Chapter 4
Developments in the 1950s–1970s

Key Topics

IBM 360
IBM 701
IBM 650
SAGE
PDP
Spacewar
Home Computers
Altair 8080
Commodore PET
Apple I and Apple II

4.1 Introduction

This chapter considers a selection of computers developed during the 1950s–1970s. The initial driver for the design and development of more powerful computers was the perceived threat of the Soviet Union. This led to an arms race between the two superpowers, and it was clear that computing technology would play an important role in developing sophisticated weapon and defence systems. The SAGE air defence system developed for the United States and Canada was an early example of the use of computer technology for the military.

The machines developed during this period were mainly large proprietary mainframes and minicomputers. They were developed for business, scientific and government use. They were expensive, and this led vendors such as IBM and DEC to introduce families of computers in the 1960s where a customer could choose a

G. O'Regan, *A Brief History of Computing*, DOI 10.1007/978-1-4471-2359-0_4,
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smaller cheaper member of the family and to upgrade to a larger computer as their needs expanded.

It was only in the mid-1970s that the idea of a home computer was born. Early home computers included the Altair-8080, Commodore and the Apple I and Apple II computers. The home computer later led to major changes for the industry and the eventual replacement of the mainframe computer with networks of personal computers and servers.

The industry witnessed major technology changes during this period. The large bulky vacuum tubes were replaced by compact transistors (invented by Shockley and others) leading to smaller and more reliable machines. The invention of the integrated circuit by Kirby allowed a large number of transistors to be placed on a single piece of silicon. Finally, the invention of the microprocessor by Intel (which provided all of the functionality of a computer on a single chip) led to the development of home computers from the mid-1970s.

The introduction of the IBM 360 series of computers was an important milestone in computing. It was a paradigm shift for the industry as up to then each computer was designed independently and customised for a particular customer. The System/360 was a family of small to large computers, and it offered the customer a choice of the size and computational power rather than a one-size-fits-all approach. The family ranged from minicomputers with 24 kB of memory to supercomputers for US missile defence systems.

This allowed a customer to start with a small member of the S/360 family and to upgrade over time in accordance to their needs to a larger computer in the family. This helped to make computers more affordable for businesses and stimulated growth in computer use.

All of the computers is the S/360 family had the same user instruction set. The main difference was that the larger computers implemented the more complex machine instructions with hardware, whereas the smaller machines used microcode.

A selection of the PDP computers designed and developed by the Digital Equipment Corporation (DEC) is discussed. The PDP family was very popular in business and scientific computing, and at its peak DEC was the second largest computer company in the world. Finally, the introduction of home computers such as the Apple I and Apple II computers are discussed.

4.2 SAGE

The Semi-Automated Ground Environment (SAGE) was an automated system for tracking and intercepting enemy aircraft in North America. It was used by the North American Aerospace Defence Command (NORAD) which is located in Colorado in the United States. The SAGE system was used from the late 1950s until the 1980s.

The interception of enemy aircraft was extremely difficult prior to the invention of radar during the Second World War. Its introduction allowed fighter aircraft to be

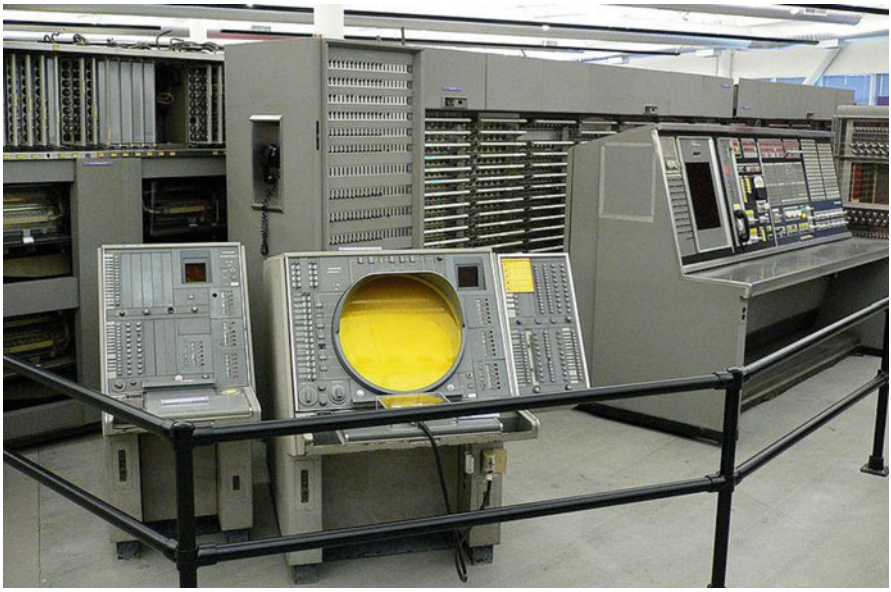

Fig. 4.1 SAGE photo (Courtesy of Steve Jurvetson)

