Computers history

I, Pre-history:

The earliest computing device undoubtedly consisted of the five fingers of each hand. The word digital comes from "**<u>digits</u>**" or fingers. Roman schools taught finger counting and actually devised methods of doing multiplication and division on their fingers. The Roman student was required to learn the multiplication tables 1 - 5. He would figure the products between 5 and 10 on his fingers. It is still actually the preferred device of every child who learns to count. Since there are ten discrete fingers (digits → digital) available for counting, both digital computation and the decimal system have enjoyed a huge popularity throughout history. However, improvements were made to replace the digits of the hand by a more reliable 'count-10' device.

It probably did not take more than a few million years of human evolution before someone had the idea that **<u>pebbles</u>** could be used just as well as fingers to count things. The ancient man collected pebbles to represent the number of items he possessed. He may have kept them in a pouch or in a place easily accessible to him to which he could add or subtract stones. In other cultures the stones were replaced by: notches in a stick, knots tied in a cord, or marks on a clay tablet. Whatever the method, all devices were a way to represent numbers.

One of the earliest devices was the **<u>sand table</u>**. It was a set of three grooves in the sand with a maximum of 10 pebbles in each groove. Each time one wanted to increase the counter by one, he would add a pebble in the right hand groove. When ten pebble were collected in the right groove they were removed and one pebble was added to the left groove. The word "calculate" is said to be derived from the Latin word "calcis", meaning limestone, because limestone was used in the first sand table.

The form the pebble container should take for handy calculations kept many of the best minds of the Stone Age busy for centuries. It was not till about five thousand years ago in the Tigris-Euphrates Valley (and as late as 460 BC in Egypt) that there arose the idea of arranging a clay board with a number of grooves into which the pebbles were placed. By sliding the pebbles along the grooves from one side of the board to the other, counting became almost semi-automatic even to the point allowing one hand to be kept free for other things. The grooved pebble container was too big a thing to be kept secret for long and the processes of cultural diffusion (e.g. deported slaves) saw to it that it became known in China, Japan, and Rome. When the diversity of these races were confronted with this leap into the future, a flowering of ingenuity - a sort of minor renaissance - resulted, which swept the pebble computer to a high plateau of development. One group came up with the idea of drilling holes in the pebbles and stringing the resulting beads in groups of ten of a frame of wire; another used reeds instead. In either case, the beads could be moved easily and rapidly along the wire or reeds, and a tremendous speed-up in calculations resulted. This device, in somewhat more sophisticated form, became known as the **<u>abacus</u>** in China.

The word 'Abacus' comes from the word "abaq"~ the Arab word for dust because the first abacus was simply a portable sand table; a board with dust strung across it. Eventually the board was replaced by a frame, the grooves by wire, and the pebbles by beads. People using the abacus for calculations can become extremely skilled in rapid computation. In some tests, an expert using an abacus has proven to be faster than a person using a mechanical calculator. The abacus remained the only computing device for over 4,000 years even if some tables of numbers were developed by the Greek and Roman cultures as well as the Mesopotamian and the Egyptians.

After reaching this first milestone, the development of computer devices seems to have stagnated for the next two thousand years, there having been, apparently, few scientific and business calculating needs during the Middle Ages that required more than ten fingers or the abacus.

The real beginning of modern computers goes back to the seventeenth century. Having divorced themselves from all past speculations and authorities, such intellectual giants as Descartes, Pascal, Leibnitz, and Napier made a new beginning in philosophy, science, and mathematics, which was to revolutionize the ancient view of the world. In mathematics, particularly, such tremendous progress was made, and the attendant calculations became so laborious, that the need of more sophisticated computing machines became urgent.

The development of **logarithms** by, the Scottish mathematician, John Napier (1550-1617) in 1614, stimulated the invention the various devices that substituted the addition of logarithms for multiplication. Napier played a key role in the history of computing. Besides being a clergyman and philosopher he was a gifted mathematician and in he published his great work of Logarithms in the book called "Rabdologia". This was a remarkable invention since it enabled to transform multiplication and division (which were very complicated tasks at the time) into simple addition and subtraction. His Logarithm tables soon became wide spread and were used by many people. Napier is often remembered more by another invention of his nicknamed 'Napier's Bones'. This was a small instrument constructed of 10 rods, on which was engraved the multiplication table. They are refer as bones because the first set was made from ivory and resembled a set of bones. This simple device enabled to carry out multiplication in a fast manner provided one of the numbers was of one digit only (i.e. 6 X 6742)

