numerical analysis, software, and theory.²

The first generation. The first Chinese digital computer, the August 1, became operational in 1958. It was based on plans and specifications of the Ural-2 machine provided as part of the Soviet technical assistance program. The Chinese copy apparently was operational before the Soviet original.15-16

The Peking Wire Factory started production of copies of Soviet machines in 1958 in cooperation with PICT. The Russians departed in 1960, but the production and development of Soviet-based designs continued. The DJS-1, the Chinese version of the M-3, went into production in 1962. The production of the DJS-2, based on the BESM-2, started in 1963.

The second and third generations. The first transistorized second-generation machine, the DJS-21, was exhibited in Peking in 1964. PICT began the design of the 109-C, a transistorized machine employing emitter-coupled logic, in 1964 and completed it in 1967.¹² Production of the DJS-6, a second-generation machine manufactured at the Peking Wire Factory, was just being stopped at the time of our visit. Integrated circuits became available in China in 1968.¹³

Figure 1. One of the racks of the 013 computer located in the computing center of the Academy of Sciences in Peking. It is a 2-MIPS machine. The rack is approximately six feet high; circuit boards can be seen in the lower half of the rack.

Figure 2. A test station for one type of 013 circuit board.
and the Model 111, developed at PICT, was the first third-generation machine. The logic was TTL.

The Model 013 computer, fastest in China, was developed by PICT (Figures 1, 2). This 48-bit, 2-MIPS, general-purpose machine has a four-way overlapped core memory of one million bytes, a cache memory, read-only memory, pipelining, overlapped instruction lookahead, and a three-functional-unit CPU. Small-scale integrated circuits using two to five gates per chip are employed in the CPU. The rating of 2 MIPS is based on a mix of fixed-point and floating-point operations.

Table 2 lists certain characteristics of the IBM Stretch and of three machines developed at PICT. The architectures of Stretch and the PICT machines have many similarities. The data in Table 2 indicate the application of advanced algorithms for the implementation of arithmetic. Stretch used the SRT division method. Note that memory access time for the PICT machines improved by a factor of three from 1965 to 1970 but has remained substantially unchanged since 1970. This is perhaps due to a limitation in core size due, in turn, to manual fabrication. A significant part of the 013's performance advantage over the 111 appears traceable to the fivefold increase in circuit speed. The clock rate of the 013 is 6 MHz. The IBM 7090 (1960) had a clock rate of 4.5 MHz, the IBM 7094 (1964) one of 7 MHz, and the CDC 6600, (1964) one of 40 MHz. These were of course second-generation machines, and the 013 is a third-generation machine.

The extensive set of peripherals includes magnetic disks. There is no relocation hardware. The one 013 is located in the computing center of the Chinese Academy of Sciences in Peking. It seems there are at present no production plans for this machine, which is currently undergoing test evaluation and software development. Problems of reliability are known to exist in the magnetic-film cache memory, and problems in the development of the disks are suspected but not confirmed. The disk on the 013 appears to be an early prototype. The TQ-6, which is in production, is supposed to use a similar disk. A mean time to failure of 20 hours was quoted for the 013, and this information coincides with that obtained by Allen and Schwartz last year.9

### Table 2.

<table>
<thead>
<tr>
<th>COMPUTER</th>
<th>YEAR</th>
<th>FIXED-POINT ADD TIME</th>
<th>FLOATING-POINT ADD TIME</th>
<th>FLOATING-POINT MULT. TIME</th>
<th>FLOATING-POINT DIVIDE TIME</th>
<th>STORE</th>
<th>MEMORY ACCESS TIME</th>
<th>CIRCUIT TECHNOLOGY</th>
<th>GATE DELAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>STRETCH</td>
<td>1961</td>
<td>1.8</td>
<td>7</td>
<td>2</td>
<td>20 NSECS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>109C</td>
<td>1965</td>
<td>7.3</td>
<td>32</td>
<td>7.6</td>
<td>6</td>
<td></td>
<td></td>
<td>TRAN-SISTOR</td>
<td>20 NSECS</td>
</tr>
<tr>
<td>111</td>
<td>1970</td>
<td>5</td>
<td>12</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>TTL-SSI</td>
<td>20 NSECS</td>
</tr>
<tr>
<td>013</td>
<td>1976</td>
<td>1.2</td>
<td>4</td>
<td>4</td>
<td>1.5</td>
<td></td>
<td></td>
<td>ECL-MSI</td>
<td>4 NSECS</td>
</tr>
</tbody>
</table>

