Computer and Disk History

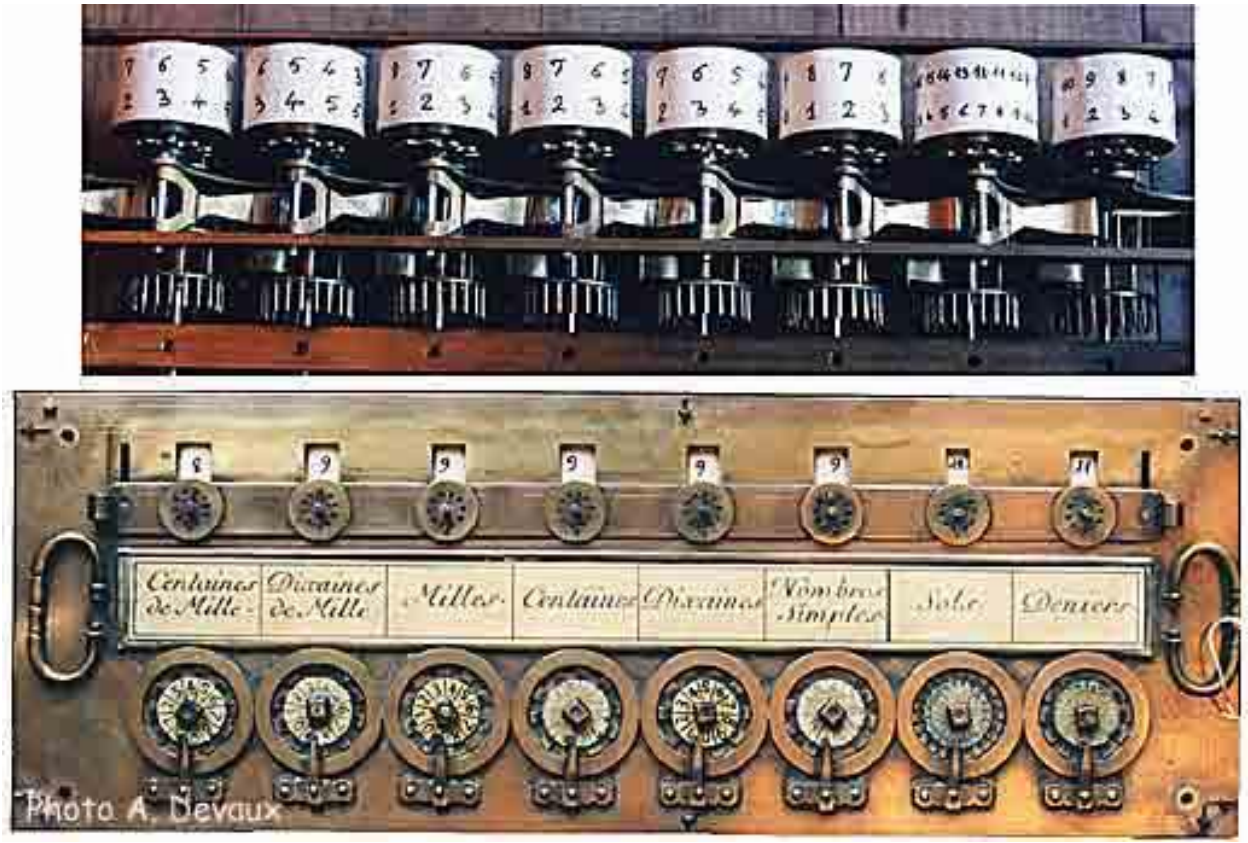
- 01. Computer History
- 02. Disk History
- 03. Disk History - 1

Part 01.

