Part I

The Historical Background.

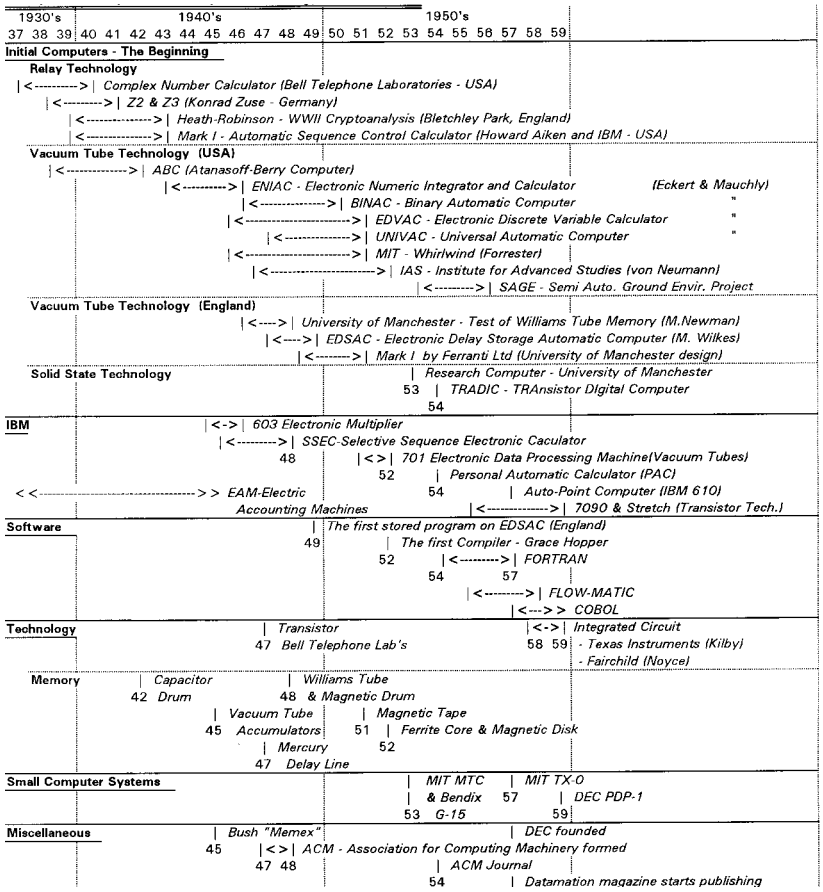

Figure 1.1: A graphical history of early computer technology (1937-1959).

Chapter 1 Development of the Computer

This chapter describes the beginning of digital computer technology. It is a cursory overview of the early significant developments. It starts with the beginning of relay technology in the late 1930s and concludes with the integrated circuit technology of 1959. The review of prior technology sets the stage for a discussion of personal computing and the microcomputer. It also forms the basis for a historic appreciation of the power and capabilities of today's personal computer, as compared to those early digital computers.

1.1 ... Original Digital Computers

Relay Technology

The original computers used mainly relay technology. Examples of these are those built by Howard Aiken in the USA, Bletchley Park in England, Konrad Zuse in Germany and those at Bell Telephone Laboratories in the USA.

Bell Telephone Laboratories developed a number of relay computers starting with the Complex Number Calculator. George Stibitz and S. B. Williams designed the calculator using 450 telephone relays and 10 crossbar switches. The machine became operational in January 1940 and Stibitz demonstrated it from a remote location, Dartmouth College in Hanover, New Hampshire in September 1940. Following this Bell Laboratories developed the Models III, IV, V and VI computers. Bell completed the Model V, also known as the Bell Laboratories General Purpose Relay Calculator in 1946. It contained over 9,000 relays. An addition or subtraction required 0.3 seconds, a multiplication 0.8 seconds and a division 2.2 seconds.