The Shanghai Institute of Computer Technology was established in 1959 as part of the Chinese Academy of Sciences. The objectives of SICT are similar to those of PICT, but SICT is smaller. It has provided computing services since 1969, using the C-2, a 25-KIPS second-generation machine built in 1968, and the 709, a 110-KIPS third-generation machine.9 (The designation 709 derives from the date—September 1970—when the project was begun.) The design and prototyping of the 709 were done in 15 months. The team involved SICT, Futan University, and the Ching Jiang Radio Factory, which was previously a neighborhood door handle factory. The conversion of the door handle factory to a computer manufacturing facility is frequently cited as a successful example of the principle that “knowledge comes from practice.” Futan constructed its own prototype of the 709, designated the 719 (named after the date when the design phase was completed); the 719 became operational in 1973. It is rated at 125 KIPS, a small improvement over the 709. There are 719 computers located in various Shanghai universities. The TQ-16, currently manufactured at Shanghai Radio Factory No. 13, seems to be the basic 709 design with an interrupt system added. At Futan we learned that the design of a 1-MIPS, multichannel, time-shared computer had begun in 1975. This will be a 48-bit machine with addressable registers. The designation is not known, but completion is scheduled for the end of 1979.

The TQ-6, with a performance of 1 MIPS, is the fastest Chinese computer in regular production. Efforts to produce this machine began in 1973 at SRF No. 13. Production has ranged from a low of two machines per year to a maximum of five. Lee12 reported the output at two units per year in 1974, which utilized almost all of the factory’s core-memory production capacity. The 1978 selling price of the machine is three million yuan (about $1.8 million), including software and peripherals.

The TQ-6 is a 48-bit binary, floating-point, 128K-core-memory machine incorporating instruction lookahead. It is designed for general scientific calculation. The peripherals include drums and a magnetic disk similar to the 013 disk. (The disk is not manufactured in Shanghai.) The operating system,
designated TQ-6 Kuan-Li, permits multiprogramming. It occupies 20K words of main memory and can handle up to four job streams concurrently, one of which is I/O spooling. Memory partitions are static and there is no virtual memory or paging, but three levels of interrupt are available. Circuit technology is MSI TTL. The TQ-6 is physically a very large machine; nine 4-foot-wide racks are used as follows: main memory (4), control (1), CPU (1), and I/O channels (3).

Szuprowicz references the DJS-11 machine. The characteristics of this machine, described in January 1974 in a Chinese publication entitled Wuhisen Tien, are identical to those of the TQ-6. It is highly likely that the DJS-11 and the TQ-6 are the same machine; the first TQ-6 came off the production line early in 1974, coinciding with the time of the news story. And 1-MIPS machines with multiprogrammed operating systems were as rare in China then as they are now. The DJS designation is of course the national designation, while TQ is a local designation used only by Shanghai Radio Factory No. 13. When asked about the existence of other 1-MIPS machines, the representatives of SRF No. 13 replied, “We do not know of any other.”

In April 1977 the Chinese announced an 8-bit microcomputer designated DJS-050, built with Chinese developed MOS LSI circuitry by the Anhwei Radio Works in collaboration with the Electronic Engineering Department of Tsinghua University and the No. 6 Research Institute of the Fourth Ministry of Machine Building. We did not see this machine during our visit. However, Tsinghua is a producer of LSI p-channel MOS devices. This plus the general state of LSI technology in China should permit the fabrication of microprocessors at Tsinghua. We were told at Tsinghua that present microprocessors use 40 separate chips, but that a single-chip microprocessor is under development.

The DJS-100 series was conceived as a series of software-compatible, 16-bit, magnetic-core minicomputers based on the Nova 1200 architecture. The Chinese purchased a licensed version of this machine made in Japan by Nippon Minicomputer Co. Initial plans called for four models, numbered 110, 120, 130, and 140. The design project was started in 1973 and involved the Tientsin Institute of Radio Technology, Tsinghua University, Peking Radio Factory No. 3, the Nuclear Energy Research Institute of the Chinese Academy, Shanghai Teacher’s University, SRF No. 13, and the Shanghai Chung-hsing Radio Plant. A design and specifications were produced. Various institutions have produced machines based on the common design. However, differences in hardware technology and architecture exist between models manufactured at different institutions. Software compatibility was not generally achieved. This failure is blamed on the Gang of Four, whose actions were said to have stymied coordination.