- Computer History
  - Generation 0
  - Generation 1
  - Generation 2
  - Generation 3
  - Generation 4
  - Generation 5

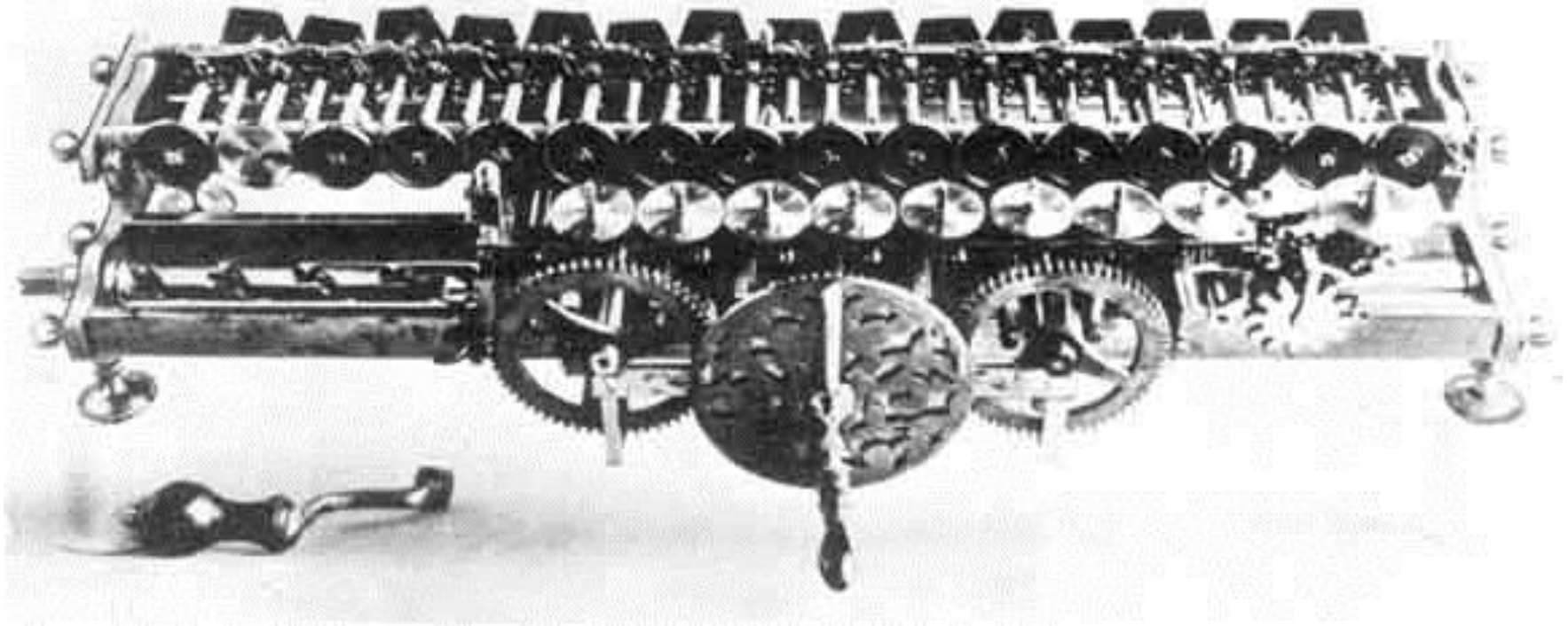
Generation 0 (1642-1945) Mechanical

- **Blaise Pascal - Pascaline - Addition and subtraction (1642)**
- Simulation of the Pascaline:
  - http://perso.wanadoo.fr/ therese.eveilleau/pages/ truc_mat/textes/ pascaline.htm#haut



