Computer Architecture
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Lecture - 2
History of Computers

In the previous lecture I talked about what is important in this course what we are going to cover in this course and in this lecture I am going to look at history of computers. History is important because by studying history we get good insight into the subject whether it is political history, economic history or history of science or history of computers and we get to know the present better as well as the future better. So we look at the developments which have taken place in the past, which have made significant impact on the computer we see today and we are going to see tomorrow.

First of all we will look at the past, half a century or so and see how this period gets divided into different generations then we will look at what had been the landmark developments which have had significant impact on history or on the design and architecture.

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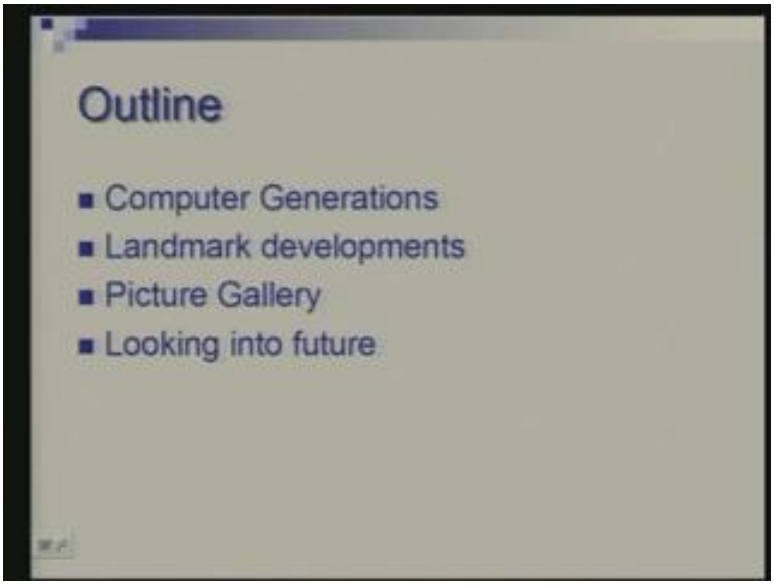

We will look at some of the interesting old pictures of computers and finally have a look at briefly, as mentioned, what technology is being worked upon in various research labs and they may decide what kind of computers they are going to have in the future.

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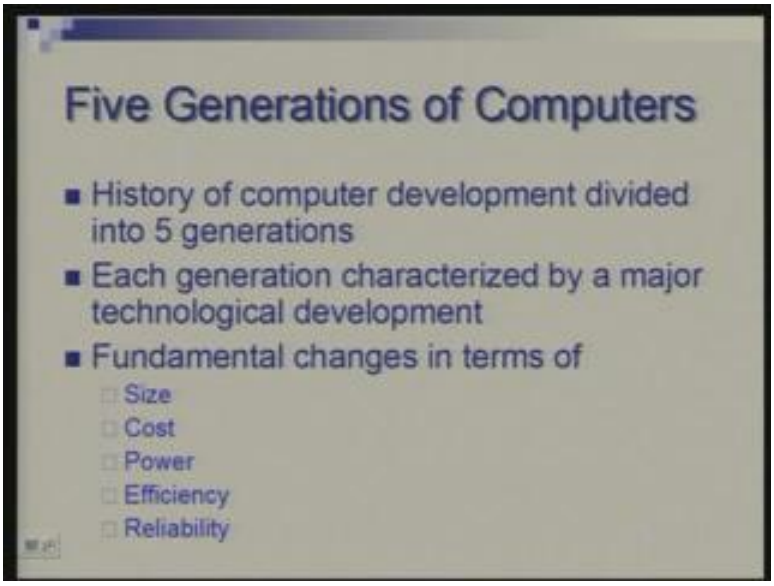

This period of about half century or so is divided into five generations. There may be some differences of opinion here. Some people recognize only four generations but some talk of five so I will talk of all the five and mention which one is the fifth one which is not a regular generation as recognized by many people. These different generations as we see are predominantly different in terms of the technology which is used to develop computer systems or electronic system in general. As some major technological development takes place everything changes; a very significant, very drastic sudden change in the shape of the things and it gives rise to a new generation. These changes the fundamental changes are in terms of size, size of computers. As I mentioned last time that what is to be a room full has not shrunk on to something small which can come on desktop.

In terms of cost, the affordability has been changed over time. Earlier computer used to be affordable by large organizations, now large number of people can afford to have the individual computers and in fact if you count all embedded computers the computer density in many cases may be more than one per person if you look at all devices, all appliances, mobile phones and various equipment the number of computers you have you can account for per person could be even more than one that is the situation today.

The power consumption has changed drastically by several orders of magnitude, the efficiency in terms of performance what they could do for a given input that has changed and of course reliability. There was a situation when every now and then something will go wrong and has to be taken care of but now computers can work very reliably for extended periods.

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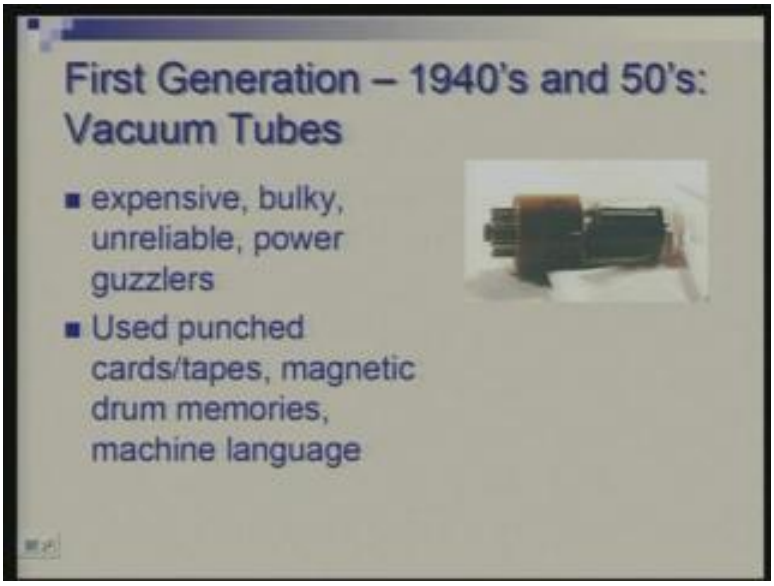