scrambled just in time to meet the enemy threat. The radar stations were ground-based, and therefore needed to send interception instructions to the fighter aircraft.

However, after the war, the speed of aircraft increased considerably, thereby reducing the time available to scramble fighter aircraft. This necessitated a more efficient and automatic way to transmit interception instructions, and the SAGE system was designed to solve this problem and to provide security to the United States. SAGE analysed the information that it received from the various radar stations around the country in real time, and it then automated the transmission of interception messages to fighter aircraft (Fig. 4.1).

IBM and MIT played an important role in the design and development of SAGE. Some initial work on real-time computer systems had been done at Massachusetts Institute of Technology on a project for the US Navy. This project was concerned with building an aircraft flight simulator computer for training bombing crews, and it led to the development of the Whirlwind computer. This computer was originally intended to be analog but instead became the Whirlwind digital computer used for experimental development of military combat information systems.

Whirlwind was the first real-time computer, and George Valley and Jay Forrester wrote a proposal to employ Whirlwind for air defence. This led to the Cape Cod system which demonstrated the feasibility of an air defence system covering New England. Following its successful deployment in 1953, work on the design and development of SAGE commenced.

IBM was responsible for the design and manufacture of the AN/FSQ-7 vacuum tube computer used in SAGE. Its design was based on the Whirlwind II computer,

Fig. 4.2 SAGE sector control room (Photo public domain)

which was intended to be the successor to Whirlwind. However, the Whirlwind II was never built, and the AN/FSQ-7 computer weighed 275 tons and included 500,000 lines of assembly code.

The AN/FSQ holds the current world record for the largest computer ever built. It contained 55,000 vacuum tubes, covered an area over 18,000 ft^2 and used about 3 MW of power (Fig. 4.2).

There were 24 SAGE direction centres and three SAGE combat centres located in the United Sates. Each SAGE site included two computers for redundancy, and each centre was linked by long-distance telephone lines. Burroughs provided the communications equipment to enable the centres to communicate with one another, and this was one of the earliest computer networks.

Each site was connected to multiple radar stations with tracking data transmitted by modem over a standard telephone wire. The SAGE computers then collected the tracking data for display on a cathode ray tube (CRT). The console operators at the centre could select any of the targets on the display to obtain information on the tracking data. This enabled aircraft to be tracked and identified, and the electronic information was presented to operators on a display device.

The engineering effort in the SAGE project was immense, and the total cost is believed to have been several billion US dollars. It was a massive construction project which involved erecting buildings and building power lines and communication links between the various centres and radar stations.

SAGE influenced the design and development of the Federal Aviation Authority (FAA) automated air traffic control system.

4.3 IBM Contributions

Chapter 6 presents a short account of the history of IBM and its contributions to the computing field. The company has a long and distinguished history, and the objective of this section is to give a flavour of some of important developments at the company during the 1950s and 1960s. The reader is referred to Chap. 6 for more detailed information.

IBM introduced its first large computer, the 701, in 1952. This was based on vacuum tube technology, and it was used mainly for government work and business applications.

It introduced the popular 650 in 1954. This was an intermediate-sized computer, which was widely used in business computing during the 1950s up to the early 1960s. It was a very successful product for IBM, and over 2,000 of these machines built and sold from its product launch in 1954 to its retirement in 1962.

The 704 was a large computer introduced by IBM in 1954. It was designed by Gene Amdahl and John Backus, and it was used for scientific and commercial applications.

IBM's first completely transistorised machine was the 608 which was introduced in 1957. This was followed by the 7090 which was a large-scale transistorised computer that was used for scientific applications. It was introduced in 1958 (Fig. 4.3).