Konrad Zuse designed a completely mechanical computer, the Z1 in 1938. Zuse then developed a hybrid relay/mechanical unit named the Z2. A successful demonstration of this machine resulted in financing from the German Aeronautical Research Institute for a more advance Z3 machine. Zuse completed the Z3 computer in December 1941 using 2,300 relays. After the Second World War Zuse formed his own company that produced relay, vacuum tube and transistor computers.

Bletchley Park in England built a number of electro-mechanical machines at the beginning of the second World War for cryptoanalysis security work. M. H. A. Newman and C. E. Wynn-Williams completed a hybrid relay-vacuum tube machine called the Heath-Robinson in April 1943. The British Secrets Act has restricted the availability of technical information for the computing machines developed at Bletchley Park.

Howard H. Aiken and IBM developed the Automatic Sequence Control Calculator (ASCC). IBM built the computer at its Endicott laboratory during the period of 1939-43. It became operational in January 1943 and IBM presented the computer to Harvard University in August 1944. It had 2,200 counter wheels, 3,300 relays, was 51 feet long by 8 feet high and had a weight of approximately 5 tons. Addition or subtraction took about 0.3 seconds, multiplication 6 seconds and division could require 16 seconds. Harvard renamed it the Mark I and during the next decade Aiken developed the Mark II, III and IV computers.

Mechanical relay technology had inherent speed limitations as applied to computation. This led to the use of vacuum tube technology that provided significant speed improvements.

Vacuum Tube Technology (USA)

John V. Atanasoff developed the first electronic computer to use vacuum tube technology at the Iowa State College during the period of 1938-42. Atanasoff confirmed the design concepts but did not use the computer in a practical sense. He developed the design to mechanize the calculation of large systems of linear

algebraic equations. Atanasoff subsequently named the computer the ABC (Atanasoff-Berry Computer) in recognition of the contributions by an associate Clifford E. Berry.

The first electronic computer used for calculations and solving practical problems, was ENIAC (Electronic Numeric Integrator and Calculator). J. Presper Eckert and John W. Mauchly developed the computer at the Moore School of Electrical Engineering, University of Pennsylvania during the period of 1943-46. ENIAC was a huge machine, having over 18,000 vacuum tubes and 1,500 relays that consumed 174 kilowatts of power. An addition or subtraction calculation took 200 microseconds, a multiplication 2,800 microseconds and a division 24,000 microseconds. The clock rate was 60-125 kHz. The U.S. Army Ordnance Department funded the computer development for use in calculating ballistic tables.

Other early computers developed and built during the late 1940s and early 1950s using vacuum tube technology were EDVAC, BINAC, UNIVAC, Whirlwind and IAS. During the early development of the digital computer there was a close liaison between research institutions in the USA and the United Kingdom. This resulted in significant research and development of vacuum tube computers in England.

Vacuum Tube Technology (England)

Between 1946 and 1948 the University of Manchester built an electronic computer to test the concept of electrostatic memory storage. F. C. Williams developed this memory concept using the cathode ray tube.

The first general purpose electronic computer in the United Kingdom was the Electronic Delay Storage Automatic Calculator (EDSAC). Maurice V. Wilkes developed EDSAC at Cambridge University between 1947 and 1949. EDSAC was the first computer to use the stored program concept.

Ferranti Ltd., did additional developmental work on the University of Manchester computer for commercial

production. They completed the first computer, the MARK I in 1951.

The invention of the transistor significantly affected computer development in England and the USA. Bell Telephone Laboratories developed the transistor in 1947/48. Utilization of solid state technology resulted in significant cost savings and reliability improvements.

Solid State Technology

The first transistor computer to operate was in England. T. Kilburn of the University of Manchester designed the experimental computer that was operational in November 1953. In the early 1950s, Bell Telephone Laboratories received an Air Force contract to build a special computer called TRADIC (**TRA**nsistor **DI**gital **C**omputer). Bell built TRADIC and had it operating in early 1954.