The beginning in 40's so 40's to 50's is what is considered as the first generation where the basic device was vacuum tube. The vacuum tube is the bulb like device as you can see in the picture here it is a basic electronic device which can amplify signals or it can switch voltage at current levels. So this is expensive, bulky, unreliable and power guzzlers. The computer is built using this where it is again huge, roomful of system and the input output devices were punched cards and paper tapes. The memory was in the form of a rotating drum, magnetic rotating drum and the language used to program was machine language so this was how the first generation computers were.

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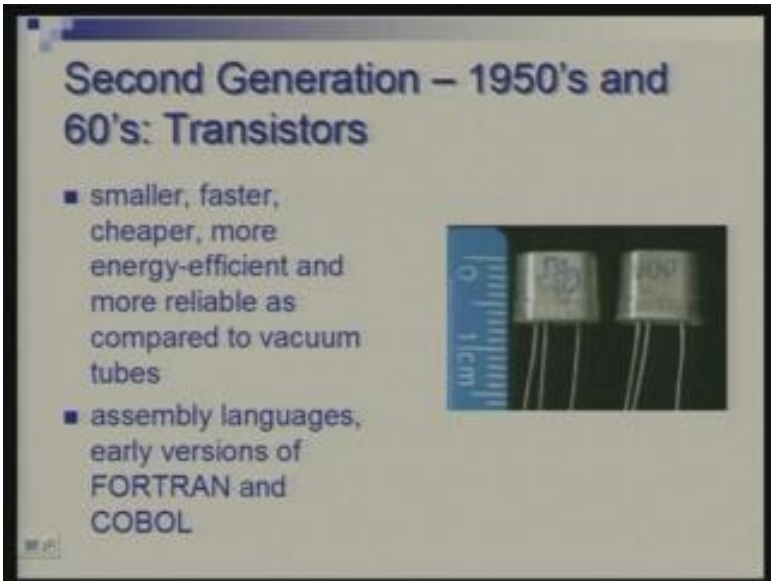

The second generation as you would notice a period which I am indicating are overlapping it is not that suddenly on day one the generation ends and next one starts so there is a transition but when there is a change there is a rapid transition otherwise all the time there is growth, development, improvement but a generation change is marked by not absolutely abrupt but rapid transition. So, that change here occurred with the arrival of transistor. So the picture shows some old transistor from Texas Instruments. These transistors performed roughly similar functions what the vacuum tube did but they were much smaller, faster, cheaper and more efficient in terms of energy; also reliability was much better in terms of the time after which the transistor is likely to fail.

There was also further development in terms of software; instead of machine language people started using assembly language and also within this period some languages high level languages their early versions they appeared such as FORTRAN and COBOL.

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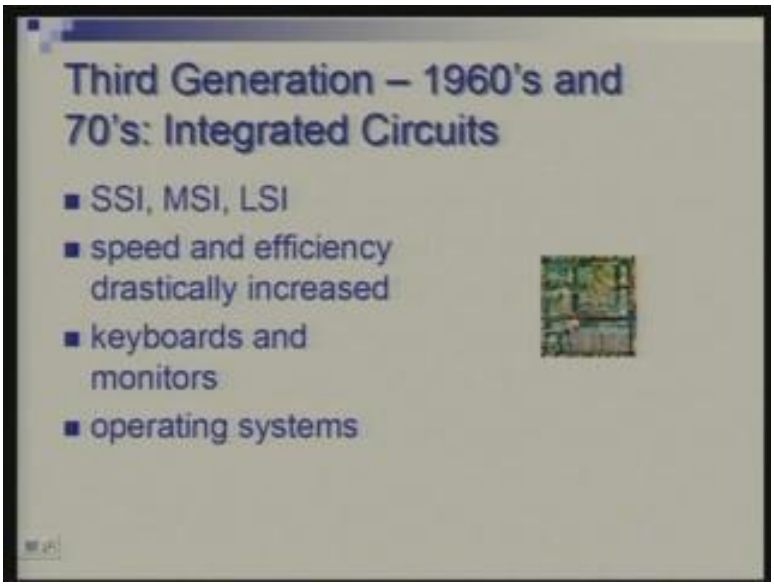

Then the technology moved further, it became possible to put several transistors together on a single silicon chip that was called integrated circuits. So you can integrate many transistors and that appears as a single device. The picture here shows the layout of some early chip. Depending upon the level of integration these were characterized as SSI, MSI or LSI. SSI stands for Small Scale Integration, Medium Scale Integration and Large Scale Integration or small scale integration would mean may be a few devices few transistors may be about ten, fifteen or so; medium scale integration would take to a few tens of transistors and large scale would scale few thousands of transistors. So with this naturally the equipment computer became more compact, the speed increased, the efficiency increased, additional peripherals became available, the computing became more interactive; with cards and paper tape it was a batch processing environment entirely that is you submit your program for running and a day later or two days later depending upon the load and efficiency of the system you will get your results. So it is not that you press a button and immediately see the results; you will have to prepare a deck of cards on which

your program is punched and data is also punched or prepare a roll of paper tape by punching program on it and submit to a central facility and sometime later some days later I should say the result will come and for all you know you might find that there was small syntactic mistakes where you had some full stop or comma missing somewhere and the program result is nil it will just say error message so you work on it make that correction submit it again and so on so it was a very tedious process.

