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Computer Research and Development in the People's Republic of China

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Computer Research and Development in The People's Republic of China

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PRÉCIS

The isolation of the Chinese during the Cultural Revolution widened the gaps in the information available on their efforts in science and technology. As in other fields, very little was learned regarding Chinese progress in computer development from mid-1966 until 1972. Evidence obtained since then, however, indicates that certain computer developments advanced with little interruption, resulting in early completion of several new computer models employing integrated circuits.

The Chinese have demonstrated the capability to design and build prototype large-scale computer models exceeding the performance of US models commercially available in 1963. Further, it is believed that the Chinese, using integrated circuit technology, have already built their first versions of airborne digital computers for navigation and control.

In the next few years they probably will progress rapidly in developing a more powerful large-scale computer as well as an extensive variety of small and minicomputers. Improvements in the performance and quality of peripheral equipment, however, must be made and, more important, software development and user service must be given greater attention if the Chinese hope to use a larger number of computers effectively or to use them in more sophisticated applications than they now do. In addition to developing more advanced domestic computers and related equipment, the Chinese probably will attempt to purchase from Western and Japanese sources a few of the largest computers commercially available.

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COMPUTER RESEARCH AND DEVELOPMENT IN THE PEOPLE'S REPUBLIC OF CHINA

[redacted]

OSI-STIR/75-2
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OFFICE OF SCIENTIFIC INTELLIGENCE

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PREFACE

This report evaluates Chinese capabilities and trends in the design and construction of digital computers, auxiliary storage devices, and peripheral equipment, as well as in the development of software for such computers. In particular, it evaluates Chinese capabilities to design and build large-scale computers and highly miniaturized computers, two categories of computers that are of the greatest significance for both civilian and military application. The report does not attempt to evaluate Chinese progress in analog computer developments. Very little information on such developments has become available since the Cultural Revolution and recent information indicates that the Chinese are primarily concerned with digital technology. This report was prepared by the Office of Scientific Intelligence and coordinated within CIA. The cutoff date for information is December 1974.

[redacted]

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[redacted]

COMPUTER RESEARCH AND DEVELOPMENT IN THE PEOPLE'S REPUBLIC OF CHINA

PROBLEM

To assess the status and trends in the development of Chinese digital computers and related equipment including those having possible military applications.

CONCLUSIONS

1. For priority civilian and military programs requiring the use of large-scale digital computers, the People's Republic of China (PRC) has built at least two computer models since 1973 that are as powerful as the largest US machines commercially available beginning in 1963. It is estimated that within the next 3 to 4 years the Chinese will be able to assemble on a one-of-a-kind basis a computer with nearly twice this capability. During this period the number and performance features of domestically developed large-scale computers probably will not be adequate to satisfy all priority needs, which according to the Chinese would include applications in numerical weather prediction, control of large industrial complexes, and seismic data processing—and, presumably, in military developments. The Chinese have recently purchased a large-scale IRIS-60 computer from France and probably will attempt to purchase a few larger machines from Western and Japanese sources.

2. Using small-scale integrated circuits, the Chinese may have built as early as 1970 small, airborne digital computers for navigation and control. No detailed specifications are available for such computers but they probably are very limited functionally, with practically no programming flexibility. The level of circuit and component technology used in such computers may be comparable in complexity with that of US aircraft computers of the early 1960s, but the Chinese could significantly improve their airborne computers as a result of the rapid progress they are making in integrated circuit technology.

3. Despite their notable achievements in hardware development, the Chinese have yet to recognize the relative importance of computer software development, equipment standards, maintenance, and other user support activities. These areas will probably be major sources of difficulty for the Chinese as they attempt to make effective use of a larger number of computers or more sophisticated use of them. Further, the geographic dispersal of Chinese computer development and production has created wide variations in the quality and reliability of computing equipment. Another constraint is the limited performance and reliability of input/output and auxiliary storage equipment. Efforts to improve such equipment have been started only recently.

4. A greater variety of digital computers utilizing integrated circuits probably will be announced by the Chinese during the next 3 to 4 years. Development efforts will probably emphasize minicomputers and large-scale computers with expanded capabilities. Minicomputers for such applications as industrial control, testing, and small-scale engineering problem solving undoubtedly represent the class of computers most needed by the Chinese. Improved machine performance in all classes of computers probably will be achieved with both sophisticated system

architecture and more advanced integrated circuit technology. But improved performance in large-scale models may be handicapped by Chinese inability to fabricate core memories with sufficiently high speeds.

5. Computer developments in the PRC are expected to remain geographically dispersed, although for selected priority programs a number of the major organizations may be forced to combine resources. Military computer developments probably will be accomplished primarily by organizations separate from, but receiving support from, major academic and industrial computer development facilities. Chinese applications of computers, particularly large-scale models, have emphasized and probably will continue to emphasize stand-alone installations for scientific and engineering problem solving. The Chinese show little capability to implement more sophisticated real-time or interactive computer systems—such as those associated with automated command and control applications.