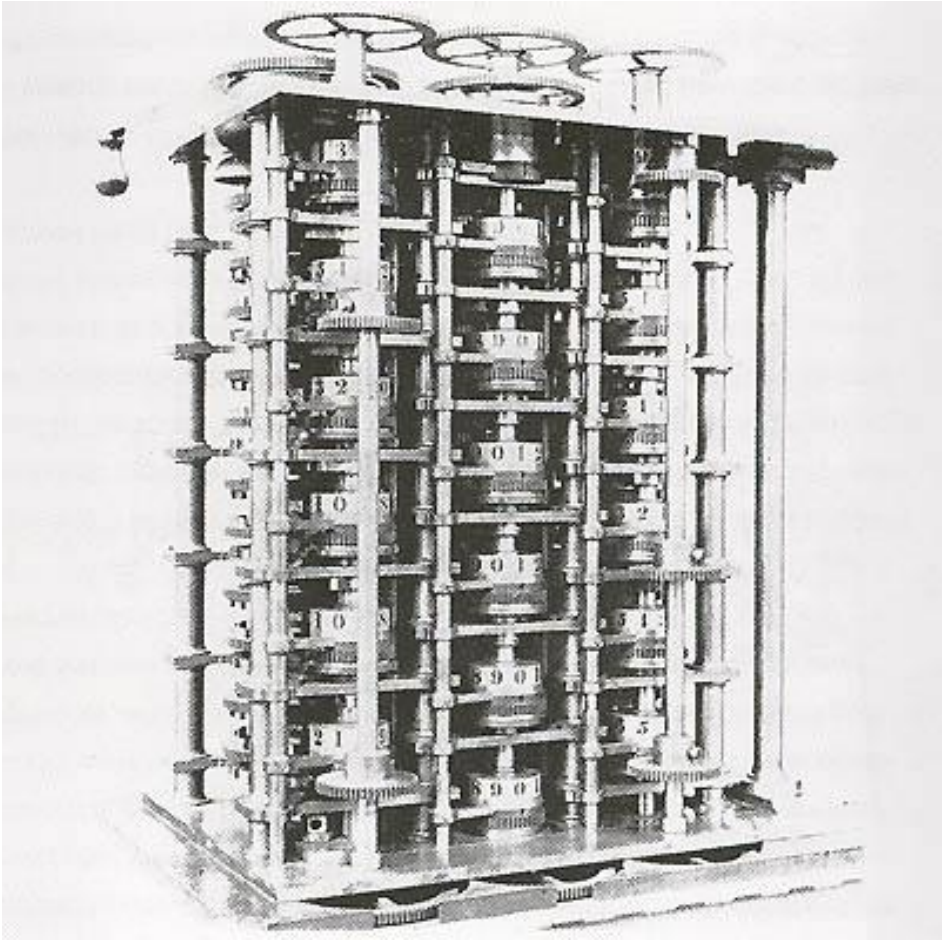
Generation 0 (1642-1945) Mechanical

- Gottfried Leibniz - The Leibniz Calculator –
- Multiplication and Division (1673-1694)