The invention of logarithms led directly to the development of the **slide rule**. The first Slide Rule appeared in 1650 and was the result of a joined effort of two Englishmen Edmund Gunter and the reverent William Oughtred. The principle behind this device is that of two scales moving against each other. This invention was dormant until 1850 when a French Artillery officer Amedee Amnnheim added the movable double sided cursor, which gave it it's appearance as we know it today. They gave it the name ´astrolabe´ because of its astronomical uses. The astrolabe was the truth forerunner of the modern slide rule and nomogram.

In 1623 Wilhelm Schickard (1592-1635), of Tuebingen, who was a friend of the astronomer Kepler made his "**Calculating Clock**". This was a 6-digit machine that could add and subtract, and indicated overflow by ringing a bell. Mounted on the machine is a set of Napier's Rods (or Bones), a memory aid facilitating multiplication's.

Perhaps most significant in the evolution of the mechanical calculators was the introduction, in 1642, of the ´toothed wheels´ (gears) by Blaise Pascal (1623-1662), the famous French philopher and mathematician. The father of Blaise Pascal was working in a tax accounting office. To make his father's work easier he designed, at the age of 19, a mechanized calculating device (the Pascaline) operated by a series of dials attached to wheels that had the numbers zero to nine on their circumference. When a wheel had made a complete turn, it advanced to the wheel to the left of it. Indicators above the dial showed the correct answer. Although limited to **addition and subtraction**, the **toothed counting wheel** is still used in adding machines.

It was not long before scientists realized that Pascal´s toothed wheels could also perform **multiplication** by repeated addition of a number. The German philosopher and mathematician, Baron von Leibnitz(1646-1716), added this improvement to the Pascal machine in 1671, but did not complete his first calculating machine until 1694. The Leibnitz ´reckoning machine´ (based on the Leibnitz wheel) was the first two-motion calculator designed to multiply by repeated addition, but mechanical flaws prevented it from becoming popular. Charles Xavier Thomas de Colmar (1785-1870), of France, makes his "**Arithmometer**", the first mass-produced calculator. It does multiplication using the same general approach as Leibniz's calculator; with assistance from the user it can also do **division**. It is also the most reliable calculator yet. Machines of this general design, large enough to occupy most of a desktop, continue to be sold for about 90 years.

However, like many other machines of the pre-history of computers these devices lacked the mechanical precision in their construction and were very unreliable.

One of the inventions of the Industrial Revolution which has a direct relationship to computers was developed in 1801. A Frenchman named Joseph Jacquard perfected the first **punch card machine** - a loom to weave intricate designs into cloth. It could weave flower designs or pictures of men and women as easily as other looms could weave plain cloth. A famous portrait of Jacquard himself was produced using 24,000 punched cards. When Jacquard first introduced his machine, he had difficulty gaining public acceptance because of the "fear of machines". In the city of Lyons, he was physically attacked and his machine was destroyed. What Jacquard did with his punched cards was, in essence, to provide an effective means of communicating with machines. The language was limited to two words: hole and no hole. The binary system is now universal in all modern day machines.

While Thomas of Colmar was developing the desktop calculator, Charles Babbage, a mathematics professor, started in Cambridge a series of very interesting developments in computers. He was an eccentric genius who inherited a sizable fortune, which he used to finance his wide range of interests. Babbage's contributions range from developing techniques for distributing the mail to investigating volcanic phenomena to breaking supposedly unbreakable codes. If Babbage had never thought about computers, he may have died a more happy man. But he, like the inventors before him, tried to free man from the slavery of computation.

In 1812, Babbage realized that many long calculations, especially those needed to make mathematical tables, were really a series of predictable actions that were constantly repeated. From this he suspected that it should be possible to do these **automatically**. He began to design an automatic mechanical calculating machine, which he called a **difference engine**. By 1822, he had a working model to demonstrate with. The machine had the advantage of being able to maintain its rate of computation for any length of time. With financial help from the British government, Babbage started fabrication of a difference engine in 1823. It was intended to be steam powered and fully automatic, including the printing of the resulting tables, and commanded by a fixed instruction program.