Now, this time the computing started becoming little more interactive in the sense that there were terminals and keyboards through which you can immediately interact; instead of a batch mode it was more interactive and online mode and operating system also evolved which were used to manage all the resources.

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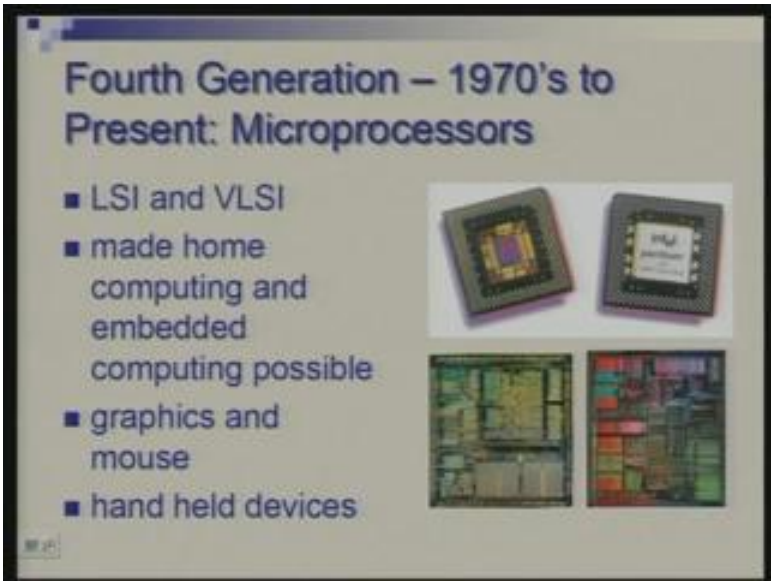

Then the next change next major change occurred when VLSI appeared on the same. Now it became possible to make an entire processor on a single chip. The number of transistors you could integrate on a chip was large enough to make it possible for entire processor to be within a single chip and with this the level of integration in this era LSI to VLSI where VLSI stands for Very Large Scale Integrated circuits. After VLSI, also terms have been defined like ULSI Ultra Large Scale Integrated circuits but they have not become popular and we from 70's late 70's we still continue to be talking of VLSI also although the number of transistors you can put now has gone to several millions in fact tens of millions tending to hundreds of millions whereas initially VLSI basically meant that a few tens and hundreds of thousands of transistors can be put on a chip.

With this level of change in the technology it became possible really to have individuals owning their computers; personal computing, home computing, embedded computing which means computers becoming just a component in a large system all that became possible when processor really shrunk to a single chip. And in terms of capabilities of

computers there was more emphasis on graphics, graphical user interface driven by a mouse, handheld devices also started appearing that was the fourth generation.

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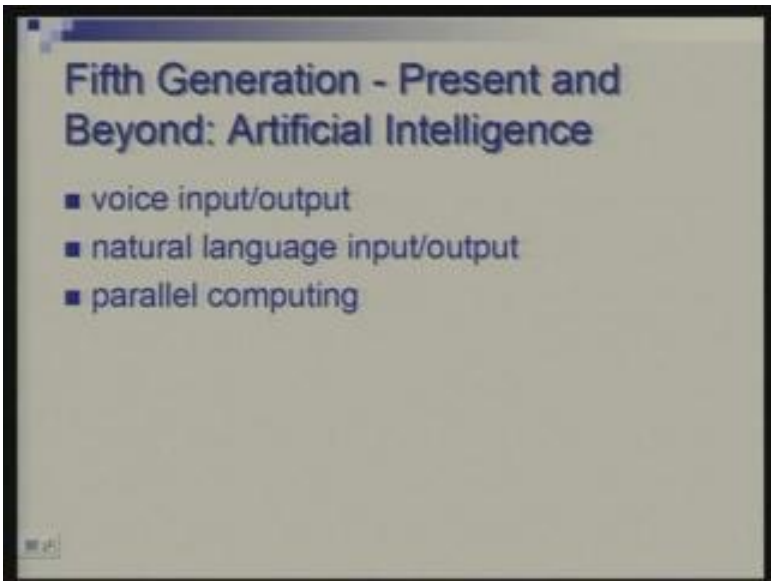

Now many people do not talk of further generations after this. they believe that it is basically the same microprocessor era or the fourth generation which is continuing but there is in literature you find a mention of the fifth generation also where one does not see so much of technological revolution but only change is in terms of the capability of computers; computers are becoming more intelligent, use of artificial intelligence more and more, use of more and more parallel processing to increase the performance and input outputs becoming more natural in human life.

In fact the term fifth generation computing came from a massive project which was undertaken in Japan. Is there a question? Okay. So unlike previous generations which were defined by change in the hardware technology here it was a change more in the style of computing and level of performance.

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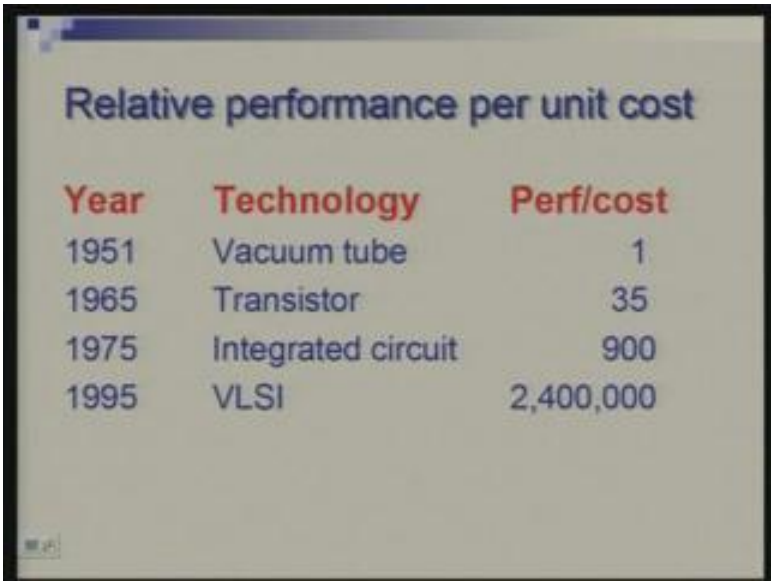

We leave now the generations here and look at a few technical features of how various parameters which are important to us have changed over time. For example, let us look at the performance with respect to the cost of a computer. So, over the period, over the time the performance has increased where the cost has decreased. If you really combine the effect of these two and look at performance divided by the cost per unit cost of a system you get a very astonishing improvement.