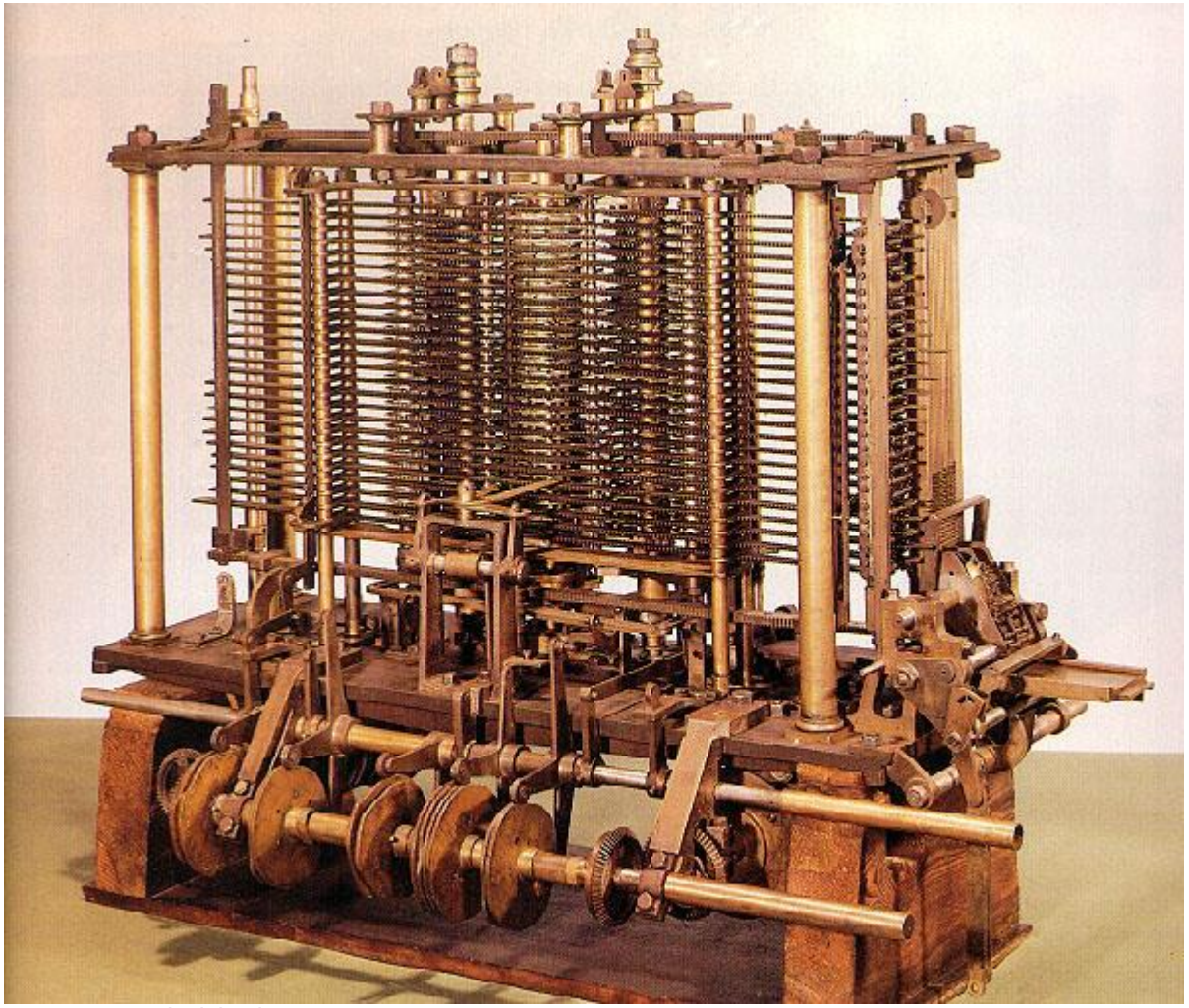
Generation 0 (1642-1945) Mechanical

- **Charles Babbage - Difference Engine –**
- Evaluated polynomials to **print tables of logarithms** and other functions through a **Newton's method of differences** (1822)