By 1842 the English government had advanced him nearly $42,000. To most people who had just become accustomed to the power loom created by Jacquard, it was inconceivable that a machine could take over the work of the brain. Besides the government grant, Babbage spent $42,000 of his own money on the machine. As it turned out, the machine was never built because he kept changing the design. A Swedish gentleman finally built the machine in 1854 and displayed it in London.

The difference engine, although having limited adaptability and applicability, was really a great advance. Babbage continued to work on it for the next 10 years, but in 1833 he lost interest because he thought he had a better idea: the construction of what would now be called a general purpose, fully program-controlled, automatic mechanical digital computer. Babbage called this idea an **Analytical Engine**. It included 5 features crucial to future computers:

- An **input** device
- A **storage** facility to hold numbers for processing
- A **processor** or number calculator
- A **control** unit to direct tasks to be performed
- An **output** device

Babbage got an idea of the analytical engine, from watching a loom attachment invented by Jacquard. The analytical engine was designed to read two sets of material, store them, and do mathematical operations on them. The first set of material would be the **operation or program**, which was to be carried out on the second set of material, the **variable or data**. However, Babbage never completed the analytical engine nor had he progressed far enough for someone else to complete it. But ultimately the logical structure of the modern computer comes from him even if one essential feature of present-day computers is absent from the design: the "stored-program" concept, which is necessary for implementing a compiler. Lady Ada Lovelace, daughter of Lord Byron, became involved in the development of the analytical engine. Lady Lovelace not only helped Babbage with financial aid, but, being a good mathematician, wrote articles and programs for the proposed machine. Many have called her the first woman programmer. It seems that computers were already being used for playing games because while Babbage was working on an automated tic-tac-toe game, Lady Lovelace proposed that it might be used to compose music.

Boole algebra represents all the mathematical theory needed to perform operations with the binary system George Boole idea was to represent information only with the two logic states true or false. He gave the mathematical ideas and formulas to do calculations on this information. Unfortunately, with the exception of students of philosophy and symbolic logic, **Boolean Algebra** was destined to remain largely unknown and unused for the better part of a century

Three American inventors and friends, who spent their evenings tinkering together, conceived the first practical typewriting machine. In 1867, Christopher Latham Sholes, Carlos Glidden, and Samual W. Soule invented what they called the Type-Writer (the hyphen was discarded some years later). It is commonly believed that the original layout of keys on a typewriter was intended to slow the typist down, but this isn't strictly true. The main inventor of the first commercial typewriter, Christopher Latham Sholes, obviously wished to make their typewriters as fast as possible in order to convince people to use them. However, one problem with the first machines was that the keys jammed when the operator typed at any real speed, so Sholes invented what was to become known as the Sholes keyboard. What Sholes attempted to do was to separate the letters of as many common digraphs as possible. But in addition to being a pain to use, the resulting layout also left something to be desired on the digraph front; for example, "ed", "er", "th", and "tr" all use keys that are close to each other. Unfortunately, even after the jamming problem was overcome by the use of springs, the monster was loose amongst us -- existing users didn't want to change and there was no turning back.

The original Sholes keyboard, which is known to us as the **QWERTY keyboard**, because of the ordering of the first six keys in the third row is interesting for at least two other reasons. First, there was no key for the number '1', because the inventors decided that the users could get by with the letter 'I'. And second, there was no shift key, because the first typewriters could only type upper case letters. Sholes also craftily ensured that the word "Typewriter" could be constructed using only the top row of letters. This was intended to aid salesmen when they were giving demonstrations. And nothing is simple in this world, instead of the top row of characters saying QWERTY, keyboards in France and Germany spell out **AZERTY** and **QWERTZU**, respectively.

The first shift-key typewriter (in which uppercase and lowercase letters are made available on the same key) didn't appear on the market until 1878, and it was quickly challenged by another flavor which contained twice the number of keys, one for every uppercase and lowercase character. For quite some time these two alternatives vied for the hearts and minds of the typing fraternity, but the advent of a technique known as touch-typing favored the shift-key solution, which thereafter reigned supreme. Finally, lest you still feel that the QWERTY keyboard is an unduly harsh punishment that's been sent to try us, it's worth remembering that the early users had a much harder time than we do, not the least that they couldn't even see what they were typing! The first typewriters struck the paper from the underside, which obliged their operators to raise the carriage whenever they wished to see what had just been typed, and so-called "visible-writing" machines didn't become available until 1883

Dorr Eugene Felt was born in Chicago in 1862. In 1885 he made his "Comptometer", the first calculator where numbers were entered by pressing keys as opposed to being dialled in or similar awkward methods.