SUMMARY

Since 1971 the PRC has displayed about a dozen new computer models, all incorporating integrated circuit components. The larger of these new models, which are also the most powerful digital computers yet displayed by the Chinese, are the DJS-11 built at Peking University and the TQ-6 built by the Shanghai Radio Factory No. 13. The performance of both models lies between that of the US CDC 3600 model, first available in 1963, and that of the CDC 3800 model, first available in 1965. The PRC models, however, exist only in prototype or in very few units. The DJS-11 is the first Chinese digital computer known to have sophisticated system and logical design features. These features allow parallel memory accessing, parallel input-output operations, and instruction look-ahead, all of which make possible higher operating speeds without major improvement in internal memory speeds. Such design concepts were first used in US machines during the mid-1960s. The Chinese have also made use of modular design concepts (as seen in the 709 model) that permit wide flexibility in the construction of large special purpose computer systems.

Chinese application of integrated circuit technology in computers appears to be progressing much more rapidly than has occurred previously in other countries. More advanced integrated circuits than those used in current computer models have been described in Chinese component handbooks [redacted] By combining the logic and system design concepts employed in the DJS-11 and 709 models with the more advanced integrated circuit components, or even with high-speed transistors if they become available in sufficient quantities, the Chinese should be able to build a computer with as much as twice the performance capability of the DJS-11. Memory technology may be a temporary though significant constraint in such developments. The Chinese are still dependent on ferrite core technology for internal memories and have not demonstrated a capability to assemble memories with cores having diameters small enough to achieve cycle times of less than one microsecond.

Strong Chinese interest in developing or acquiring computers more powerful than the DJS-11 and TQ-6 has been apparent since 1971—in publications as well as in contacts with Western computer specialists. In 1973 the Chinese attempted to acquire such computers from US and other foreign manufacturers but were unsuccessful. Recently they purchased an IRIS 60 model from the French but continuing needs for larger computer models should prompt additional purchasing efforts.

Considerable evidence has been found to suggest that in the next few years the Chinese may develop a greater variety of minicomputers and other small computing and calculating equipment for industrial and scientific applications. [redacted] Chinese versions with capabilities comparable with early US minicomputer models have appeared in isolated instances since 1972. Strong Chinese interest in the engineering construction of minicomputers has been evident in discussions with US and Japanese specialists. This interest may have been prompted in part by military airborne computing developments, though minicomputers can certainly satisfy the majority of Chinese civilian computer requirements for such uses as industrial control, testing, and small-scale engineering problem solving.

The Chinese S&T University in Peking and the Fourth Institute of the National Defense Scientific

Committee in Peking probably were responsible in 1970 for using integrated circuits to build an airborne digital computer for navigation and control. Integrated circuits described in handbooks appeared in prototype computers by 1970. These integrated circuits as well as multilayer printed circuit boards fabricated by the Chinese are comparable with those used in US airborne computers built by 1962.

The Chinese have reached the stage in which the limited performance and poor reliability of auxiliary storage and input/output equipment are recognized as major handicaps to the full utilization of computers. The best examples of Chinese magnetic drum and tape units, which are used with only a few known models of Chinese computers, are comparable with US commercial models available in the early 1960s. The only example of a magnetic disc unit, which is used in the only known DJS-11 installation, compares favorably with the first US units available in 1957. Paper tape, typewriters, and other input/output equipment have changed very little in the last 5 years or more, but a few very modern line printers and digital plotters comparable with US models available in the late 1960s have begun to appear.

The Chinese computer delegation that visited the United States in 1973 clearly expressed Chinese concern for developing improved peripheral equipment for computers, and they probably acquired useful information on equipment design and assembly. Improvements, at least in the reliability of this equipment, are necessary before the Chinese can attempt to implement more sophisticated real-time or interactive computer systems.

Software developments lag considerably hardware developments in the PRC. Higher-level programming language compilers have been written for many computer models, the most thoroughly developed one being the ALGOL type for the 109C. In contrast, operating systems in general are very primitive. Recent visitors to the PRC have observed that knowledgeable Chinese software specialists are not generally aware of the significance of such basic concepts as job control languages and certain memory protection techniques. It is also clear that the Chinese do not appreciate the importance of maintenance and other support for computer users. Nor have they taken measures to establish equipment standards. This is not surprising since the Chinese have a very small inventory of computer installations, most of which are used in scientific and engineering problem solving. The lack of attention to these areas even at this early stage, however, suggests that the Chinese will make very slow progress in the more sophisticated applications of computers and in the effective use of greater numbers of computers when they become available.

Computer development in the PRC is much more widespread than has been reported [redacted] The major development centers [redacted] two cities and in Shenyang, but many development efforts, especially military, appear to be conducted at other places, such as Harbin, Sian, Chungking, and Wuhan. In the PRC there is no identifiable centralized direction for computer development or established standards for computer equipment, except possibly for military developments. Few details are available regarding specific military computer developments but the technology involved does not appear to be markedly different from or more advanced than that observed openly at well-known organizations. In some cases the assembly of the same computer models by different organizations using local materials and talent has resulted in serious reliability problems, possibly occurring even in priority programs.

DISCUSSION

STATUS AND DIRECTIONS OF DEVELOPMENT

Since the withdrawal of Soviet technical assistance from the People's Republic of China (PRC) in 1960, Chinese computer technology has gradually evolved from one that was essentially Soviet-based to one which reflects strong Japanese and Western influence. From 1960 to about 1965 new computer models announced by the Chinese were primarily extrapolations and modified versions of the earlier Soviet models. From 1965 to about 1970 a variety of transistorized models were developed that reflected a stronger Western than Soviet influence. The Cultural Revolution in the late 1960s curtailed many computer development activities but did not seriously affect programs at certain facilities. Since 1971 the variety of new Chinese models has increased markedly and virtually all models now incorporate integrated circuit components, most of very limited complexity (see appendix A).