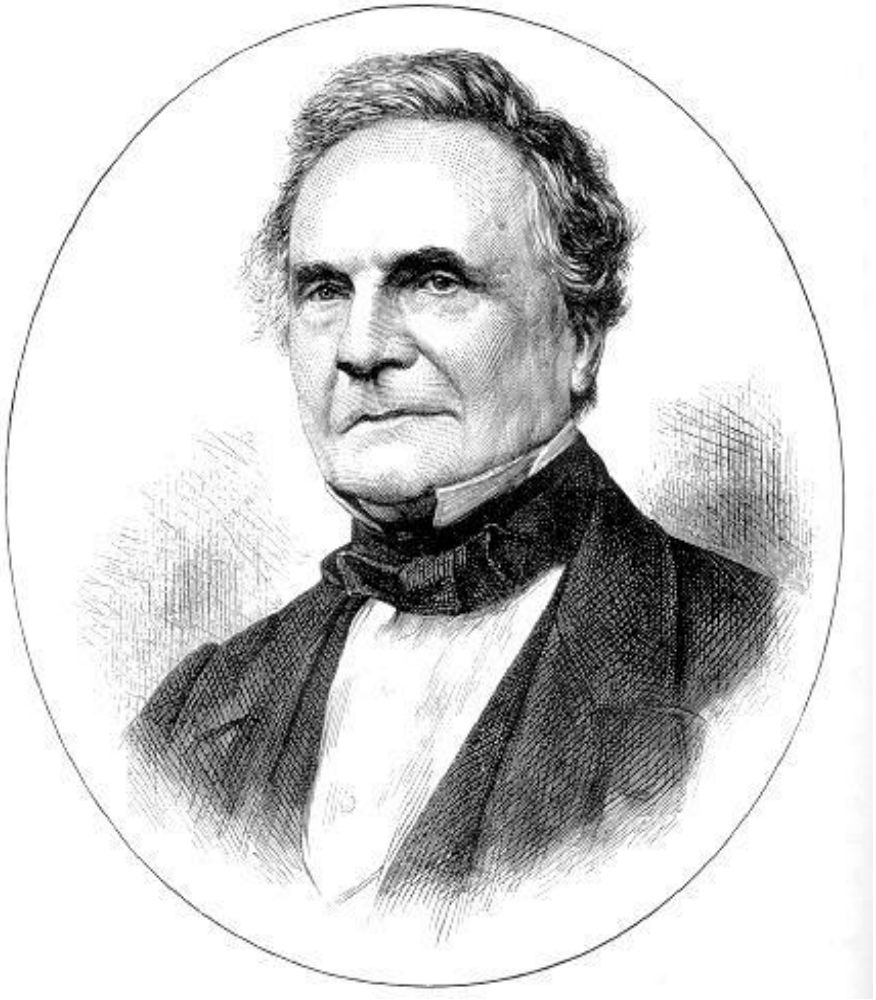


Generation 0 (1642-1945) Mechanical

- **Charles Babbage** - **Analytical Engine** - Calculate general formulas under the control of a looping program stored on punch cards (1834)