A step towards automated computing was the development of punched cards, which were first successfully used with computers in 1890 by Herman Hollerith and James Powers. They both were working for the US Census Bureau and John Billings made a comment to Herman Hollerith, a nineteen year old engineer, that he felt that there ought to be some mechanical way of doing this job. Perhaps a way of using the principle of the Jacquard loom, where holes in the card regulate the pattern of weave. They went to work on this idea and the first machine they devised used paper strips with holes punched on them according to a code, similar to a player piano. The paper strip was found to be impractical, so in 1887 a punched card was devised. Hollerith worked out a system that a person's name, age, sex, and other relevant information could be coded by punching holes in a card. It said that the size of the card is the size of the 1887 dollar bill because when Hollerith was designing the card, not knowing what size to make it, he pulled out a one dollar bill and traced it. However there is a controversy about this point and some affirm that they are much smaller. The card was divided into 240 separate areas (20 rows of 12 punches).

They developed devices that could read the information that had been punched into the cards automatically, without human help. Because of this, reading errors were reduced dramatically, workflow increased, and, most importantly, stacks of punched cards could be used as easily accessible memory of almost unlimited size. Furthermore, different problems could be stored on different stacks of cards, accessed when needed and easily transported. Those punched cards were read electronically: the cards were transported between brass rods, and when there were holes in the cards, the rods made contact and an electric current could flow.

As compared to today's machines, these computers were slow, usually processing 50 - 220 cards per minute, each card holding about 80 decimal numbers (characters). At the time, however, punched cards were a huge step forward and despite the increased population to 63 million in 1890, the census was tabulated in 2 1/2 years, a job that might have taken 9 - 10 years manually.

Punched cards provided a means of I/O, and memory storage on a huge scale. For more than 50 years after their first use, punched card machines did most of the world's first business computing, and a considerable amount of the computing work in science.

In 1896, Dr. Hollerith organized the **Tabulating Machine** Company to promote the commercial use of his machine. Twenty-eight years later, in 1924, after several take-overs the company became known as International Business Machines (IBM).

In 1879, the legendary American inventor Thomas Alva Edison publicly exhibited his incandescent electric light bulb for the first time. Edison's **light bulbs** employed a conducting filament mounted in a glass bulb from which the air was evacuated leaving a vacuum. Passing electricity through the filament caused it to heat up enough to become incandescent and radiate light, while the vacuum prevented the filament from oxidizing and burning up. Edison continued to experiment with his light bulbs and, in 1883, found that he could detect electrons flowing through the vacuum from the lighted filament to a metal plate mounted inside the bulb. This discovery subsequently became known as the Edison Effect.

Edison did not develop this particular finding any further, but an English physicist, John Ambrose Fleming, discovered that the Edison Effect could also be used to detect radio waves and to convert them to electricity. Fleming went on to develop a two-element vacuum tube known as **diode**. In 1906, the American inventor Lee de Forest introduced a third electrode called the grid into the **vacuum tube**. The resulting triode could be used as both an amplifier and a switch, and many of the early radio transmitters were built by de Forest using these triodes. De Forest's **triodes** revolutionized the field of broadcasting and were destined to do much more, because their ability to act as switches was to have a tremendous impact on digital computing.

II, And mankind created the computer

In 1927, with the assistance of two colleagues at MIT, the American scientist, engineer, and politician Vannevar Bush designed an **analog computer** that could solve simple equations. This device, which Bush dubbed a Product Intergraph, was subsequently built by one of his students. Bush continued to develop his ideas and, in 1930, built a bigger version that he called a **Differential Analyzer**. The Differential Analyzer was based on the use of mechanical integrators that could be interconnected in any desired manner. To provide amplification, Bush employed torque amplifiers that were based on the same principle as a ship's capstan. The final device used its integrators, torque amplifiers, drive belts, shafts, and gears to measure movements and distances (not dissimilar in concept to an automatic slide rule).