On a relative scale four technologies are compared here: vacuum tube, transistor, integrated circuit and VLSI the four different generations we talked of and roughly look at the years 1951, 65, 75, and 95 the performance per cost per unit cost rises from 1 to 35 to 900 to 2.4 million. So you can see the amount of progress which has taken place in terms of performance you can buy for a rupee or a dollar.

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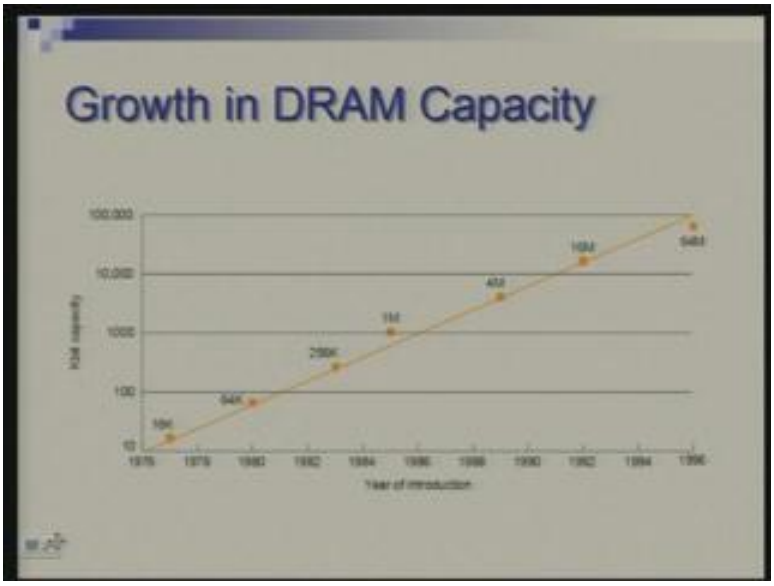

Another interesting thing you would notice is how memory capacity has changed. We are looking at not the entire period but the time when DRAM or dynamic ram the basic semiconductor memory which you find in all computers today, how it has changed in terms of capacity so we are talking of capacity per chip. Therefore, you see, almost a linear rise on a log scale which means essentially there has been an exponential rise in the capacity as the years have passed by from 1976 to 1996 whereas in early period here you see a 16k capacity 16k bits and now you can see in 96 which is about 20 years later that it is 64 million bits. The rate at which the capacity changes from year to year is…… roughly in one and a half years the capacity doubles or if you take a period of three other it is quadruple.

If you look at the clock frequency at which the processors run there also you would find that you see an exponential rise so again roughly for every two years or one and a half to two years you will see that the frequency of processor keeps doubling.

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This graph shows the overall performance on some relative scale of complete computer system which will actually include performance, contribution made by CPU as well as the memory as a single figure. Now again just over a ten years period from 1987 to 1997 you could see an exponential rise in performance. Some of the early machines in this decade was Sun 4/260 and then there are few MIPS machines IBM machines, HP, Deckel and lastly you see Deckel for 21264 where the performance has gone from almost ten on the scale to more than thousand.

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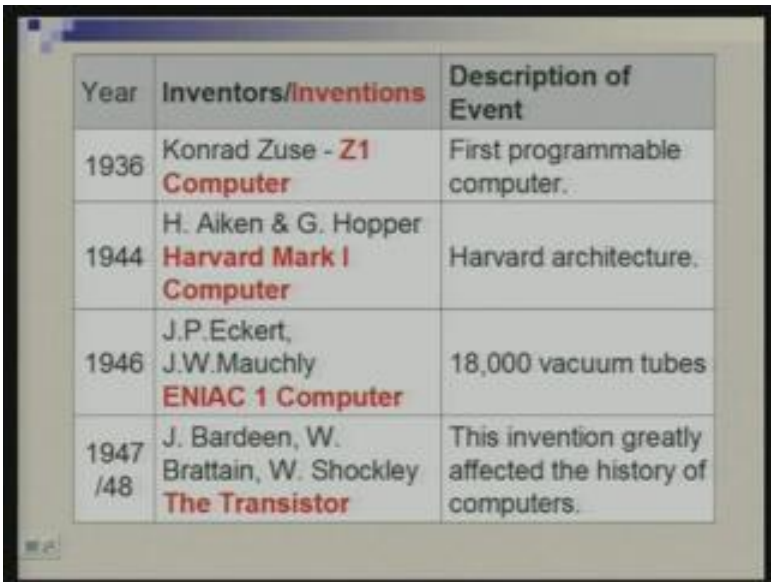

Year	Inventors/Inventions	Description of Event
1936	Konrad Zuse - Z1 Computer	First programmable computer.
1944	H. Aiken & G. Hopper Harvard Mark I Computer	Harvard architecture.
1946	J.P.Eckert, J.W.Mauchly ENIAC 1 Computer	18,000 vacuum tubes
1947 /48	J. Bardeen, W. Brattain, W. Shockley The Transistor	This invention greatly affected the history of computers.