Most early computer development had occurred in the USA and England at university research institutions. However a major USA corporation providing tabulating equipment worldwide entered the computer field. That company was IBM and they became the dominant supplier of computers.

1.2 ... IBM -- International Business Machines

Thomas J. Watson Sr., left National Cash Register Company and became General Manager of the Computing-Tabulating-Recording Company in May 1914. The company name changed to International Business Machines Corporation (IBM) in 1924. Tabulating machines were the basis for the initial growth of the corporation. These evolved from simple mechanical card punching, counting and sorting machines to electric accounting machines. These machines met the diverse needs of business, industry and some fields of science into the 1940s.

The first entry of IBM into the field of computers was the collaborative effort of the company

with Howard Aiken of Harvard University. IBM approved construction of the Automatic Sequence Control Calculator (ASCC) in 1939 and completed it as described in Section 1.1 in January 1943.

The second world war created a significant growth in electronic technology. Utilization of this new technology resulted in the development of the 603/4 Electronic Multiplier in September 1946. IBM initiated construction of the "Super Calculator," the SSEC (Selective Sequence Electronic Calculator) in 1945 and dedicated it in January 1948. It had 21,400 relays, 12,500 vacuum tubes and operated until January 1952.

With the start of the Korean war in June 1950, IBM initiated steps to assist in the war effort with the development of the Defense Calculator. This new computer started in 1951, utilized a number of concepts new to IBM's existing products. Some of these were binary notation, magnetic drum storage, electrostatic cathode ray tube storage, magnetic tape storage and utilization of germanium diodes. The system became known as the IBM Electronic Data Processing Machine and the individual units had 700 series numbers assigned. The first production 701 system shipped in December 1952. Another important project was the joint development of the SAGE (Semi-Automatic Ground Environment) computer with MIT between 1952 and 1956. The company announced their last vacuum tube computer system, the 705 Model III, in September 1957. In October 1957 the company issued a memo stating a policy to use solid-state technology on all new computer developments.

IBM demonstrated a transistorized version of the Type 604 calculator in October 1954 and the first transistorized product was the 608 calculator that shipped in December 1957. These two machines did not have a stored program. Consequently IBM called them calculators, not computers. IBM initiated a project in late 1955 for a supercomputer utilizing transistors and the latest technology that became known as the Stretch system. Then in October 1958 they announced the 7090 Data Processing System using the Stretch technology. The first delivery of a 7090 system was in November 1959.

Computer development at IBM and other institutions was very dependent on technology advances. Of particular importance were the advances in memory capabilities and solid state technology.

1.3 ... Technology

Memory

The following is relative to the computer internal memory and not auxiliary storage units such as magnetic drums, disks or tape drives. Memory was a crucial technology in the expanding use of the computer.

The first electronic digital computer developed by Atanasoff during the period of 1938-42 used capacitors on a rotating drum for memory. The computer had two drums and each drum had 32 bands of 50 capacitors around the circumference. This is a memory capacity of 1,600 bits, or in more familiar terms 200 bytes.

The ENIAC computer used vacuum tubes for memory storage. It used the decimal system and had 20 accumulators for storage of variables. Each accumulator could hold a 10 place number. Each place number was a 10 stage ring counter corresponding to the digits 1 to 9. Therefore it required 100 unique flip-flop vacuum tubes (plus 2 for sign) in each accumulator to store a 10 place number. By taking certain liberties we could say the system had 100 unique bits in each of the 20 accumulators, for a total of 2,000 bits or 250 bytes in our more familiar terms.

The acoustic delay line concept increased the capacity and significantly reduced the number of vacuum tubes used for memory. A typical delay line used piezoelectric quartz crystals at each end of a mercury filled tube and could store 1,000 bits. Eckert and Mauchly applied the concept on the EDVAC computer during the period of 1945-51. Other early computers such as EDSAC, BINAC for Northrop Aircraft, Inc., and the initial UNIVAC computers also used the acoustic delay line concept

The Princeton University, Institute for Advance Studies (IAS) considered using electrostatic memory

utilizing the cathode ray tube for the IAS computer in 1945. However F. C. Williams developed the first functional implementation of electrostatic memory on the University of Manchester test computer between 1946-48. This was the first high speed random access memory. By the middle of 1948 Williams was able to demonstrate a unit with a capacity of several thousand bits. Subsequently it was operational on the IAS computer and the IBM 701 System in 1952.