Although Bush's first Differential Analyzer was driven by electric motors, its internal operations were purely mechanical. In 1935 Bush developed a second version, in which the gears were shifted electro-mechanically and which employed paper tapes to carry instructions and to set up the gears. In our age, when computers can be constructed the size of postage stamps, it is difficult to visualize the scale of the problems that these early pioneers faced. To provide some sense of perspective, Bush's second Differential Analyzer weighed in at a whopping 100 tons! In addition to all of the mechanical elements, it contained 2000 vacuum tubes, thousands of relays, 150 motors, and approximately 200 miles of wire. As well as being a major achievement in its own right, the Differential Analyzer was also significant because it focused attention on **analog computing** techniques, and therefore detracted from the investigation and development of digital solutions for quite some time.

Almost anyone who spends more than a few seconds working with a QWERTY keyboard quickly becomes convinced that they could do a better job of laying out the keys. Many brave souls have attempted the task, but few came closer than efficiency expert August Dvorak in the 1930s. When he turned his attention to the typewriter, Dvorak spent many tortuous months analyzing the usage model of the QWERTY keyboard . The results of his investigation were that, although the majority of users were right-handed, the existing layout forced the weaker left hand (and the weaker fingers on both hands) to perform most of the work. Also, thanks to Sholes' main goal of physically separating letters that are commonly typed together, the typist's fingers were obliged to move in awkward patterns and only ended up spending 32% of their time on the home row. Dvorak took the opposite tack to Sholes, and attempted to find the optimal placement for the keys based on letter frequency and human anatomy. That is, he tried to ensure that letters which are commonly typed together would be physically close to each other, and also that the (usually) stronger right hand would perform the bulk of the work, while the left hand would have control of the vowels and the lesser-used characters. The result of these labors was the Dvorak Keyboard, which he patented in 1936.

Note that **Dvorak's keyboard** had shift keys and the results of Dvorak's innovations were tremendously effective. Using his layout, the typist's fingers spend 70% of their time on the home row and 80% of this time on their home keys. Thus, as compared to the approximately 120 words that can be constructed from the home row keys of the QWERTY keyboard, it is possible to construct more than 3,000 words on Dvorak's home row. Also, Dvorak's scheme reduces the motion of the hands by a factor of three, and improves typing accuracy and speed by approximately 50%, and 20%, respectively. Unfortunately, Dvorak didn't really stand a chance trying to sell typewriters based on his new keyboard layout in the 1930s. Apart from the fact that existing typists didn't wish to re-learn their trade, America was in the heart of the depression years, which meant that the last thing anyone wanted to do was to spend money on a new typewriter. In fact, the Dvorak keyboard might have faded away forever, except those enthusiasts in Oregon, USA, formed a club in 1978, and they've been actively promoting Dvorak's technique ever since.

In 1937, George Robert Stibitz, a scientist at Bell Laboratories built a digital machine based on relays, flashlight bulbs, and metal strips cut from tin-cans. Stibitz's machine, which he called the "Model K" (because most of it was constructed on his kitchen table), worked on the principle that if two relays were activated they caused a third relay to become active, where this third relay represented the sum of the operation. For example, if the two relays representing the numbers 3 and 6 were activated, this would activate another relay representing the number 9. Bell Labs recognized a potential solution to the problem of high-speed complex-number calculation, which was holding back contemporary development of wide-area telephone networks. By late 1938

the laboratory had authorized development of a full-scale relay calculator on the Stibitz model; Stibitz and his design team began construction in April 1939. The end product, known as the Complex Number Calculator, first ran on January 8, 1940.

The British mathematician Alan Mathison Turing was one of the great pioneers of the computer field. In 1937, while a graduate student, Turing wrote his paper "On Computable Numbers with an Application to the Entscheidungs problem." One of the premises of Turing's paper was that some classes of mathematical problems do not lend themselves to algorithmic representations and are not amenable to solution by automatic computers.

Since Turing did not have access to a real computer, he invented his own as an abstract "paper exercise." This theoretical model, known as a Turing Machine, is a hypothetical device that presaged programmable computers. The **Turing machine** was designed to perform logical operations and could read, write, or erase symbols, essentially zeros and ones, written on squares of an infinite paper tape. These ones and zeros described the steps that needed to be done to solve a particular problem or perform a certain task. The Turing Machine would read each of the steps and perform them in sequence, resulting in the proper answer. This kind of machine came to be known as a finite state machine because at each step in a computation, the machine's next action was matched against a finite instruction list of possible states.