Now let us go through some key developments which took place. We so far saw in terms of generation how technology changed but now let us look at the events the significant events which occurred, the year in which they occurred, what was the event and what was the impact. Let us go through the next couple of slides for some of the major events beginning with introduction of the first programmable computer by Konrad Zuse which is called Z1 in 1936. In 1944 the computer called Harvard Mark 1 was introduced. This computer is known for what is called Harvard architecture. This architecture essentially means that the memory used for storing program and memory used for storing data are two separate things. What we see most commonly today is a single memory which accommodates program and data but here there were two different memory units for program and data and in some forms you see that idea. Even today although the main memory is a single memory but you often find that the caches for program and data are different. This basic idea could be actually traced back to that time.

Then there is in a ENIAC 1 computer and its developers were Eckert and Mauchly. This was significantly large as compared to the previous attempts. actually in that period there were several attempts; some were partially successful, some were fully successful and in this periods of 40's many groups who were working who were researching on development of computers developed their own system but this one ENIAC 1 is considered to be the most significant in terms of its size, its capabilities and also it formed the basis of many things which came later on.

Often it is difficult to pin point who can be considered as the inventor of computer because there were many competing claims; some had some virtues some have others but it was John von Neumann who was not involved in developing any of the machine which you see listed on this slide but he first wrote down very neatly, very precisely the concept of a store program which we consider as the basic principle of computer. This is what I mentioned in the previous lecture also that the basic idea is that you have a program in the form of instructions and with the help of program counter the processor picks instruction by instruction and then executes. That is a simple idea but in this form it was first stated by John von Neumann whereas around the same time these computers which were being made some of them were not really programmable; you could not store programs you have to actually plug in wires from one slot to another slot to change the functionality so they were sort of computers which were not very easy to program. Then in 1947, 48 is the time when transistor was invented so that is one event which has changed the history.

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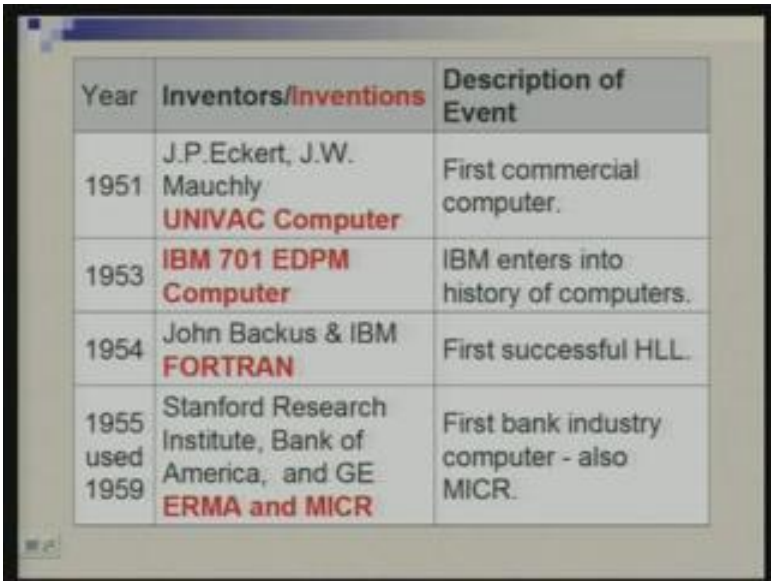

Year	Inventors/Inventions	Description of Event
1951	J.P.Eckert, J.W. Mauchly UNIVAC Computer	First commercial computer.
1953	IBM 701 EDPM Computer	IBM enters into history of computers.
1954	John Backus & IBM FORTRAN	First successful HLL.
1955 used 1959	Stanford Research Institute, Bank of America, and GE ERMA and MICR	First bank industry computer - also MICR.

The first commercial computer is considered as UNIVAC and people who were involved with ENIAC 1 were actually responsible for development of this. It is a different matter that you develop a one of a kind system in a research lab and it is another matter that you have something which is repeatable, it is commercially available and people can go and buy. Then IBMs first computer is IBM 701 so that way IBM enters the history of computers and has remained a very significant player in the industry.

The language FORTRAN the first high level language which is easy when used even today in some form, it is not in the original form there were FORTRAN 1, 2, 3, 4, FORTRAN 77, 8 , 9 and so on so various versions have come but the original event is 1954 when the first version was made available.

In 1955 by Stanford Research Institute and Bank of America and GE a computer was developed which was the first use of the computer in the banking industry and also MICR was made available at that time; MICR you would know is Magnetic Ink Character Reading.

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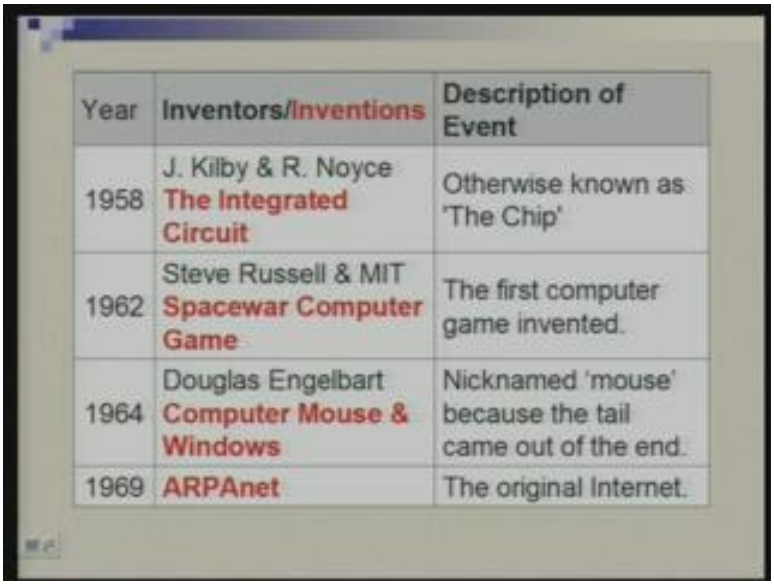

Year	Inventors/Inventions	Description of Event
1958	J. Kilby & R. Noyce The Integrated Circuit	Otherwise known as 'The Chip'
1962	Steve Russell & MIT Spacewar Computer Game	The first computer game invented.
1964	Douglas Engelbart Computer Mouse & Windows	Nicknamed 'mouse' because the tail came out of the end.
1969	ARPAnet	The original Internet.