Chinese imports of Japanese and Western European computers before 1970 reflected the inability of the PRC to satisfy its own military and civilian requirements for computers in all sizes and performance levels.[1] Although quantities of imports were never great, after 1970 they dwindled considerably, suggesting that the Chinese probably have been able to satisfy their own needs at least for small and medium size computers.

The Chinese shift to integrated circuit technology may have been prompted by a number of considerations but two reasons are immediately apparent: the propaganda value of developing and utilizing a component technology which can be closely compared with leading worldwide state-of-the-art technology, and the savings in time and cost for constructing assemblies with integrated circuit components versus discrete transistors. The latter reason was a major consideration in a similar transition that occurred earlier in the West. Clearly, the Chinese established integrated circuit technology much quicker than the West because they were able to learn from Western experience and acquire the manufacturing skill that the West had earlier invested time and effort to develop.

Organization of Computer Research and Development

Computer research and development in the PRC are conducted at a large number of research institutes, universities, plant facilities, and military organizations. A partial listing of these organizations and their relationships with specific computer developments are shown in appendix A. Peking, Shanghai, and Shenyang have been known to be the locations of the major development and production facilities. Recent information indicates that several other cities including Harbin, Sian, and Chungking are important locations of special purpose developments, some of which directly support the military. The Chinese Academy of Sciences, the Fourth Ministry of Machine Building, and the Seventh Ministry of Machine Building direct most of the research and development activities that have been identified at the major institutes and plants. There is, however, no evidence of central direction for computer development nor of any efforts to establish national standards for computer-related equipment.

There is little evidence of cooperation among development organizations except among those within the Chinese Academy of Sciences or the Fourth and Seventh Ministries. In fact, there have been numerous examples of parallel developments of computers with comparable capabilities, such as the 111 with the 709 and the DJS-11 with the TQ-6. Each locality tends to build machines for local requirements using locally available materials and skills. Recent information indicates that some computer models such as the 709 have been built and possibly modified by different organizations using documentation provided by the responsible plant.[2] The extent of this transfer of computer design documentation is unknown but is a practice that is likely to be followed by some organizations that support the military.

While computer models are designed and built at universities and research institutes and at times transferred to the plants for production, the plants also design their own models. These are generally of higher quality and reliability. Computers designed and built at the academic facilities undergo frequent modifications and in some cases serve as test beds for software development and as special system configurations for users. Serious reliability problems have been attributed to recent models, such as the 111, because of poor quality assembly techniques.[3]

Available evidence indicates that comprehensive maintenance and other user support activity are not provided by computer manufacturers. There are also no indications that the Chinese are planning to establish in the foreseeable future support organizations for these purposes—or now appreciate the importance of such support. Current priorities seem to be concerned with manufacturing capabilities.

Military Development and Applications of Computers

Information regarding military computer developments or military computer applications in the PRC is extremely limited. [redacted] Computing equipment associated with classified programs probably incorporates design and component technology which is comparable with that observed in nonmilitary computing activities, though there is a good possibility that larger stand-alone computers or more highly miniaturized computers exist than those openly displayed by Chinese.

[redacted]

Several other facilities have been linked to military developments or applications occurring before the Cultural Revolution but there is insufficient information to determine the exact nature of such activities [redacted]

[redacted]

LARGE-SCALE COMPUTERS

The limited amount of information on Chinese digital computers available before 1972 does not indicate development of machines any larger than the DJS-6, a transistorized model with a published speed of 100,000 operations per second.[12] The tight security restrictions imposed by the Chinese on advanced computer developments, however, suggests that there is a good chance that the Chinese have developed machines larger than those they have displayed.

The largest and highest performance Chinese digital computers displayed since 1972 have also been among the first integrated circuit models. The first of the larger integrated circuit computer models, the 111, built by the Institute of Computer Technology, Peking, and the 709, built by the Institute of Computer Technology, Shanghai, appeared to be experimental developments in which the Chinese were more concerned with the assembly and electronic features of integrated circuit machines than with elaborate system design.

The 709 is noteworthy because of its modular construction, allowing upward expansion in both logic and memory capabilities.[2] This feature is particularly important in the construction of special purpose systems for unique applications including those for military uses.

Figure 1. DJS-11 Computer at Peking University

The DJS-11 computer, announced in August 1973, represents the largest and most powerful digital computer displayed by the Chinese and the first Chinese application of sophisticated system designs for increased computer performance (see figure 1).[13] Major characteristics of the DJS-11 are listed in appendix B, but the most notable of these are the arithmetic speed and internal memory capacity, which greatly exceed those of previously displayed models. An arithmetic speed of one million operations per second has been published by the Chinese, but separate reports of a cycle time of 1.2 microseconds indicate that the actual machine speed may be closer to 800 thousand operations per second.[14] The design and construction of the DJS-11 required support from several organizations in Peking and elsewhere and is the first known instance in which such a joint effort has been made. It illustrates the limitations of the dispersed organizational structure of computer R&D in China.