So as a mathematician Turing applied the concept of the algorithm (A precise rule or set of rules specifying how to solve some problem) to digital computers. His research into the relationships between machines and nature created the field of **artificial intelligence**. His intelligence and foresight made him one of the firsts to step into the information age.

In 1936, the American psychologist Benjamin Burack from Chicago constructed what was probably the world's first electrical logic machine. Burack's device used light bulbs to display the logical relationships between a collection of switches, but for some reason he didn't publish anything about his work until 1949. In fact the connection between Boolean algebra and circuits based on switches had been recognized as early as 1886 by an educator called Charles Pierce, but nothing substantial happened in this area until Claude E. Shannon published his 1938 paper. So in 1937, nearly 75 years after Boole's death, Claude Shannon, a student at MIT recognised the connection between **electronic circuits and Boolean algebra**. He transferred the two logic states to electronic circuits by assigning different voltage levels to each state and in published an article based on his master's thesis at MIT showing how Boole's concepts of TRUE and FALSE could be used to represent the functions of switches in electronic circuits. It is difficult to convey just how important this concept was; suffice it to say that Shannon had provided electronics engineers with the mathematical tool they needed to design digital electronic circuits and these techniques remain the cornerstone of digital electronic design to this day

Following Shannon's paper, a substantial amount of attention was focused on developing electronic logic machines, but the interest in special-purpose logic machines waned in the 1940s with the advent of general-purpose computers, which proved to be much more powerful and for which programs could be written to handle formal logic.

From the end of the 1930s to the beginning of the 1950s, a lot of "first computers" began to be constructed. There is a never-ending debate as for which one of them was the first computer. In this document we assume that they are all close ancestors of the computer but that the first real computer was the EDVAC, because it was the first internally stored program computer to be built.

In 1939 Atanasoff formulated the idea of using the **binary number** system to simplify the construction of an electronic calculator. He was looking for someone to help him design and build a computing machine when a colleague recommended a graduating electrical engineering student, Clifford Berry. In the fall of 1939 Atanasoff and Berry began building the prototype of the first computing machine to use electricity and vacuum tubes, binary numbers, capacitors in a rotating drum for memory elements, and logic systems for computing. A working model by the end of the year demonstrated the validity of their concepts and won them a grant of $850 to build a full-scale computer. Berry and Atanasoff worked together in their basement laboratory over the next two years, with both professor and student suggesting improvements and innovations. The result was the **Atanasoff Berry Computer** (ABC), the world's first electronic digital computer.

In 1937, Professor Howard Aiken of Harvard became interested in building an automatic calculating device. In 1939 he started the MARK series of computers. The Mark I was completed in 1944 with the help of IBM engineers. The **Mark I** was 51 feet long, 8 feet high, contained 760,000 parts using 500 miles of wire, and weighed 5 tons. Aiken's machine was built on the concept of using information from punched cards as input and making decisions through electromechanical devices (addition and subtraction took .3 of a second, multiplication less than 6 seconds and division less than 16 seconds), and produced results on punched cards. Mark I is considered to be the first general purpose digital computer with all operations being carried out by a system of switches and relays. It could do five operations, addition, subtraction, multiplication (6 seconds), division and reference to previous results; moreover, it had special built-in programs, or subroutines, to handle logarithms and trigonometric functions. It stored and counted numbers mechanically using 3000 decimal storage wheels, 1400 rotary dial switches, and 500 miles of wire but transmitted and read the data electrically. The machine was used extensively by the U.S. Navy during the Second World War.

In 1940, Stibitz performed a spectacular demonstration at a meeting in New Hampshire. Leaving his computer in New York City, he took a teleprinter to the meeting and proceeded to connect it to his computer via telephone. In the first example of **remote computing**, Stibitz astounded the attendees by allowing them to pose problems, which were entered on the teleprinter and, within a short time, the teleprinter presented the answers generated by the computer.