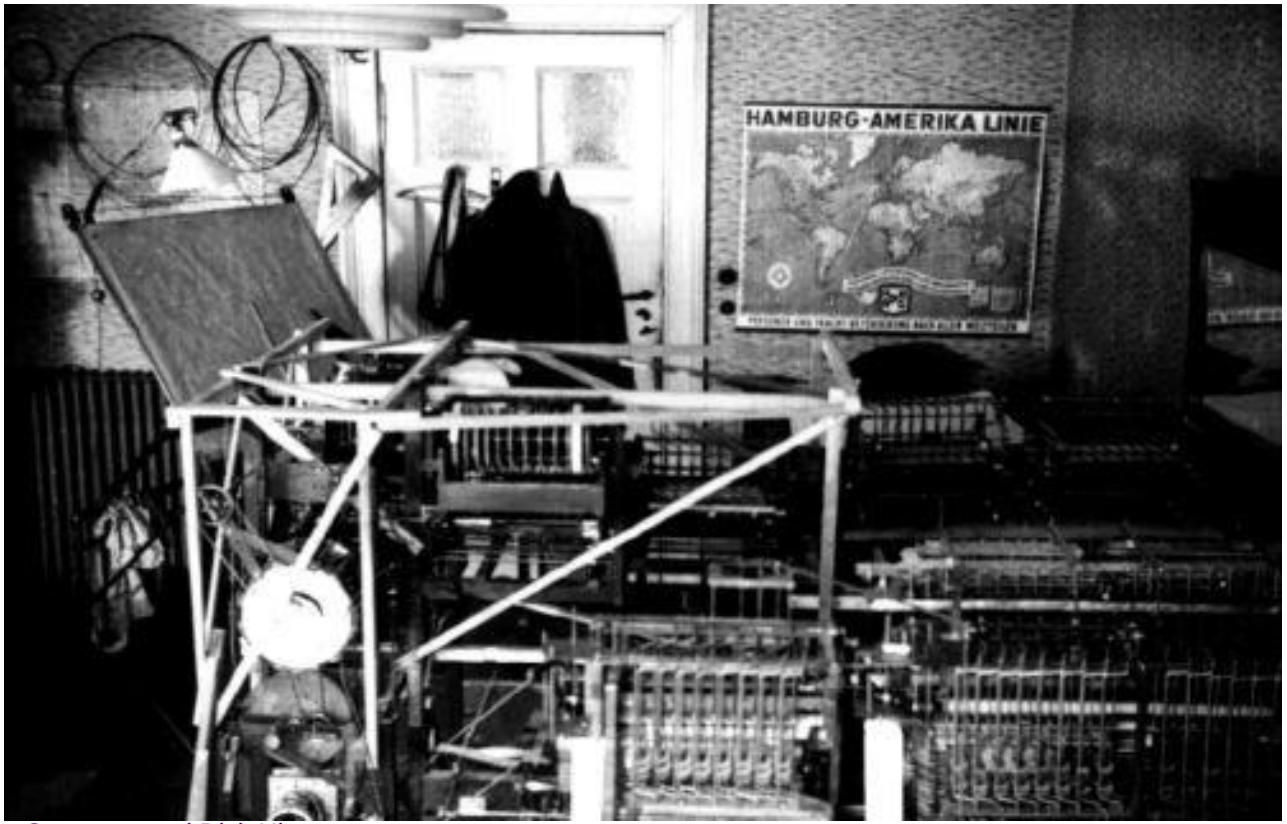
C. Babbage and Ada Lovelace



Ada Lovelace

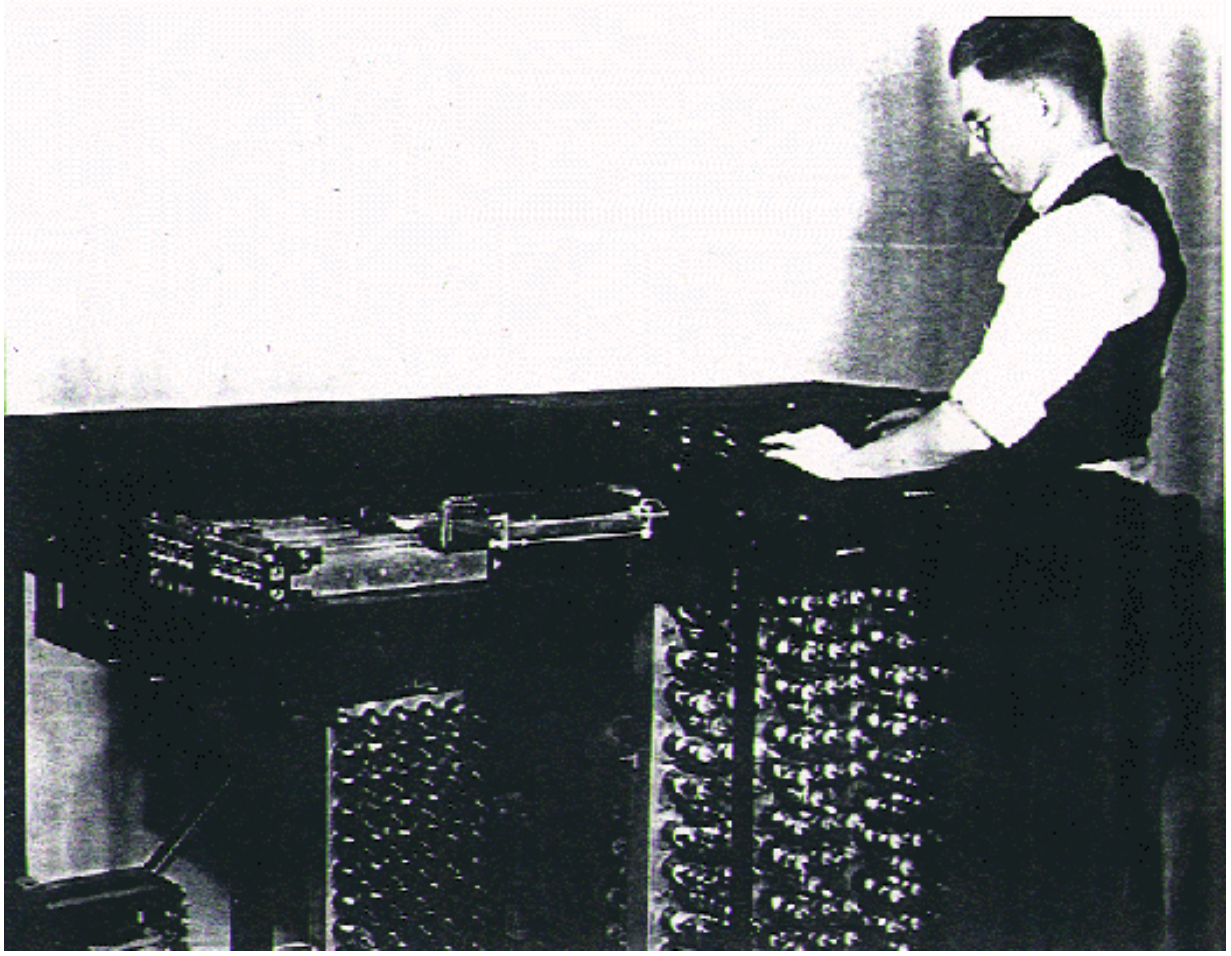
Generation 0 (1642-1945) Mechanical

- **Konrad Zuse - Z1 -** Mechanical computer using **22-bit binary representation** and a **mechanical storage based** on small pins and thin sheets of moving metal and pins. The **program was on paper tape** and there were separate input and output units. A hand crank provided a variable speed clock signal. (1936)