The typical machine in this series incorporates a 32K core memory with a 2-μsec cycle time; the logic is TTL. Programs are input via paper tape. Most machines have compilers for Basic and Fortran and an assembler.

The DJS-131 (Figure 3) is the 130 design with floating-point hardware. Speed is given as 500 KIPS. This machine is in production at SRF No. 13; nine completed units were observed in final test.

The DJS-154 (Figure 4) is built at the Peking Wire Factory. Production started in 1977 and is proceeding at a rate of 60 units per year. The DJS-154 was designed for general-purpose computation and process control. Add speed is listed as 4.8 μsecs. The main memory is 16K to 32K words of core; a magnetic drum provides the only mass storage. DMA and programmed I/O are available, and up to 62 I/O devices may be connected, including A/D and D/A converters. A real-time operating system is available for this machine, as is the standard 100 series software.

The series DJS-200 is a family of general-purpose computers for batch computation. They are similar in architecture but have different speeds, word lengths, and memory sizes. These machines have 16 addressable registers and use ROMs for the implementation of microinstructions. The set of 192 machine-language instructions is to be the same for all models.
The basic data word is 64 bits, and the basic instruction word is 32 bits. Fixed-point and floating-point capabilities exist. The series 200 architecture is original, but it was specified after detailed studies of the IBM 360/370 and the CDC 6600/6700 designs. It was stated that this project was started before the Gang of Four era but that actions of the Gang delayed the project. The DJS-200 series project team includes factories, research institutes, and universities. Although software compatibility and program interchangeability are goals of the series 200 effort, various factories will not use identical hardware. The four models in the 200 series are listed below.

210 - 100 KIPS, 16-bit memory word.
220 - 200 KIPS, 32-bit memory word, 32K to 64K. The 220 operates in the 100-150 KFLOPS (thousand floating-point operations per second) range.
240 - 400 KIPS, 64-bit memory word.
260 - 1 MIPS, 64-bit memory word.

The different models employ varying degrees of serial-parallelism to obtain compatibility between the basic word length and the memory word length.

Nanking University did the 210 and 220 hardware organization. The operating system design for both of these machines is a current project at Nanking. The design of the operating system for the 240 machine is a current Peking University project; the 260 machine is also being designed in Peking. A factory in Wuhsi is producing the 210. Prototypes of the 220 have just been completed and are being tested at the Peking Wire Factory (Figure 5), the Nanking Telecommunications Factory, and SRF No. 13. Languages planned for the 200 series include Algol 60, Basic, Cobol, Fortran IV, and an assembly language. Nanking is also developing a Pascal-type compiler-writing system for the series.

The Fortran compiler for the 013 was written in assembly language, representing a significant advance in systems programming methodology. It is a two-pass compiler with an editor. An 013 PCY compiler has also been developed for systems programming, but details concerning its use are not available.

Operating systems technology lags behind hardware technology, undoubtedly a consequence of the way computers are used in China. User pressure for linking loaders, supervisors, time-sharing, and virtual memory is developing slowly. Most operating systems have been the minimal compile-and-go type, a situation partially due to the absence, until recently, of magnetic disks. Disks are now in use on the TQ-6 and the 013. Considerable effort is being devoted to both the theory and practice of operating systems both at Nanking University and at PICT.

The 013 operating system now has both a supervisor mode with privileged instructions and a compute mode. The system does include a linking loader. Software relocation is also under consideration.

Operating systems developed for production machines include a real-time operating system for the DJS-154 process control computer and an operating system supporting multiprogramming for the general-purpose TQ-6 machine. Operating systems for the 200 series are now being developed at Nanking and Peking.

Programming methodology in China is affected by the almost universal use of paper tape, making careful formatting of programs unnatural. Present printers carry only Roman characters, a limitation creating a problem in recording program comments. Three choices are available at the present time: (1) carry the comments in a foreign language; (2) carry the comments in the Chinese phonetic Pinyin system, which is unnatural for most Chinese; and (3) put the comments in by hand. Since none of these is an ideal solution, there is considerable research directed toward developing I/O systems to handle standard Chinese characters.

Software

Numerous high-level computer languages are used in China, but all languages may not be available at each installation. Basic, PCY (a Chinese version of Algol 60), and Fortran IV are the most common languages, and Cobol and Pascal compilers are under development. Lisp has been developed for a very small machine at the Peking Mathematics Institute. It appears that most of the introductory computer programming courses use Basic or Fortran; the extent to which high-level languages are used in applications programming is unknown. Assembly language predominates at Tsinghua, high-level language at Peking. Apparently PCY was available for several machines, including the 709 at Shanghai and the 109-C in Peking, in the 1972-74 period. However, assembly languages were not common then, and the compilers were developed using machine-language octal code.