Konrad Zuse studied construction engineering in Berlin. Tired of repeating calculation procedures he built a first mechanical calculator, the **Z1**. Then he developed from waste material, together with a few friends in the living room of his parents, the world's first electronic, programmable calculator, the **Z3**. The original was unfortunately destroyed later during the war. Knowing that his invention could do a week's work of a whole calculation department within a few hours Konrad Zuse remained silent due to the dark times and the resulting relevance of his early knowledge. During the last days of war the next model **Z4** was transported under adventurous circumstances via truck and horse-drawn cart from Berlin to Göttingen and then to the Allgäu. Hidden in a stable it remained undiscovered by the war parties and was later in 1949 transported to the Eidgenössische Technische Hochschule Zürich. Another extraordinary achievement is the first algorithmic programming language "Plankalkül" that was developed by Konrad Zuse in 1945/46.

From various sides Konrad Zuse was awarded with the title "Inventor of the computer". When asked about it Konrad Zuse used to reply - "Well, I guess, it took many inventors besides me to develop the computer as we know it nowadays. I wish the following generation All the Best for their work with the computer. May this instrument help you to save the problems which we old folks have left behind."

The Z3 was controlled by punched tape, using discarded movie film, while the input and output were via the same four-decimal-place keyboard and lamp display. The entire machine was based on relay technology, about 2,600 of them being required, 1,400 for the memory, 600 for the arithmetic unit, and the rest as part of the control circuits. They were mounted in three racks, two for the memory and one for the arithmetic and control units, each about 6 feet high by 3 feet wide. The 64-word memory was floating-point binary in organization but this time the word length was increased to 22 bits: 14 for the mantissa, 7 for the exponent, and one for the sign.

The speed of the Z3 was comparable to that of the Harvard Mark I. The Z3 could perform three or four additions per second and multiply two numbers together in 4 to 5 seconds. The Z3's floating point representation of numbers made it more flexible than the Mark I. Started in 1939, the Z3 was operational by December 5, 1941. The total cost of materials was 25,00 RM (about $6,500 at the time). It was never used for any large problems because its limited memory would not enable it to hold enough information to be clearly superior to the manual methods for solving a system of linear equations. It remained in Zuse's house until it was destroyed in an air raid in 1944.

In January 1943, along with a number of colleagues, Turing began to construct an electronic machine to decode the Geheimfernschreiber cipher. This machine, which they dubbed COLOSSUS, comprised 1,800 vacuum tubes and was completed and working by December of the same year. By any standards COLOSSUS was one of the world's earliest working programmable electronic digital computers. But it was a special-purpose machine that was really only suited to a narrow range of tasks (for example, it was not capable of performing

decimal multiplication). Having said this, although COLOSSUS was built as a special-purpose computer, it did prove flexible enough to be programmed to execute a variety of different routines.

The start of World War II produced a large need for computer capacity, especially for the military. New weapons were made for which trajectory tables and other essential data were needed. In 1942, John P. Eckert, John W. Mauchly (left), and their associates at the Moore school of Electrical Engineering of University of Pennsylvania decided to build a high - speed electronic computer to do the job. This machine became known as **ENIAC** (Electrical Numerical Integrator And Calculator) and was finished in 1946. Its construction included 18,800 vacuum tubes. Two and one half years were needed just to solder the 500,000 connections the tubes required. The ENIAC weighed 30 tons and took up 1500 sq. ft. of floor space and required 150 kilowatts of power. ENIAC could perform 500 additions and 300 multiplication in one second, and in one day performed what would take 300 days to do by hand. Input and output was through punched cards. ENIAC, however, could only store 20 ten-digit numbers.

The executable instructions making up a program were embodied in the separate "units" of ENIAC, which were plugged together to form a "route" for the flow of information. These connections had to be redone after each computation, together with presetting function tables and switches. This "wire your own" technique was inconvenient (for obvious reasons), and with only some latitude could ENIAC be considered programmable. It was, however, efficient in handling the particular programs for which it had been designed. ENIAC is commonly accepted as the first successful high - speed electronic digital computer (EDC) and was used from 1946 to 1955. A controversy developed in 1971, however, over the patentability of ENIAC's basic digital concepts, the claim being made that another physicist, John V. Atanasoff (left) had already used basically the same ideas in a simpler vacuum - tube device he had built in the 1930's while at Iowa State College. In 1973 the courts found in favor of the company using the Atanasoff claim.

An interesting note is that in 1846, William Shanks had spent twenty years of his life computing to 707 decimal places. ENIAC computed to 2,000 in 70 hours and showed that Shanks made an error in the 528th decimal place.