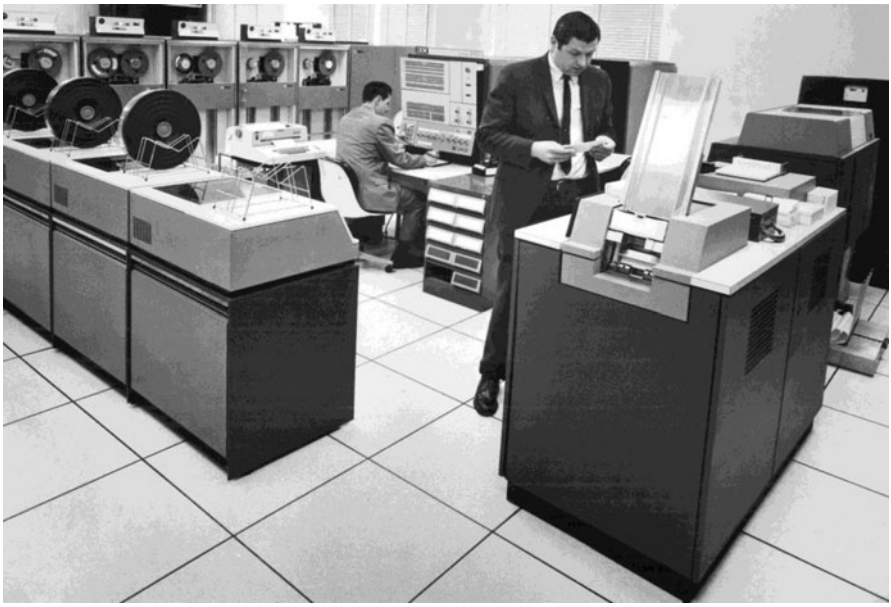

Fig. 4.3 IBM 360 Model 30 (Courtesy of IBM archives)

IBM introduced a new generation of electronic computing equipment known as the IBM System/360 in 1964. The IBM chairman, Thomas Watson, called the event the most important product announcement in the company's history. The chief architect for the IBM 360 was Gene Amdahl, and the S/360 project manager was Fred Brooks.

The IBM 360 was a family of small to large computers, and it offered a choice of five processors and 19 combinations of power, speed and memory. There were 14 models in the family. The concept of a '*family of computers*' was a *paradigm shift* away from the traditional *'one-size-fits-all' philosophy of the computer industry*, as up until then, every computer model was designed independently. The family of computers ranged from minicomputers, with 24 kB of memory, to supercomputers for US missile defence systems. However, all these computers had the same user instruction set, and the main difference was that the larger computers implemented the more complex machine instructions with hardware, whereas the smaller machines used microcode.

The S/360 was used extensively in the Apollo mission to place man on the moon. The contribution by IBM computers and personnel were essential to the success of the project. IBM invested over $5 billion in the design and development of the S/360. However, the gamble paid off, and it was a very successful product line for the company.

4.4 PDP Minicomputers

The programmable data processor (PDP) computer refers to a series of minicomputers developed by the Digital Corporation[1] (also known as DEC) from the 1960s until the 1990s. The various PDP machines can be grouped by word length. These minicomputers were very popular in the scientific and engineering communities during the 1970s and 1980s.

The first PDP computer developed was the PDP 1 which was introduced in 1960. This was an 18-bit machine with an early time-sharing operating system. One of the earliest computer games, Spacewar, was developed for this computer by Steve Russell and others at MIT. The machine could be used to play music in four-part harmony.

It had 9 kB of main memory which was upgradable to 144 kB. It had a clock speed of 200 kHz, and most arithmetic instructions took 10 μs (100,000 operations per second). An instruction had two memory cycles: one for the instruction and one for the data fetch operand.

[1] Digital Corporation was taken over by Compaq in the late 1990s. Compaq was subsequently taken over by HP.