Figure 5. Part of the DJS-220 computer undergoing prototype testing at the Shanghai Radio Factory No. 13.
High speed memory technology

Both the 013 and the TQ-6 machines use magnetic ferrite cores in their main memories; cycle times for these memories is 2 μs. Speed is obtained by a four-way overlapping of the memory access. The core dimensions (in millimeters) are 0.6 outside diameter and 0.4 inside diameter for the 013, and 0.8 outside and 0.56 inside for the TQ-6, with the cores manually assembled into three-wire planes. The 013 incorporates a single-error-correcting, double-error-detecting code, so the basic word length in memory is 56 bits—48 data bits and 8 parity bits.

The 013 uses a biaxial ROM with an access time of 400 nsec to store parts of the operating system. In 1977 the size of this store was reported as 16K.1,2,4 However, we were told it is 140K. This may be an error or it may be an indication of operating system developments at PICT.

Microprogrammed instruction interpretation used in the DJS-220 machine involves a 512 x 53-bit ROM. The Nanking Telecommunications Factory has implemented this ROM as a diode. The detailed design is not known, but it is known that the system is not reliable.

Tsinghua has produced 1024-bit RAMs with a 600 nsec access time,11 but their yield and reliability is unknown. Memory technology and computer performance, in general, are held up by inadequate facilities and technology for the production of large numbers of LSI devices. Performance of Chinese computers should improve when this problem is solved and LSI semi-conductor devices replace magnetic cores.

Peripheral equipment

We saw many standard peripherals attached to various computers, including teletypewriters, high-speed paper-tape readers and punches, and 16-track magnetic tape units recording at 25 bits per millimeter. Various line printers exist, with performance ranging from 600 lines per minute at 80 characters per line to 800 lines per minute at 120 characters per line. Floating-head magnetic drums are common and have capacities on the order of 6 million bits. We saw numerous x-y plotters of standard design; quantization of data, however, was coarse.

At Tsinghua University we saw a digitizer used for IC masks. Also of interest was a graphics display (Figure 6) developed by Tsinghua, now beginning production at the Nanking Telecommunications Factory and at SRF No. 13. At the moment, only four or five working units exist in China. Designated SZX-1,19 the terminal is equipped with a light pen and employs single buffering, with the display buffer holding 4K words. Vectors are generated digitally and the display has 1024 x 1024 resolution; 16 bits are used to represent the longest vectors. The vectors are somewhat noisy, with poor end-point matching. The terminal is to be used for computer-aided design. Numerous alphanumeric terminals, with raster-type CRT displays, also exist. The keys include some Chinese characters.

At the Nanking Telecommunications Factory we saw an interesting impact matrix printer similar to a DECwriter. Driven by an 8K x 8-bit RAM, it prints at 50 characters per second with 80 characters per line. Dots are separated 0.26 millimeters horizontally and 0.4 millimeters vertically. This device can print Chinese characters.
PICT has developed an electrostatic printer with a 7 x 9 dot matrix and a print rate of 30 lines per second. There are 120 characters per line. Software for printing Chinese characters is under development.

The magnetic disk presently used on the 013 and the TQ-6 looks like an early developmental model (Figure 7). The disk drive is a cylindrical unit about 1.8 meters long and 0.7 meters in diameter, with a horizontal axis. The motor is in the middle of two stacks of 11 double-sided disks measuring 50 centimeters in diameter. Four movable heads are provided for each disk surface. With a 10M-bit capacity per drive, the unit rotates at 1500 rpm and has an access time of 50 msecs. The drive is contained in a plexiglass cabinet and kept in a separate room, apparently isolated for additional cleanliness.

The graphics terminal, the light pen, and the impact printer were part of a recent national design project. Factory prototyping is now underway.

Development of smaller disks, approximately 35 centimeters in diameter, and the continued development of I/O devices for Chinese characters can be expected.

Applications

Applications mentioned during our visit fall into three categories—scientific computation, industrial control, and design automation. Some fraction of the computers in China are employed in military activities, about which we obtained no information. Scientific application areas include shipbuilding, power-network analysis, crystal structure evaluation, geodesy, surveying, and lens design. The TQ-6 has been used for weather forecasting and seismic data analysis.