The ICs Integrated Circuits date back to 1958. The first computer game was developed in 1962 Spacewar; invention of computer mouse which you use so frequently now was developed in1964, the first computer network ARPAnet was in 1969 so this was actually a network developed by Defense funding and ARPA stands for Advanced Research Project Agency it is a Defense Agency which funds research projects in USA.

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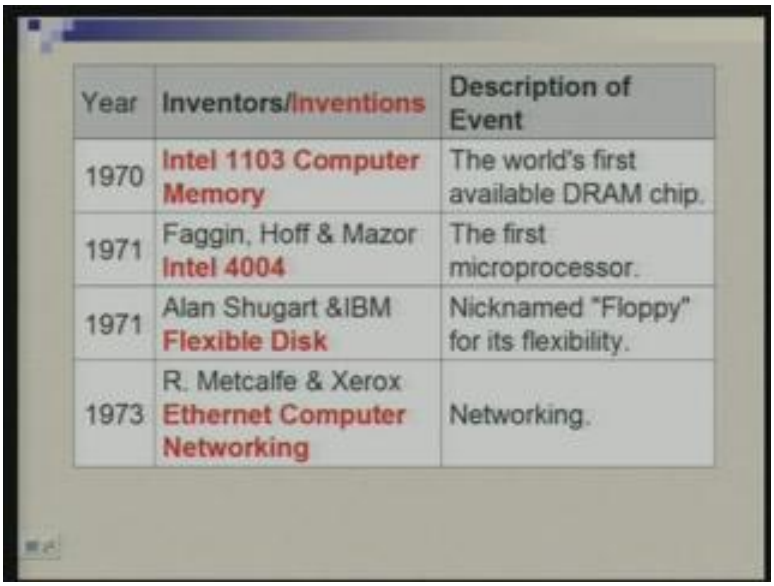

Year	Inventors/Inventions	Description of Event
1970	Intel 1103 Computer Memory	The world's first available DRAM chip.
1971	Faggin, Hoff & Mazor Intel 4004	The first microprocessor.
1971	Alan Shugart &IBM Flexible Disk	Nicknamed "Floppy" for its flexibility.
1973	R. Metcalfe & Xerox Ethernet Computer Networking	Networking.

Large scale integration begins here. It was Intel first memory chip 1103, first dynamic RAM chip and the first microprocessor is Intel 4004. A flexible storage unit, flexible disk or more commonly known as floppy disk because of its flexible nature, the Ethernet

computer networking is used in that 1973; the first computer used by the consumer, the first home computer or consumer computers were developed in 74, 75.

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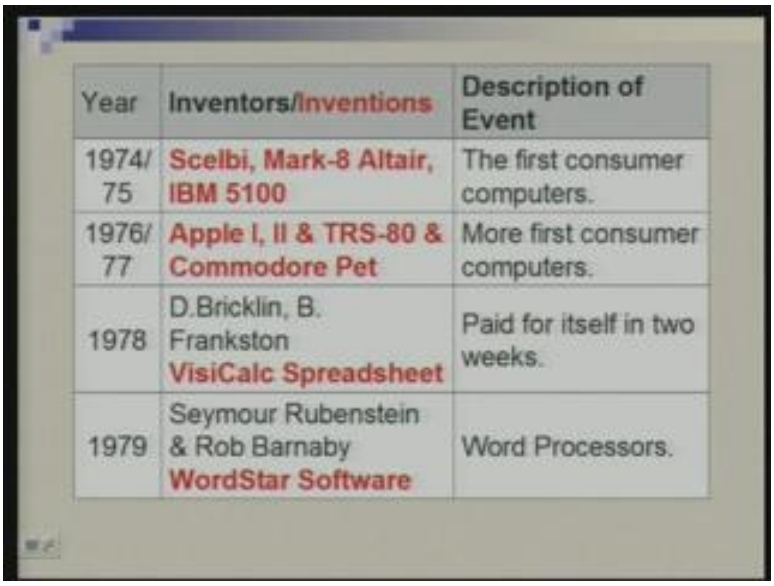

There are some more popular computers which actually spanned many years and the one from apple was the TRS-80 and Commodore; spreadsheet program which is very popular now……the first spreadsheet was VisiCalc developed in 1978; first word processor WordStar was in 1979.

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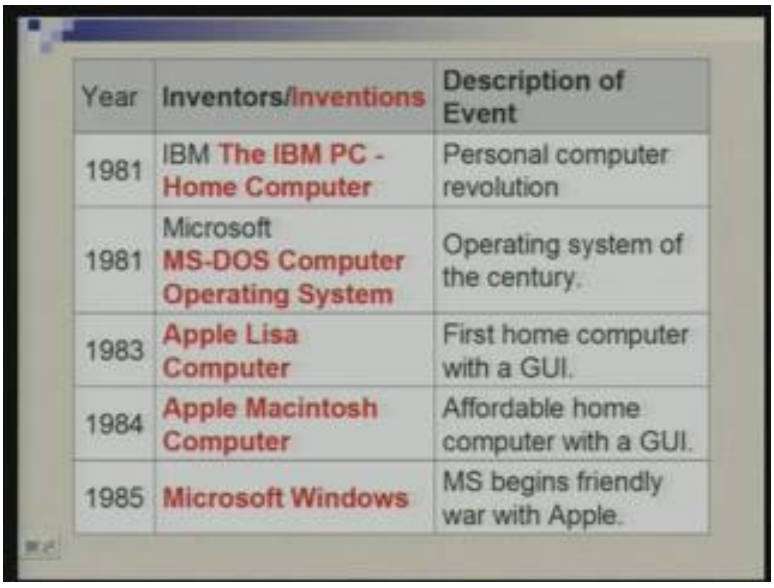

IBM PC once again which is a very very important landmark in the history was developed in 1981 and the significant impact of this was actually that computing came to a personal level, serious computing. Earlier the consumer computers which I mentioned was used more for hobby but with PC serious computing also moved to individuals and the companies which actually reaped maximum benefit out of this event were Microsoft and Intel and what they are today is largely because of this.