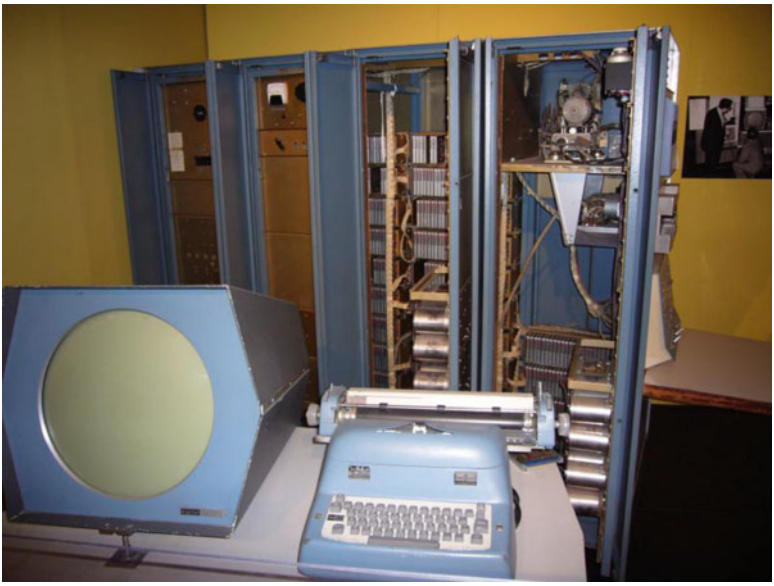

Fig. 4.4 PDP 1 computer (Photo courtesy of Matthew Hutchinson)

It used punched paper tape as the primary storage medium. This was a cumbersome approach as paper tape is difficult to edit. It represented signed numbers in one's complement notation (Fig. 4.4).

The first PDP-1 computer was delivered to Bolt, Beranek and Newman (BBN) Technologies in 1960.

4.4.1 Spacewar Computer Game

Spacewar was one of the earliest computer games. It was developed by Steve Russell and others at Massachusetts Institute of Technology. The game was developed on the PDP-1 computer, and its first version was available in early 1962. The game involves two armed spaceships trying to shoot one another while manoeuvring to avoid a nearby star.

Each ship fires missiles, and it has a limited amount of missiles and fuel available. Each player controls one of the ships and must attempt to shoot the other ship and avoid the star. The player has various controls including rotation, thrust, fire and hyperspace. Hyperspace could be used as a last resort by a player to avoid a missile; however, re-entry from hyperspace was random, and its use increased the probability of the machine exploding the next time that it was used (Fig. 4.5).

The PDP-8 was a very successful 12-bit minicomputer introduced by DEC in 1965. Its product sales were in excess of 50,000 machines. There were

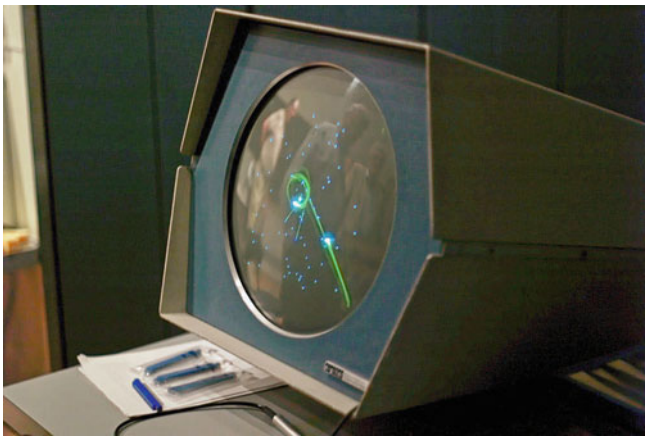

Fig. 4.5 Spacewar (Photo courtesy of Joi Ito)

several models of the machine, and the PDP-8/E was well regarded with several types of I/O devices available for it. It was often configured as a general-purpose computer, and its low cost made the computer available to many new users.

The PDP-11 was a series of 16-bit minicomputer originally introduced in 1970 with sales continuing up to the mid-1990s. It was a commercial success for DEC, and the VAX11/780 super minicomputer is a 32-bit extension of the PDP-11. It was introduced in 1977.

4.5 Home Computers

The Altair 8080 was the first commercially successful home computer, and it was developed by Ed. Roberts at MITS (Micro Instrumentation Telemetry Systems). It featured on the cover of the January 1975 edition of the magazine, *Popular Electronics*. The cost of the machine assembly kit was $439, and it was initially purchased and assembled by computer hobbyists. The Altair 8080 kit came with a front panel, a CPU board with the Intel 8080 microprocessor, 256 bytes of RAM, a 4-slot back plane and an 8-amp power supply. MITS had sold over 5,000 machines by August 1975.

Bill Gates and Paul Allen saw the magazine and started writing software for the machine. They spent a short time working with MITS and founded Microsoft later that year. Their first product was the Altair BASIC interpreter.