Jay W. Forrestor evaluated magnetic core memory at the Massachusetts Institute of Technology (MIT) between 1949 and 1951. Ferrite cores were operating at MIT and on the IBM 405 Accounting Machine in 1952. The first computer application of ferrite cores was on the Whirlwind computer at MIT in 1953. The preceding computer evolved into the SAGE (Semi Automatic Ground Environment) computers for a USA national air defense system. MIT selected IBM to build the computers. This defense program added significant impetus to the development of ferrite core technology.

Each of these stages of memory development resulted in lower costs and greater reliability. This also enabled the use of larger and more complex software. Associated developments in secondary memory storage complemented the advances in internal memory.

Secondary Memory (Storage)

The first electronic computers used paper cards for storage. Atanasoff's computer used 8.5-by-11-inch cards and ENIAC used IBM cards.

A. D. Booth of the United Kingdom was an early developer of various forms of memory storage. Booth experimented with thermal, rotating disk-pin and magnetic drum memories after the Second World War. By May of 1948 he had installed and demonstrated a working magnetic drum memory in the Automatic Relay Computer (ARC). In the USA a company called Engineering Research Associates Inc., (ERA) presented papers describing magnetic tape and magnetic drum storage research in 1947 and 1948.

The concept of magnetic disk storage was conceived by Jacob Rabinow at the National Bureau of Standards (NBS) in 1952. In early 1952, IBM established an advanced research development laboratory in San Jose, California that began looking at magnetic disk storage as an inexpensive fast data retrieval system. The requirements evolved from advance development of card-related applications and a United States Air Force request for a large random access storage device. Also customers for inventory and accounting applications were requesting a change from batch to random access in the method of updating file systems. Extensive research was conducted on disk materials and coatings, various types of movable heads and electronic control systems for data storage.

IBM demonstrated the first magnetic disk drive assembly with movable read-write-heads in May 1955 and described the concept at the Western Joint Computer Conference in February 1956. The assembly consisted of a stack of fifty coated aluminum disks, 24 inches in diameter, rotating at 1,200 revolutions per minute. Each disk surface contained 100 concentric recording tracks that provided a total storage capacity of 5 million characters (the equivalent of 50,000 IBM cards). The system was subsequently announced as the IBM 350 Disk Storage system. The preceding and a scheme for automatic addressing of data, was incorporated into the IBM 305 RAMAC (Random Access Method of Accounting and Control) system announced in September 1956. IBM announced a 14 inch diameter hard disk drive with a removable disk-pack in October 1962.

Improvements in memory technology were important in advancing computer capabilities. However solid state research that created the transistor and integrated circuit would also provide significant improvements in computer technology.

Transistor and Integrated Circuit

William B. Shockley was the director of a team of researchers that developed the transistor at Bell Telephone Laboratories in New Jersey, USA. The first transistor was operational in December 1947. John Bardeen and Walter Brattain received a patent for the transistor in 1948.

The concept of including a number of components on a single semiconductor chip was first developed by Jack St. Clair Kilby at Texas Instruments, Inc., in 1958. Kilby constructed the integrated circuit in germanium. Each component on the integrated circuit required precise and laborious interconnection by hand.