In terms of performance, the DJS-11, which exists in prototype or very limited numbers, lies between the CDC 3600, first delivered in the United States in 1963 and the CDC 3800, first delivered in 1965 (see table). The increased performance of the DJS-11 is the result of system design features, such as memory overlaps, instruction look-ahead, and parallel input/output operation and control. These characteristics permit parallel machine operations involving an inherently slow internal memory.[15] Such design concepts, applied to US machines built in the early 1960s, are attractive when internal memories are considerably slower than arithmetic and logic circuits and thus become a major bottleneck in achieving increased computer performance. While technical details are lacking regarding certain other recent computer models announced by the Chinese, the DJS-11 appears to be the first model incorporating all of these features. Previously built models, such as the 111, display relatively simple, straightforward machine architectures in which memory cycle time is the limiting performance factor.[16]

Integrated circuits used in the DJS-11 appear to be comparable in sophistication although considerably

Table

Comparison of PRC and US Large-scale Computer Models

	PRC			US		
	111	DJS-11	TQ-6	CDC 3600	CDC 3800	CDC 6600
First year of availability	1970[2]	1973[2]	1973[2]	1963	1965	1964
Add time (microseconds)	5.0	1.5–2.0[1]	1.5–2.0[1]	2.1	1.0	0.3
Storage cycle time (microseconds)	2.0	1.2	NA	1.4	0.9	1.0
Maximum storage capacity (words)	64,000	131,000	262,000	262,000	262,000	131,000
Word length	48 bits	48 bits	48 bits	48 bits	48 bits	60 bits

NA—Data not available.
[1] Estimated values.
[2] Chinese models exist only in prototype.

higher in performance than those used in the earlier integrated circuit computers [redacted] Published articles indicate that the DJS-11 uses thick film and semiconductor circuits, and a 1973 Chinese computer delegation to the US reported the use of Schottky high speed TTL (transistor-transistor logic) circuits in the DJS-11.[15] [17] Recent photographs of the circuit boards of the DJS-11 (see figure 2) indicate that some of the circuits are externally similar to and may correspond with the 5JZ bipolar types shown in the 1970 components handbook published in Shanghai. The 5JZ circuits contain no more than one or two logic gates per package, which is essentially the same as circuits described in earlier computer models.[18]

Another Chinese integrated circuit computer model with a reported speed of one million operations per second, the TQ-6, has recently been observed in prototype at Shanghai Radio Plant No. 13 (see figure 3).[19] [20] It has a larger internal memory than the DJS-11, but the details on performance and system design that would permit a more accurate comparison with the DJS-11 are not available.

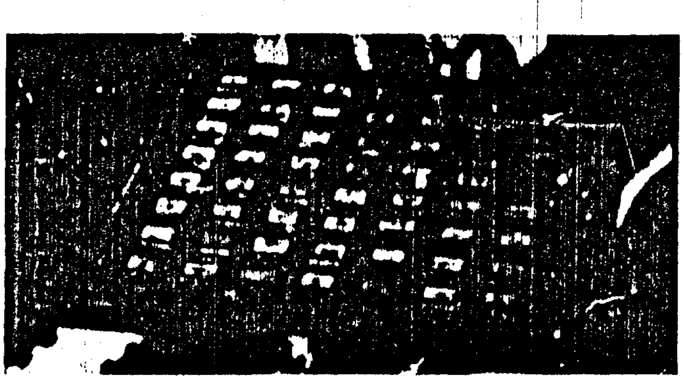

Figure 2. DJS-11 Circuit Board

A substantial Chinese interest in the engineering design and assembly of digital computers much larger than the DJS-11 and TQ-6 has been evident since 1971. Chinese translations of US publications reflect in-depth research of the literature on the designs of some of the largest US machines, such as the IBM 360/91, produced during the last 8 years.[21] [redacted]

Chinese needs for large-scale computers with greater performance levels than domestically originated models became particularly apparent in 1973 when the Chinese began negotiating with IBM for the purchase of its largest commercially available model, the 370/168.[24] [25] Specific end uses for the imported computer were not identified, but a likely use would have been for a major computing center such as the Institute of Computing Techniques in Peking. Because of Chinese refusal to submit end-use documentation required by export controls, the IBM negotiations were terminated. The Chinese also have been negotiating with the Japanese for a large system, but the status of these negotiations is not known at the present time.[26–28] In June 1974 the Chinese purchased an IRIS 60 model from the French for processing seismic data.[29] This is the only Chinese acquisition of a large-scale computer since the Cultural Revolution; but because the IRIS 60 is comparable with an IBM 360/65, it probably