At the Nanking Telecommunications Factory we saw two special-purpose systems for real-time control. The DJF-2 subway control system will maintain schedules and train separation for the Peking subway. Other applications, involving the DJF-220—such as control of railroad yards—are being considered. The 702 computer, also designed at NTF, controls a weather radar. Numerous applications of computer control to industrial plants manufacturing such things as cement, semiconductors, and terramycin were mentioned. All of these applications use the DJS-120 computer.

Direct numeric control of machines is receiving special attention, including the development of the APT compiler for the DJS-120. Several numerically controlled machines, including a milling machine, a single-column jig boring machine, and a heavy duty lathe, were displayed at the Shanghai Industrial Exhibit. At the moment, the standard model is a controller designated the SK 3-5. This device has no internal memory and is driven by paper-tape input specifying step-by-step increments in x, y, and z coordinates, with a Nixie tube display of the x, y, and z positions.

We saw two examples of the application of computers to automatic testing. The Peking Wire Factory uses a prototype of the DJS-154 to test circuit boards, and Shanghai Radio Factory No. 13 a prototype DJS-131 to test the core plane for the TQ-16 memory.

Tsinghua University has a CAD project for semiconductor mask generation, and PICT has used a computer to generate wiring lists. These are the only two examples of CAD we encountered.

Integrated circuits

IC production facilities exist at major universities, research institutes, and factories, although an accurate listing of IC producers, products, and rates is unavailable. During the Cultural Revolution, small neighborhood factories were established; the Torch Semiconductor Factory in Shanghai is an example. Converted from wooden-crate manufacturing to tube and IC production in 1967-69, its personnel were trained by major factories such as Shanghai Radio Factory No. 14. The extent to which neighborhood factories exist today is unknown, but SRF No. 14 itself is now building a modern IC production facility. Bipolar MSI, PMOS, and CMOS LSI devices have been produced. The bipolar logic is both TTL and ECL; no IFL has been reported. The 013 uses MSI ECL with a four-nsec gate delay and two to five gates per chip. This technology is supposedly five years old. The gate delay for the MSI TTL circuitry used on the TQ-6 is 50 nsecs.

The state of the lithographic art is 8-micron line widths; but we were told this could easily be reduced to 4 microns. FET gate widths are 6.6 microns. Most IC production is accomplished with manual techniques involving photo-reduction (50:1 at Futan), although Tsinghua is developing design automation. The latter has also developed a step-and-repeat camera system now found in most IC production facilities. However, these systems do not appear to be used in the production of current IC circuits.

In 1977, SRF No. 14 produced two million devices, including transistors and PMOS and CMOS circuits. Ion implantation is used to produce p-channel CMOS. A 40-mm wafer produces 10 chips with up to 100 active CMOS devices per chip. A minicomputer controls the final test of LSI circuits. The overall yield is 10 percent for LSI and 25 percent for SSI. Demand for LSI circuits exceeds factory production.

Shanghai Radio Factory No. 7 produces bipolar transistors and ICs. Annual production is 16 million devices, of which 1.7 million are small-scale ICs used in computers and control. The yield for ICs is less than 50 percent. There is no production of MOS devices, and trial production of ECL ICs for a super-speed computer has just started. These devices are supposedly equivalent to the MECL 10,000 product line.

Major environmental problems are the probable cause of the low IC yields. The general level of air particulates is too high, and at Shanghai Radio Factory No. 7 there is no control of humidity. Bipolar devices
were being encapsulated in an atmosphere of 50 percent humidity at the time of our visit.

Tsinghua University produces LSI p-channel MOS devices. The most recent product is a 1024-bit RAM with a 600-nsec access time, power dissipation of 60 to 70 mW, and a chip area of 8.88 mm². Other devices produced at this laboratory are the type WM-220 1024-bit MOS dynamic shift register and a 2240-bit MOS ROM. A 4096-bit PMOS ROM is under development, but this project is being done by hand even though the various CAD systems mentioned earlier exist at Tsinghua.

Futan University has facilities for limited IC production. These include an in-house-built ion implantation machine. Linear IC operational amplifiers similar to the Fairchild 741 are produced, as well as FET operational amplifiers.

Production methodology

With one exception, all computing machines in China are designed and constructed without design automation of any kind. The exception is the 013, for which a computer was used to generate wiring lists. There is no simulation of design, and proof of logical design correctness is done manually. No automatic testing equipment exists, and final testing of completed computers is also done manually. We did observe minicomputers being used to test both circuit boards and ICs. Semi-automatic machines are used to test magnetic cores.