Independently in 1959, Robert N. Noyce at Fairchild Semiconductor Corporation also developed a monolithic concept of integrating components on a single silicon chip. However, Noyce had also developed a practical method to interconnect the components. This new technology deposited an insulating layer on the silicon semiconductor that could be selectively removed by a photo resist technique. Then by depositing a vaporized metal layer, interconnection of the components was achieved in a practical manner. Noyce's concept had been facilitated by the invention of the planar process by Jean Hoerni, a technique to make a flat, or planar surface for transistors. The founding of Fairchild Semiconductor in 1957, had been financed by Fairchild Camera and Instrument Corporation, who completed its ownership of the new company in 1959.

For commercial viability, the practical method of interconnecting the components and the planar process were just as important as the integrated circuit concept. This would be crucial in the ensuing patent litigation between the two inventors and respective companies. In resolving the coverage of the patent applications between the two companies, an agreement resulted in Jack Kilby and Robert Noyce being declared as co-inventors of the integrated circuit.

Technology improvements and memory advances in particular resulted in increased utilization of the

computer. However, it is software that facilitated the practical application of the computer.

1.4 ... Software

Development of the stored program concept had a direct relationship to advances in memory technology. The size, speed of access, reliability and cost of memory were crucial factors in the evolution of software.

The Beginning

The initial computers did not have a stored program, or what became known later as software. The first practical electronic computer ENIAC, used forty plug-boards, that required a configuration of wire connections for each instruction. Later changes utilized three panels, each containing 1,200 ten-position switches to control the instruction sequence.

John von Neumann described the concept of storing a program and data in 1945 during the construction of ENIAC. However, the first computer to function with a stored program was EDSAC at Cambridge University, England in 1949.

Grace M. Hopper was an early pioneer in the development of initial programming languages. Her initial work started on the Mark 1 at Harvard University in 1944. Then at the Eckert-Mauchly Computer Corporation. The first compiler was A-0 and ran on the UNIVAC computer in 1952. This compiler formed the basis for other variations such as ARITH-MATIC, MATH-MATIC and FLOW-MATIC (1955-58) which assisted in the later development of COBOL.

Graphics

One of the earliest applications of computer graphics was on the MIT Whirlwind computer, that was operational by 1953. This was an interactive system that was used to display radar information. It was then applied to the SAGE defense system built by IBM.

FORTRAN

In 1954 IBM established a project directed by John W. Backus to develop a compiler for the Model 704 computer. This project resulted in the creation of the language FORTRAN (FORmula TRANslation) that IBM finished in April 1957. The language had a notation oriented to mathematicians and scientists. Improvements in the language followed with the subsequent release of versions II, III and IV.

COBOL

By 1957 a number of people had become concerned that a common programming language designed for commercial users was not available. The United States government also stated a concern about the proliferation of different compilers from the various computer manufacturers. In 1959 the Defense department initiated activities that resulted in an Executive Committee being formed called CODASYL (Committee On DAta SYstem Languages). The committee coordinated the development of a new language that became COBOL (COmmon Business Oriented Language). CODASYL formed other committees, to work on the definition and further development of the language. These developments resulted in the 1960 release of COBOL.

Games

Artificial intelligence researchers started using computers and developed game software such as chess and checkers between the late 1940s and the 1950s. There were many researchers in this field of artificial intelligence. Early chess playing programs were developed by Claude E. Shannon in 1949 and Alex Bernstein in 1957. Arthur L. Samuel of IBM developed various games, especially checkers in the 1950s.

William Higinbotham and associate Dave Potter developed the first video game at Brookhaven National Laboratory in Upton, New York in 1958. Called Merlin, it simulated a game of tennis using an analog computer, oscilloscope display and paddle-type controllers for rackets.

Software was facilitating and extending the utilization of computers. As the number of users increased, new periodicals were published and new associations formed to disseminate information and facilitate user interaction.

1.5 ... Other Developments

Associations

One of the first groups to be formed in the computer industry was the Association for Computing Machinery (ACM), founded during 1947/48. The Data Processing Management Association (DPMA) formed in 1949, is one of the largest groups with involvement in education and certification of data processing professionals. IBM customers were one of the first to form user groups. The SHARE group that formed in 1955 had an initial orientation to scientific users. An IBM commercial users group called GUIDE (Guidance of Users of Integrated Data-processing Equipment) formed in 1956. Then the International Federation for Information Processing (IFIP) formed in 1959.