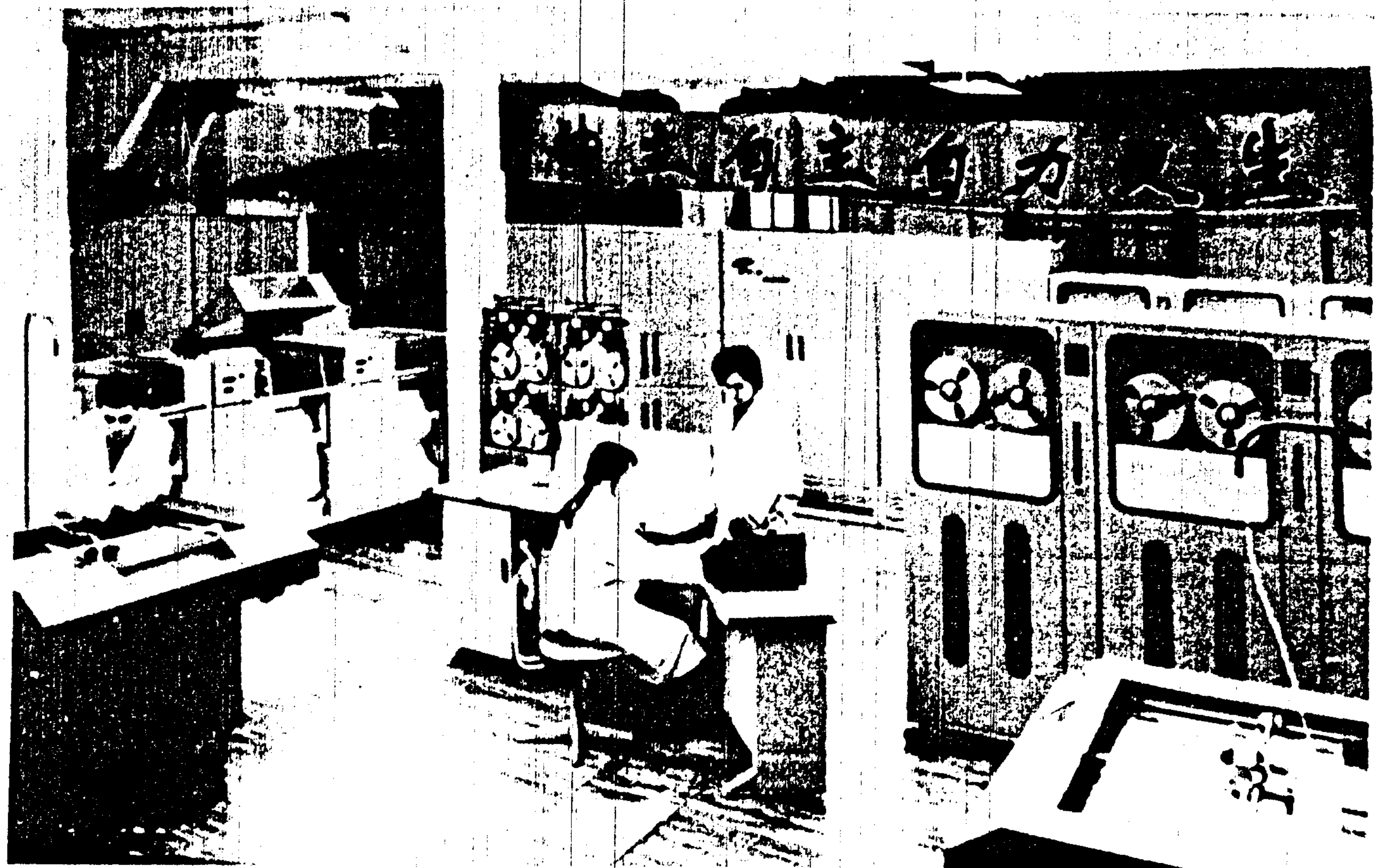

Figure 3. TQ-6 Computer at Shanghai Radio Plant No. 13

satisfies only part of the original Chinese requirement. The Chinese are, therefore, expected to continue efforts to import one or two larger models either from Japanese, European, or US sources.

SMALL AND MINICOMPUTERS

The Chinese have displayed a strong interest in small and minicomputers for industrial control applications and for conventional engineering and scientific computation. This interest was clearly highlighted during a visit of the Chinese computer delegation to the United States in 1973 and has been reflected in computer and test equipment imports, primarily from Japan, since 1972.[23 30] The interest in minicomputers may also be associated with classified developments of airborne computing equipment since both kinds of equipment use much of the same circuit technology and assembly techniques.

Examples of small Chinese desk size computers include the DJS-17 and TQ-11 models, first displayed in 1972.[31 32] These models offer capabilities no better than those of early minicomputers built in the US about 1965. Their external appearance and specifications suggest that they use much of the same engineering design as early, small transistorized computers like the DJS-7. Desk-top computers such as the Type-4 and an unidentified model shown in Figure 4 have been displayed on only a few occasions.[33 34] Externally they appear to be close copies of early US Digital Equipment Corporation PDP or Data General minicomputers but the specifications

Figure 4. Unidentified Chinese Minicomputer

that have been released do not permit precise performance comparisons.

A major source of minicomputer technology in the form of finished minicomputer models and technical assistance in engineering design and applications has been the Japanese instrument manufacturer Takeda Riken and its affiliate, Nihon Minicomputer. These companies manufacture under license and sell minicomputer models of the US Data General Corporation. The TACC 1200, which is the Japanese version of the Data General Nova 1200, has been sold to the PRC on at least four occasions since 1969 either as part of test systems or separately.[35-38] The Chinese have visited the factories of both Japanese companies and displayed particular interest in the manufacturing methods. The strong and continued interest of the Chinese in the TACC 1200 and its potential applications suggests that the TACC 1200 will serve as a pattern for similar developments in the PRC.