Fabrication at all levels is manual (Figures 8,9). Hand soldering is used throughout; wave soldering and wire wrapping are not employed. Heat sinks are not used to protect semiconductor components during fabrication.

The 013 has 4 x 6-inch eight-layer circuit boards, with chips and components mounted on both sides. The DJ1-11 uses four-layer boards. All other machines we observed used large two-layer boards, usually unplated and usually with wide traces and rough edges. The components on the two-layer boards are mounted on long leads, creating vibration problems.

The machines we saw use forced-air cooling, with no control of temperature or humidity. Two old machines in air-conditioned environments were exceptions. Components and computers in China are expected to operate over a much larger temperature range than they are in the US.

Component testing is done, but the collection and analysis of defect data is minimal (see Figure 10).

In general, we felt that packaging, manufacturing, reliability, and yield are the least understood and appreciated computer problems in China. Improvement in these areas would reap substantial benefits.

Question-answer sessions

Most of our meetings with the Chinese included time for mutual asking and answering of questions.
There was often lively and interesting discussion, in spite of delays and ambiguities caused by translation. A complete mismatch between the formal IEEE Computer Society lectures offered during the visit and the audience occurred on several occasions, but this was not the rule. There was a good match between most Chinese factory and university presentations and the IEEE audience, and a similar good match at the informal sessions presented by the IEEE. The knowledge displayed by a number of the Chinese technologists was impressive. These individuals spoke fluent English and were conversant with current US computer research and development. Many technically competent individuals may have escaped our attention simply because they could not communicate directly in English. The questions we were asked give some insight into the knowledge and activities of the questioners. Some of the questions, asked in Chinese and translated, are listed below; of special note are questions on the use of microprocessors to build supercomputers. This question, in one form or another, was asked at almost every meeting.

- What will be the effect of microprocessors on computer mainframes?
- Is the pursuit of micro-based large machine architectures the right direction?
- Can we use microprocessors in an Illiac-IV-type architecture to build supercomputers?
- What key problems have been encountered in attempts to implement general-purpose computers using microprocessors?
- How do you solve the communication problem between user and software designer?
- What new tools are needed to automate VLSI design?
- What are the testing techniques for VLSI?
- Have you developed standard software?
- What is your opinion of the proof of program correctness?
- What is the most popular programming language?
- Which is better—Modula or Euclid?
- Dijkstra thinks better languages are needed. Naur and Ralston think we should improve existing languages. What is your opinion?
- Do you prefer the green or red design of DoD-1?
- How do you solve the problems of software manufacture, maintenance, and reliability?
- How do you guarantee the reliability of software?
- What is your experience with compilers?
- Should we pursue direct execution machines?
- Will bubble memories replace disks?
- Can you report on the practical and theoretical aspects of operating systems?

There is a consistency between the things we saw and what others have reported, but the "data base" of hard facts—both for us and other visitors—remains quite small. This is a consequence of the limited number of visits by technical delegations, the changes in Chinese computer technology, the breadth of computer technology itself, and a scarcity of data and written material. Moreover, a government policy of self-reliance and independence has discouraged standardization or cooperation on a national level, making technical communication difficult even within China.

I have attempted to outline the current state of computer technology in the People's Republic, drawing both on my observations and those of other delegation members. The direction and timetable of Chinese computer technology, however, are unknown. Continued interchange may enlarge our "data base," enabling us to plot the future course as well as the present state of the art.
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References


Harvey L. Garner is a professor of electrical engineering at the University of Pennsylvania’s Moore School of Electrical Engineering; he was director of the school from 1970 to 1976. He has worked with digital computers since 1951. From 1958 to 1970 he was a member of the faculty of the Departments of Electrical Engineering and Computer and Communications Sciences at the University of Michigan. At Michigan, he was involved in the design of the Midec and Midsec computers. An ACM national lecturer in 1965 and general chairman of the first National Computer Conference in 1973, he has published papers in the areas of computer architecture, digital computer arithmetic, education, and computer applications.

Garner received BS and MS degrees in physics from the University of Denver in 1949 and 1951, and the PhD in electrical engineering from the University of Michigan in 1958. He is a Fellow of the IEEE and a member of the ACM, Sigma Xi, Sigma Pi Sigma, Eta Kappa Nu, the American Association for the Advancement of Science, and the American Society for Engineering Education.