Magazines

One of the earliest periodicals was the *Digital Computer Newsletter* started by the Office of Naval Research in 1949. Another early publication was the *IBM Technical Newsletter* series started in 1950. The ACM issued a quarterly *Journal* in 1954 that evolved into the *Communications of the ACM* in 1958.

A popular data processing magazine called *Datamation* started in October 1957 as *Research and Engineering (The Magazine of Datamation).* It started as a semi-monthly publication, then became a monthly publication in 1967.

Memex

Vannevar Bush published a futuristic article entitled “As We May Think” in the July 1945 issue of *Atlantic Monthly* [12, pp. 47-59]. The article described a “future device for individual use” called “Memex” in which a person “stores all his books, records, and

communications ... that may be consulted with exceeding speed and flexibility." Another essential feature of Memex was "associative indexing ... whereby any item may be caused at will to select immediately and automatically another." Bush's Memex was similar to future concepts of an interactive personal computer navigating a field of knowledge with hypertext links.

Most of the activities in computer development and use related to large mainframe computers. However various organizations were attempting to lower the cost of computers by introducing small computer systems.

1.6 ... Small Computer Systems

MIT

MIT built the **M**emory **T**est **C**omputer (MTC) between 1952 and 1953 to test magnetic core memory planes for the Whirlwind 1 computer. Harlan Anderson and Kenneth Olsen designed MTC and would later co-found Digital Equipment Corporation (DEC). The computer was a 16-bit unit built from standard Whirlwind plug-in circuit package forms.

Following the completion of the MTC computer Olsen and Wesley A. Clark proposed the construction of a large transistorized computer, the TX-1. Rejected by management, Clark designed a smaller 18-bit unit, the TX-0 in 1957. Then MIT developed the ARC (Average Response Computer) and a much larger computer, the TX-2 in 1958. One of the students using these computers was Charles E. Molnar. Molnar and Clark would later develop the first personal computer, the MIT LINC.

IBM

John L. Lentz worked on the development of a small Personal Automatic Calculator (PAC) project, starting in the late 1940s. He then described details of an engineering model of the PAC project in December 1954. This project evolved into the IBM 610 Auto-Point Computer announced in September 1957. The system consisted of three units. A floor-standing cabinet that enclosed the electronics, two paper-tape readers and

punches, plugboard and magnetic drum. The other two units were an operator keyboard for control and data entry and an electric typewriter for printed output. It was one of the last two vacuum tube computer models built by IBM and the company considers this to be the first "Personal Computer." IBM built about 180 units at a purchase price of $55,000.

DEC

One of the earliest entrepreneurs in the minicomputer market was Kenneth H. Olsen. After graduating from MIT he worked at the Lincoln Laboratories, then on the Whirlwind and SAGE computer systems between 1950 and 1957. Olsen co-founded Digital Equipment Corporation (DEC) with Harlan E. Anderson in August 1957, to provide low cost logic modules and computers for engineers and scientists.

The first DEC minicomputer was the 18-bit PDP-1 (Programmed Data Processor - One). DEC demonstrated the PDP-1 prototype at the Eastern Joint Computer Conference in December 1959. It had a cathode-ray tube display, keyboard and was the first small commercial interactive general-purpose computer.

Conclusion

The general use of large commercial and scientific computers was firmly established by the end of the 1950s. However the major computer manufacturers did not commit sufficient resources to the development of small competitive computer systems. This resulted in other companies releasing small computers such as the Bendix Aviation Corporation G-15, the Librascope/General Precision LGP-30 in 1956 and the DEC PDP-1 announcement in 1959.

These small systems were lowering the cost of computer technology. Although they targeted at scientific users, they were a part of the evolution to personal computing and the first personal computer in the 1960s.