The first operating system first version of Microsoft operating system MSDOS came up in 1981 at the same time. Apple Lisa computer was the first computer with extensive GUI Graphic User Interface till then primarily computed in used with textual interface you will give command textually and see the results but with graphics interface it became much more convenient.

Another popular computer was Apple Macintosh. Windows appeared in 1985 and it is still being used today in different versions. I have not traced history of events beyond this. But as you see lot of significant events took place in this period.

Now, before we go to an end let us look at some of the old photographs of old computers and you will get a feel of how different they looked as compared to what we see today.

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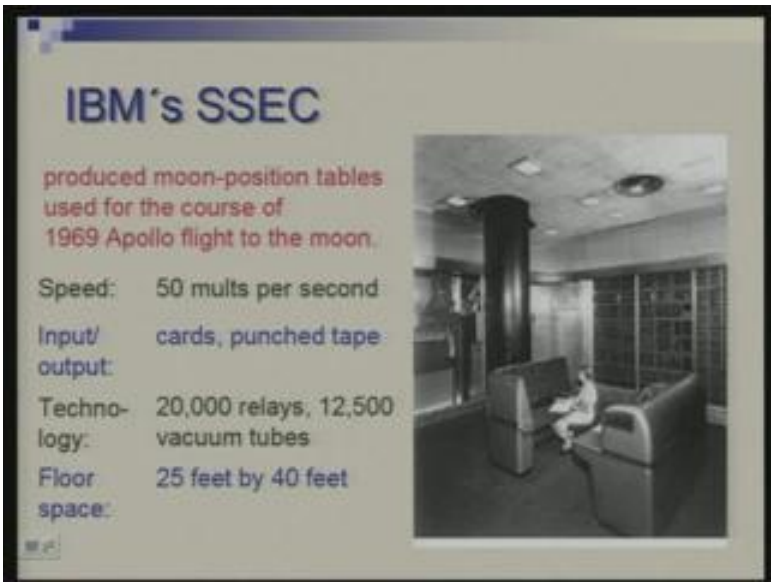

This is one of the very early computers from IBM IBM's SSEC; it was used to compute tables indicating moon positions and this was used for the Apollo flight to moon in 1969. The speed of this was only 50 multiplications per second. Now we talk of millions of operations per second. The input and output was using cards and punched tape. The technology used here was vacuum tubes and Relays. Relays are devices again which can be with a control voltage or current they can be switched on and off. The idea of size you can get by looking at this picture and it required a floor space of 25 feet by 40 feet.

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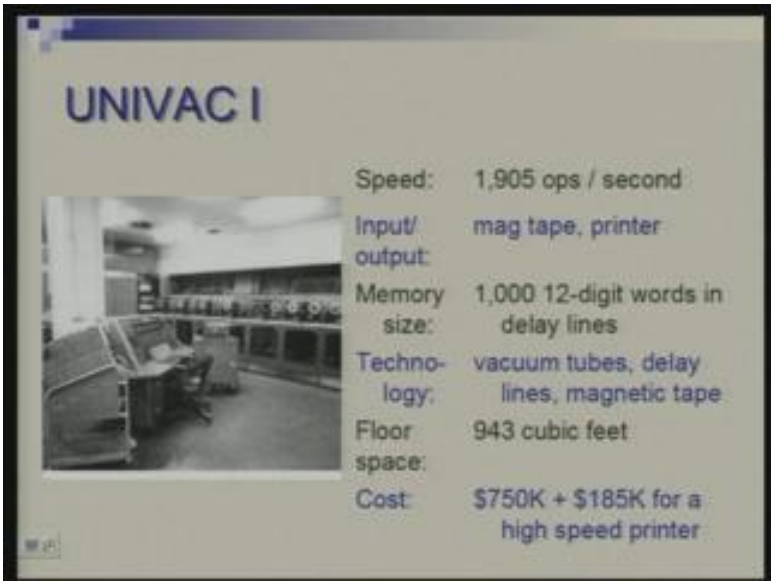

UNIVAC 1 which I mentioned as the first commercial computer; again a few thousands of operation per second, input output was in terms of magnetic tape printer; memory size was just about thousand words so thousand numbers it could store each with 12 digits and the technology used for storage was delay lines. Apart from delay lines this had vacuum tubes, magnetic tapes these were the technologies. The cost is that of 75000 USD which is several orders of magnitude as compared to today's systems and you can also look at cost of printer which is of similar order.

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Two very popular systems: IBM360 on the left and CDC6600 on the right. Architecturally CDC 6600 was very significant. It introduced the idea of pipelining and some of the ideas of the modern day processors are actually traceable to this computer. I will discuss that when we go into more architectural details.

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ILLIAC IV was a system a parallel system developed by University of Illinois at Urbana-Champaign. This was the first major attempt to develop a large parallel system.