AUXILIARY STORAGE AND PERIPHERAL EQUIPMENT

The Chinese have given little attention to improving the quality, performance, and reliability of computer storage and peripheral equipment in comparison with central processor development. This is not surprising in light of the limited number of computers in use and their predominantly scientific rather than data processing application. Effective utilization of existing computer installations, however, probably has been hampered by the poor performance and reliability of the storage and peripheral equipment.

The best known examples of magnetic drum and tape units used with Chinese digital computers compare in performance with models available in the United States during the early 1960s. The largest capacity drum reported has a capacity of 64,000 48-bit words and an average transfer time per word of about 10 ms.[39] This drum has been observed only with the 111 computer at the Institute of Computer Technology, Peking. Tape units with maximum storage capacities of 500,000 to 700,000 48-bit words, recording densities of 500 bits per inch (b/in), and transfer time of 150 microseconds have been displayed. Assuming various recording formats and redundant recording these specifications imply tape speeds on the order of 50 to 80 in/s, which is again early 1960s technology. The Chinese are heavily dependent upon foreign suppliers, mainly French, for high quality magnetic tape.[41] [42] Questions asked by Chinese visiting the United States in 1973 indicated that the PRC has not been able to solve major technical problems of quality control associated with the manufacture of magnetic tape. Possibly the only good quality tape available to military and other priority users is that supplied from foreign sources. Better quality magnetic drum and tape units, some of which may have been imported, are believed to be available to priority users. Those of Chinese manufacture would be of higher reliability but probably would not offer significant performance improvements over those more commonly available.

The only magnetic disc storage unit of Chinese origin has been one with the DJS-11 computer system at Peking University. It has neither been photographed nor observed by US specialists, but the visiting Chinese computer delegation to the United States in 1973 described it in some detail. It is a fixed disc unit with 16 discs, 256 tracks each, and a recording density of 500 b/in. [redacted] it closely resembles the IBM RAMAC disc drive developed in the 1950s.[43] Its design does not incorporate the flying or floating head technology which is critical in the high performance and high precision disc drives commonly used in the West. It is a very unsophisticated drive and easily reproducible and may be perfectly adequate for most immediate Chinese computing requirements. It does not, however, reflect a capability to build the more sophisticated disc drives, even types comparable with US models available in the early 1960s.

A similar lack of progress has been evidenced in Chinese development of input-output equipment for computers with but two exceptions, line printers and digital plotters. Input continues to be primarily paper tape, with few externally apparent differences from equipment used 5 years ago. Typewriters and paper tape punches show a similar lack of advancement, and there is no evidence of card equipment except with imported machines. The Institute of Computer Technology in Peking has conducted experimental developments of cathode-ray tube displays, electrostatic printers, and character recognition equipment, but such equipment has been observed only at experimental installations.[16] [44] Considerable progress has been apparent in the development of digital plotters and line printers. Line printers with speeds up to 1,200 lines per minute with 120 characters per line have been observed. These capabilities are comparable with those of US models available in the late 1960s.[19]

Beginning with the visit of the Chinese computer delegation to the United States in October 1973, there have been a number of indications that the Chinese are now placing increased emphasis on the development and manufacture of improved auxiliary storage and peripheral equipment for computers. The delegation expressed an unusually strong interest in the engineering design and assembly of US equipment, particularly magnetic disc units.[42 45 46] Their detailed examination of US equipment was clearly aimed at extracting information on equipment design and layout to be used in similar developments of their own. It is doubtful that the Chinese obtained any significant assistance in duplicating the manufacturing process for such equipment but it may have provided considerable guidance and time savings in initial prototype construction. The increased attention given to such equipment developments may be prompted by plans for more sophisticated civilian and military use of larger computer systems represented by the DJS-11 and TQ-6. Chinese press releases of these systems have emphasized the variety and number of pieces of peripheral equipment installed.

COMPUTER SOFTWARE

Software development clearly lags far behind computer hardware developments in the PRC. Before 1970 virtually all machines were programmed in machine or assembly languages. Only within the past 4 years have higher level programming language compilers been written for several Chinese computer models. Operating systems appear to be very primitive and only one computer, the DJS-11, has been described as having a multiprogramming capability.[3 15] The only identified group known to have a strong and continuing software development effort is the Peking Institute of Computer Technology.

The major source language used with most Chinese computers is ALGOL, existing in several Chinese variants with compilers written for several different models.[3 47] The compiler for the Chinese BCY-B version of ALGOL, which was written for the 109C computer at the Peking Institute of Computer Technology, appears to be the most advanced and thoroughly developed Chinese compiler.[3] Unlike other Chinese ALGOL compilers, it accepts some Chinese keywords spelled phonetically. Other source languages investigated by the Chinese include: FORTRAN, which has been implemented at least on models 111 and 109; COBOL; and PL/1. The predominant use of computers for scientific and engineering problem solving has prompted the Chinese emphasis on ALGOL and this situation is not expected to change for several years.

At their current stage of computer development the Chinese appear to be unusually reluctant to develop more sophisticated operating systems or to apply well-known techniques for data storage and manipulation. In fact, US specialists have observed that some of the most expert Chinese software specialists are not generally knowledgeable of such basic concepts as job control languages and memory protection techniques, which have been widely applied in the West.[3] While such concepts are not essential to the types of computer applications now under way in the PRC, the current lack of understanding of these concepts could be a serious handicap to future Chinese efforts to apply computers to more sophisticated data processing and control applications in both civilian and military programs.