Fascinated by the success of ENIAC, the mathematician John Von Neumann undertook, in 1945, an abstract study of computation that showed that a computer should have a very simple, fixed physical structure, and yet be able to execute any kind of computation by means of a proper programmed control without the need for any change in the unit itself. He recommended that the binary system be used for storage in computers and proposed that instructions to control the computer, as well as data, be stored within the computer.

Von Neumann contributed a new awareness of how practical, yet fast computers should be organized and built. These ideas, usually referred to as **'the stored - program technique'**, became essential for future generations of high - speed digital computers and were universally adopted.

The Stored - Program technique involves many features of computer design and function besides the one that it is named after. In combination, these features make very - high - speed operation attainable. A glimpse may be provided by considering what 1,000 operations per second means. If each instruction in a job program were used once in consecutive order, no human programmer could generate enough instruction to keep the computer busy. Arrangements must be made, therefore, for parts of the job program (called subroutines) to be used repeatedly in a manner that depends on the way the computation goes. Also, it would clearly be helpful if instructions could be changed if needed during a computation to make them behave differently. Von Neumann met these two needs by making a special type of machine instruction, called a Conditional control transfer - which allowed the program sequence to be stopped and started again at any point - and by storing all instruction programs together with data in the same memory unit, so that, when needed, instructions could be arithmetically changed in the same way as data.

As a result of these techniques, computing and programming became much faster, more flexible, and more efficient with work. Regularly used subroutines did not have to be reprogrammed for each new program, but could be kept in "libraries" and read into memory only when needed. Thus, much of a given program could be assembled from the subroutine library.

The all - purpose computer memory became the assembly place in which all parts of a long computation were kept, worked on piece by piece, and put together to form the final results. The computer control survived only as an "errand runner" for the overall process. As soon as the advantage of these techniques became clear, they became a standard practice.

The first generation of modern programmed electronic computers to take advantage of these improvements was built in the late 1940s. This group included computers using Random - Access - Memory (RAM), which is a memory designed to give almost constant access to any particular piece of information. . These machines had punched - card or punched tape I/O devices and RAM's of 1,000 - word capacity and access times of .5 Greek MU seconds (.5*10-6 seconds). Some of them could perform multiplication in 2 to 4 MU seconds. Physically, they were much smaller than ENIAC. Some were about the size of a grand piano and used only 2,500 electron tubes, a lot less then required by the earlier ENIAC. The first - generation stored - program computers needed a lot of maintenance, reached probably about 70 to 80% reliability of operation (ROO) and were used for 8 to 12 years. They were usually programmed in ML, although by the mid 1950's progress had been made in several aspects of advanced programming. This group of computers included **EDVAC** and **UNIVAC** the first commercially available computers.

The EDVAC was constructed at the Moore School of Electrical Engineering and delivered to the BRL Computing Laboratory at Aberdeen Proving Ground in August 1949 for installation. Initially there were very few logical errors, which were solved in eighteen months and the machine started to operate on a limited basis late in 1951. By early 1952 it was averaging 15-20 hours of useful time per week for solving mathematical problems. By 1961 the EDVAC was operating 145 hours out of a 168-hour week.

EDVAC was the first internally stored program computer to be built and was organized as follows:

- Control. This unit contained all operating buttons, indicating lamps, control switches, and an oscilloscope for aid in maintenance.
- Dispatcher. This unit decoded orders received from the control and memory.
- High-Speed Memory. This consisted of two identical units, each containing 64 acoustic delay lines.
- Computer. This unit performed the rational operations (addition, subtraction, multiplication, and division). Any disagreements stop the machine and give an abnormal halt indication.
- Timer. This unit emitted the clock pulses at intervals of 1 microsecond, and timing pulses at intervals of 48 microseconds.

After ten years of operation the EDVAC was still in use because of its great reliability and productivity, its low operating cost, its high operating efficiency and its speed and flexibility in solving certain types of problems.
Then throughout the technical and science evolutions, the computer evolves a lot. The generally accepted generations of computers are:

1.First generation used vacuum tubes -- 1940 - 1950
2.Second generation: transistors -- 1950 - 1964
3.Third generation used integrated circuits -- 1964 - 1971
4.Fourth generation uses microprocessor chips -- 1971 - present

Some of the milestones of the latest evolutions may be found in the timeline given in annex but the complete description of the latest improvements can not be written in few pages.