Apple Computers was founded by Steve Jobs and Steve Wozniak on 1 April 1976. The Apple I computer was introduced later that year, and the machine had 4 K of RAM (expandable to 8 K), 256 bytes of ROM and was intended to be used

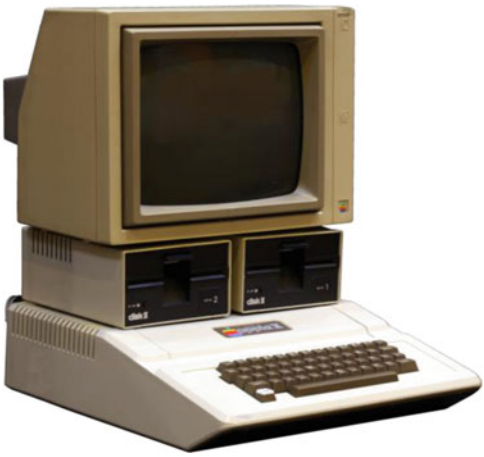

Fig. 4.6 Apple II computer (Photo public domain)

those for whom computing was a hobby. It did not have a case, power supply, keyboard or display, and these needed to be supplied by the user.

The Apple II computer was a significant advance on the Apple I, and it was released in 1977. It was a popular 8-bit home computer and was one of the earliest computers to have a colour display. It had the BASIC programming language built in; it contained 4 K of RAM (which was could be expanded to 48 K). The VisiCalc spreadsheet program was released on the Apple II, and this helped to transform the computer into a credible business machine. The Apple II and its successors were very successful (Fig. 4.6).

The Commodore PET (Personal Electronic Transactor) was a home computer introduced by Commodore International in early 1977. It was the first computer produced by Commodore, which was up to then an electronics company that sold calculators. Commodore realised that the future was in computers rather than calculators, and it purchased MOS Technology in 1976 as part of its strategy of building a home computer. MOS had designed a simple home computer based on their new 6502 microprocessor.

The Commodore PET was a reasonably successful machine, and it became popular in schools and became known as 'Teacher's Pet'. It was a single board computer design in a metal case. However, it was not as popular as a home computer since its sound and graphics capabilities were limited. This was addressed in later models such as the VIC-20 which sold over 2.5 million units.

Its keyboard was quite small and was not popular with users. The machine used the 6502 microprocessor, 4 K or 8 K of RAM and a small monochrome monitor with 40 $\times$ 25 graphics. The computer's main board contained four expansion ports, extra memory and a parallel port.

Commodore introduced the Commodore 64 in the early 1980s, and this popular home computer sold in excess of 22 million units. It had excellent sound and graphics.

4.6 Review Questions

1. Describe the IBM System/360 and its impact on the computer field.
2. Describe the SAGE defence system.
3. Describe the PDP family of computers developed by DEC.
4. Describe the development of the home computer.

4.7 Summary

There were major changes to the design of computers between the 1950s and 1970s. Initially, computers employed vacuum tubes, but these were large, bulky and unreliable. The development of the transistor by Shockley and others at Bell Labs provided an alternative to this bulky technology. Transistors were smaller and more reliable. These were later replaced by integrated circuits which allowed hundreds of thousands of transistors to be placed on a piece of silicon.

The SAGE system was developed as part of the airborne defence of the United States in the late 1950s. It was a massive engineering project involving the construction of buildings, power lines and communication infrastructure.

IBM developed several computers during the period. Its first vacuum tube computer was the 701 which was introduced in 1952. This was followed by the popular 650, which was used for business computing. It was a very successful machine with over 2,000 of these machines sold. Its first transistorised machine was the 608, and this was followed by the introduction of a large transistorised machine, the 7090, in 1958. This machine was used for scientific applications.

The IBM System/360 was a family of small to large computers, and it offered the customer a choice of the size and computational power rather than a one-size-fits-all approach. It ranged from minicomputers with 24 kB of memory to supercomputers for US missile defence systems.

It allowed a customer to start with a small member of the S/360 family and to upgrade over time in accordance to their needs to a larger computer in the family.

The PDP computers were designed and developed by the Digital Corporation. The PDP-1 was released in 1960, and this was an 18-bit machine. It could be used to play music in four-part harmony and one of the earliest computer games.

The early home computers were of interest to mainly computer hobbyists rather than a mass consumer market. The Altair 8080 was the first successful home computer, and it was introduced in early 1975. The Apple I computer was introduced by Apple in 1976. It was followed by the Apple II computer in 1976, and this machine was popular for business use as well as home use.