The multiprogramming capability attributed to the DJS-11 appears to be minimal. Program protection is provided only by the physical segmentation of the memory into four blocks. There appear to be no software features to allow the flexibility of handling programs that overlap into other blocks without occupying two or more complete blocks. There is also no evidence of privileged instructions.

SUPPORTING COMPONENT TECHNOLOGIES

The Chinese have clearly made the transition from transistor to integrated circuit technology in the assembly of logic and arithmetic circuits for computers. Integrated circuits may have been used experimentally as early as 1968 in some kinds of computing equipment.[48] A variety of both hybrid and integrated circuits have been observed in all recently announced computer models and in published component and equipment handbooks since 1970.[18] For example, thick film circuits similar to IBM solid-logic-technology (SLT) types are used in the DJS-17 and both diode-transistor-logic (DTL) and transistor-transistor-logic (TTL) bipolor integrated circuits with one or two logic gates per package are used in the 111 and in the DJS-11.[25 49 31] Circuit complexity remains at or below about 16 gates per chip for all Chinese bipolor devices shown thus far.[3]

Circuit delays as short as 10 ns have been reported for the two-gate Schottky TTL circuits used in the DJS-11, which is about twice as fast as circuits used in the 111 and other integrated circuit models announced by the Chinese during the past 2 years.[51] The speed of the Chinese Schottky TTL circuits is impressive but less than half the speed of similar US circuits. Emitter-coupled-logic (ECL) circuits with a 3- to 4-ns rise-time have been reported by the Shanghai Metallurgical Research Institute.[52] Details on the complexity of the ECL circuits have not been reported but they are assumed to be no more than one or two gate devices. The combination of ECL circuit functions available in quantity probably is far too small for the construction of anything more than small, special purpose computing equipment. If sufficient varieties become available, however, and the Chinese can make comparable performance improvements in internal memory speeds, they should be able to assemble a large scale computer with a performance level slightly below that of a CDC 6400 model, assuming computer architecture similar to that used in the DJS-11. Such a one-of-a-kind development would not be surprising within the next 3 years.

Bipolar TTL and DTL integrated circuits of Chinese origin probably exist in the greatest number of functional varieties for use in computer arithmetic and logic applications, but some examples of metal-oxide-semiconductor (MOS) circuits have also been observed. For example, [redacted] have reported MOS research and experimental devices as sophisticated as a 64-bit memory chip.[53] The Chinese have also imported from Japan advanced integrated circuit test systems specifically designed for MOS and very sophisticated bipolar circuits.[54] Although bipolar and certainly MOS circuits probably exist in very limited quantities, the Chinese appear to be making very rapid progress in advanced semiconductor device developments. The use of these devices in special purpose computing equipment for military applications can not be ruled out at this time.

The availability of integrated circuit components would not be a prerequisite to Chinese construction of a large-scale computer exceeding the performance of the DJS-11 or TQ-6. US experience has shown that machines such as the CDC 6600, with more than three times the speed of the DJS-11, can be built with discrete transistors using sophisticated logical design, system design, and assembly techniques (see table). The high speed, parallel multiplication circuits and system architecture of the DJS-11 demonstrate Chinese capabilities to implement such design techniques. However, the Chinese have not demonstrated a capability to supply the necessary high-speed transistors or small-diameter ferrite cores needed in the construction of a computer like a CDC-6600. There is a good possibility that transistorized computers more powerful than the DJS-11 may exist in China and even predate the DJS-11 announcement, although available information does not confirm such a development.

The cycle time or speed of ferrite-core internal memories of computers currently poses a major constraint to the arithmetic speeds of PRC digital computers. The speed of arithmetic and logic circuits has surpassed core memory speeds, forcing the Chinese to use more complicated computer architectures to permit parallel memory accessing. Memory speed is directly related to ferrite core dimensions and drive-current levels; and small diameter cores and higher drive currents provide increased speed, with reductions in the core diameter providing the greatest improvement. The smallest diameter cores in Chinese computers have outer diameters of 30 mils, though a limited capability to fabricate cores as small as 24 mils probably can be credited to the Chinese.[19 35] With the 24-mil core the Chinese would not be expected to achieve much better than a microsecond cycle time for a 32,000 48-bit word memory, without overlaps, or about a factor of two improvement in a DJS-11 type of computer. Therefore the reduction of core diameters may be a significant concern to the Chinese in the development of higher performance large scale computers. The use of thin film scratch pad memories already demonstrated in the 111 and 109C, small semiconductor memories, and parallel system architectures probably will be continued in an effort to circumvent this problem.[3 19]

The Chinese have shown a budding capability to fabricate the multilayer printed circuit boards needed in the high-density assembly of computing equipment employing integrated circuits. Four-layer boards have been observed in the model 111 and, although not positively confirmed, comparable boards probably are also used in the DJS-11.[19] The fabrication of five-layer boards has been accomplished by the Wuhan Institute of Mathematics, Computer Technology, and Automation.[8] While the number of layers is a significant achievement, the print density—at least in the 111 boards—is believed to be very low.