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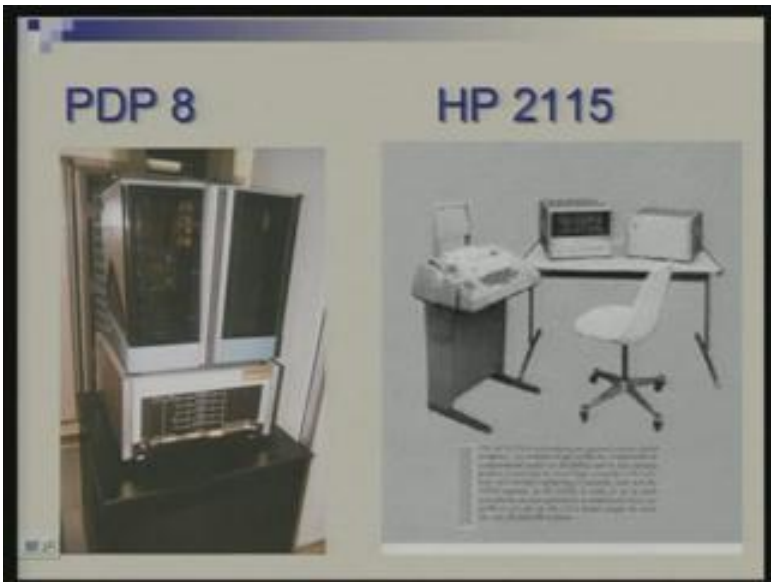

These are mini computers. In 70s with the level of integration becoming high computers shrunk from roomful to may be a cabinet or something on a pedestal and these were called mini computers. On the left you have PDP 8 and on the right you can see it is on the table it is HP 2115 and introduction is through a typewriter like device and it is not a CRT monitor it has a keyboard but the output is in the form of a printer it is like a type writer but it acts as a terminal for the computer.

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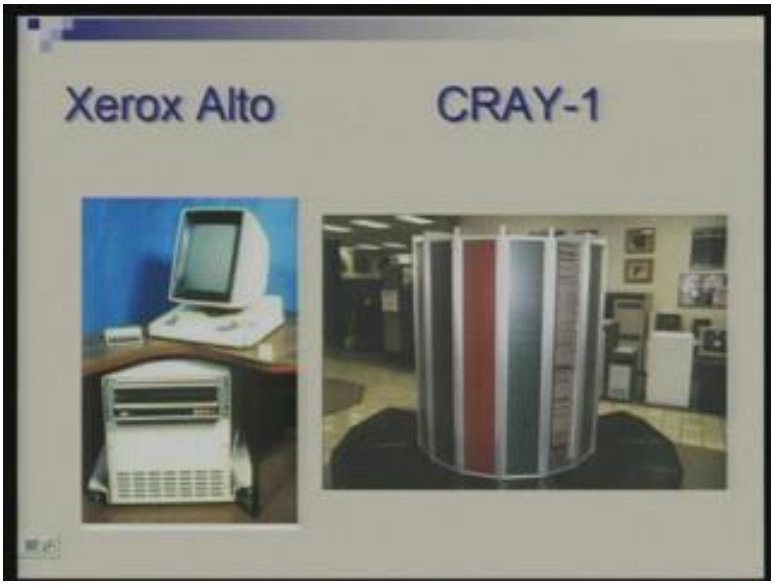

On the left we have in this picture Xerox Alto machine, which is considered one of the first work stations. Work stations are basically powerful desktop computers which have full-fledged capability of large computers but good user interface graphic user interface. Xerox did some pioneering work in developing window based interface which you almost take for granted today. On the right there is a super computer one of the early super computers CRAY-1. There have been many machines from this company called CRAY which fall in the category of super computers. This was a very high performance computer perhaps the highest performance computer at that point of time and you would see that it has a number of cabinets which are arranged in a circular form and the idea of that is to reduce the length of wire length of cables which connect the back panels of these cabinets. The reason for keeping this cable short is to reduce the delay. This required extensive cooling to make it work at high speed.

These were some interesting pictures of computers that I had gone by what kind of technology we see in the future. There are lot of things on which research is taking place. The devices are shrinking further and further to the extent that they are reaching the atomic dimensions. So the transistors would be built using just a few atoms of some specific elements. We are getting into what is called Nanotechnology area. Nanotechnology means all dimensions are of that of nanometers.

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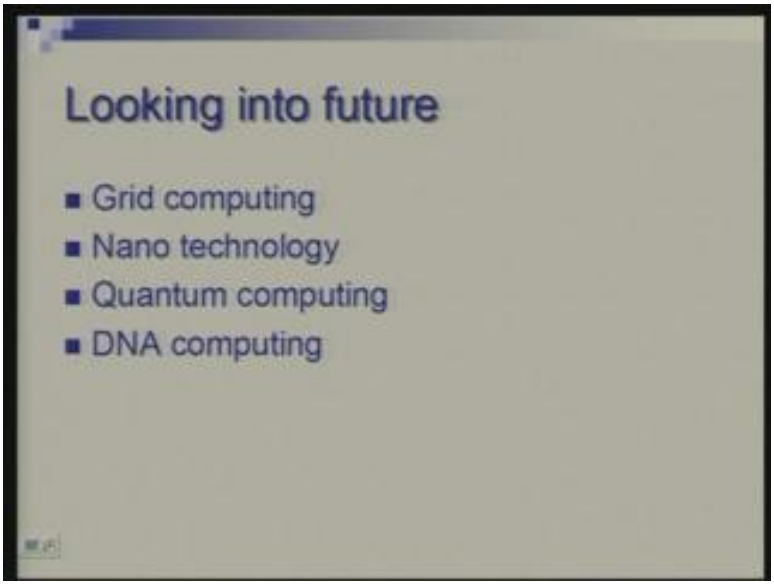

Grid computing refers to computing which is spread worldwide. you have massive number of hundreds, thousands, millions of computers all networked together trying to solve a single problem so that is another way the computing capability is getting extended.

Quantum computing is based on quantum principles. It has a promise of solving some of the tough computing problems in very very shorter time.

DNA computing: Again DNAs are very complex structure and computing based on those structures is a possibility in the future. We do not know at this point of time which of these technologies would be successful and to what extent and depending upon how these grow how these technologies develop you might see totally different kind of computers in future.

We will stop at this and in the next lecture we will start looking at a very simple architecture and go into the depth and understand how we can use it from a programmers point of view, how we can design from a hardware designer point of view. Thank you.