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APPENDIX A

CHRONOLOGY OF PRC DIGITAL COMPUTER DEVELOPMENT

Design Facility	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74
Institute of Computer Technology, CAS, Peking	103	104			105* 106*		119	108* 109		109B*	109C*		111				
Peking Wire Communications Plant No. 738				DJS-1		DJS-2			DJS-21		DJS-7	DJS-6			DJS-17	DJS-11 DJS-k19	
Tientsin Electronic Instruments Plant									441-B-1								
Tsinghua University				911										112			
Peking Radio Plant No. 3							Production 911				Unnamed Model						
Futan University				602												719	
Institute of Computer Technology, CAS, Shanghai		Unnamed Model					C-2(X-2)							709			
Shanghai Radio Plant No. 13										Unnamed Model					TQ-3 TQ-11	TQ-16 TQ-6	
Northeast Computer Center, Institute of Computer Technology, CAS, Shenyang				501				D-302					Unnamed Model				
Wuhan Institute of Mathematics, Computer Technology, and Automation	103				X-1*			AK-1*									

*Dates estimated.

- - - - Represents joint development or transfer of prototype to production.

APPENDIX B

CHARACTERISTICS OF SELECTED PRC DIGITAL COMPUTERS

Model	First Operational Date	Operating Speed/ Add/Multiply	Internal Storage: Capacity/Cycle Time	Word Length	Auxiliary Storage: Type/Capacity/ Speed	Input Equipment/ Speed	Output Equipment/ Speed	Component Technology
DJS-6	1969	100,000 ops/10 μs NA	16-32 K words/≅ 5 μs	48 bits	Drum/64 K words/ NA	Paper tape/1000 cps	Line printer/1200 lpm, 15 cpl Typewriter/NA X-Y Plotter/NA	Transistor
DJS-7	1968	2,700 ops/NA/NA	4 K words/15 μs	21 bits	Drum/24 K words/ NA	Paper tape/NA Typewriter/NA	Typewriter/NA	Transistor
DJS-11	1973	8-900,000 K ops/ about 1.5 μs/NA	131 K words/1.2 μs	48 bits	Tape/NA/NA Disc/2 M words/25,000 wps	Paper tape/NA Typewriter/NA	Line printers/ 600 lpm Cathode-ray-tube display/NA	Integrated circuit
DJS-17	1972	100,000 ops/NA/NA	8-16 K words/NA	24 bits	Drum/50 K words/ NA	Typewriter/NA	Line printer/NA Typewriter/NA	Integrated circuit
DJS-21	1966	50,000 ops/26 μs/ NA	8-16 K words/NA	42 bits	Drum/16 K words/ NA Tape/NA/NA	Paper tape/ 1000 cps	Line printer/ 1200 lpm, 15 cpl	Transistor
109C	1968	115,000 ops/7.3 μs/ 11.0 μs	32 K/6 μs, 4K word instruction store/ NA, 6 K read-only store/NA	48 bits	Drum/32 K words/ 18 μs per word Tape/260 K words/ 150 μs per word	Paper tape/ 1000 cps	Line printer/7.5 lps, 72 cpl	Transistor
111	1970	180,000 ops/5 μs/ 12.0 μs	32 K words/2 μs, 4 K word buffer/ 6 μs, 256 word thin film/660 ms	48 bits	Drum/64 K words/ 9.2 μs per word Tape/700 K words/ 150 μs per word	Paper tape/ 1000 cps	Line printer (same as 109C cathode-ray-tube display)/ 20 fps	Integrated circuit
709	1971	110,000 ops/NA/NA	32 K words/2.4 μs	48 bits	Drum/14 K words/ 10 μs per word	Paper tape/800 cps	Line printer/NA	Integrated circuit
719	1973	130,000 ops/NA/NA	32 K words/NA	48 bits	Drum/NA/NA	NA	NA	Integrated circuit
TQ-3	1972	80,000 ops/6 μs/ 18 μs	8-16 K words/3 μs	24 bits	Drum/40 K words/ 100 μs per word	Paper tape/NA A/D converter/ 100 samples per second	Line printer/NA D/A converter/ 100 samples per second	Integrated circuit

TQ-6	1973	900,000 ops/NA/NA	131-262 K words/ 2 µs	48 bits	Tape/NA/2 meters per second Drum/NA/NA	Paper tape/NA	Line printer/1200 lpm, 120 cpl X-Y plotter/NA Paper tape/NA Teletype/NA	Integrated circuit
TQ-11	1972	25,000 ops/NA/NA	8-16 K words/8 µs	36 bits	Tape/NA/9 K bits per second	Paper tape/NA	Line printer/600 lpm, 80 cpl	Integrated circuit
TQ-16	1973	110,000 ops/NA/NA	32 K words/2 µs	48 bits	Drum/14 K words/ 40 µs per word Tape/NA/2 meters per second	Paper tape/80 cps	Line printer/10 lps, 80 cpl	Integrated circuit
441-B1	1966	NA	16 K words/NA	40 bits	Tape/NA/NA	NA	NA	Transistor
130	1973	10-50,000 ops/NA/ NA	NA	NA	NA	NA	NA	Integrated circuit
Type 4	1972	100,000 ops/NA/NA	NA	24 bits	NA	NA	NA	Integrated circuit

NA—Data not available.
cpl......Characters per line.
cps......Characters per second.
fps......Frames per second.
lpm......Lines per minute.
lps......Lines per second.
ops......Operations per second.
wps......Words per second.