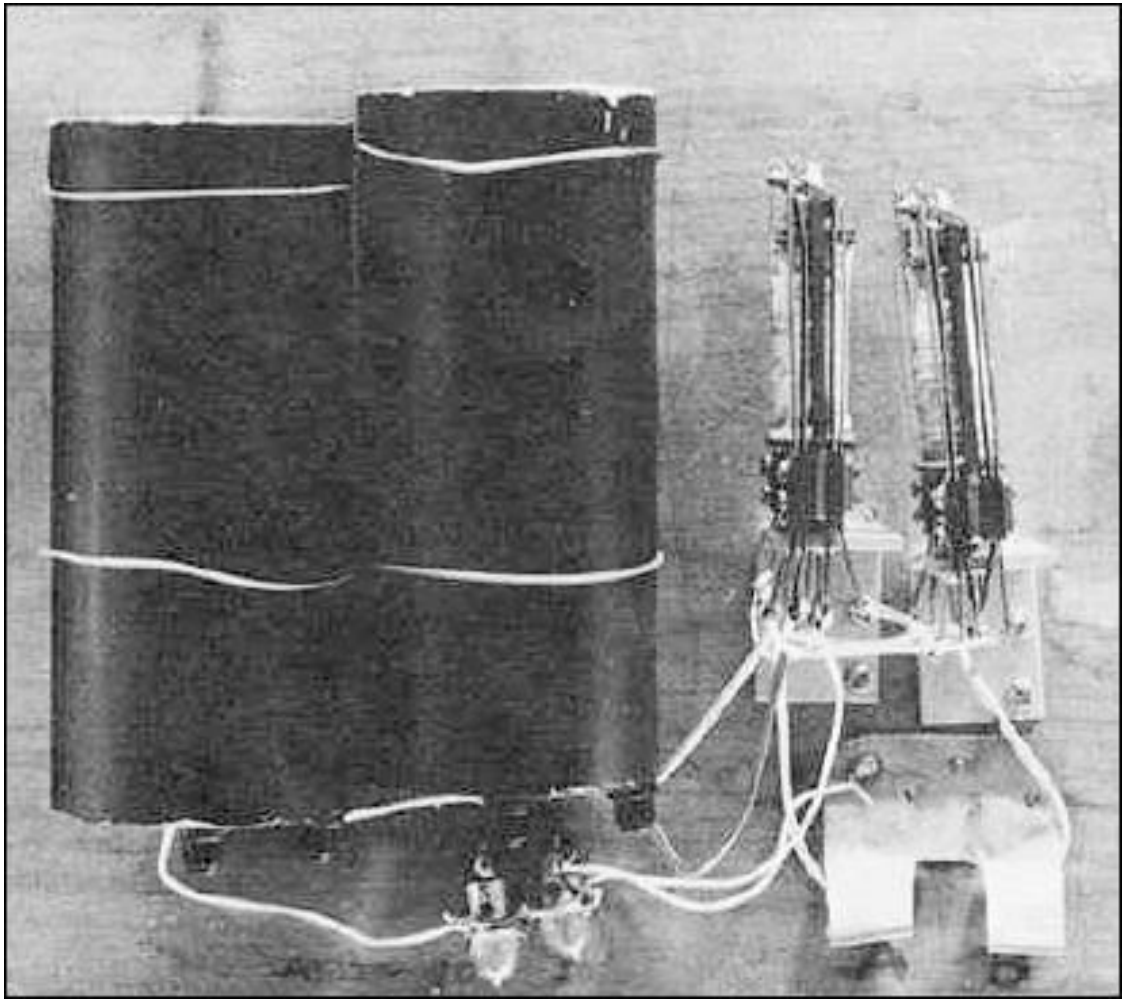
Generation 0 (1642-1945) Mechanical

- **John Atanasoff - ABC Computer** - Solved systems of **linear equations**. Utilized binary representation and **regenerative capicator memory (DRAM).** - Iowa State College (1939)



Generation 0 (1642-1945) Mechanical

- **Goerge Stibbitz - Model K and Complex Number Calculator** - Utilized **electromechanical relays** and the latter could be operated remotely over telephone lines. Bell Labs (1937, 1941)



Generation 0 (1642-1945) Mechanical

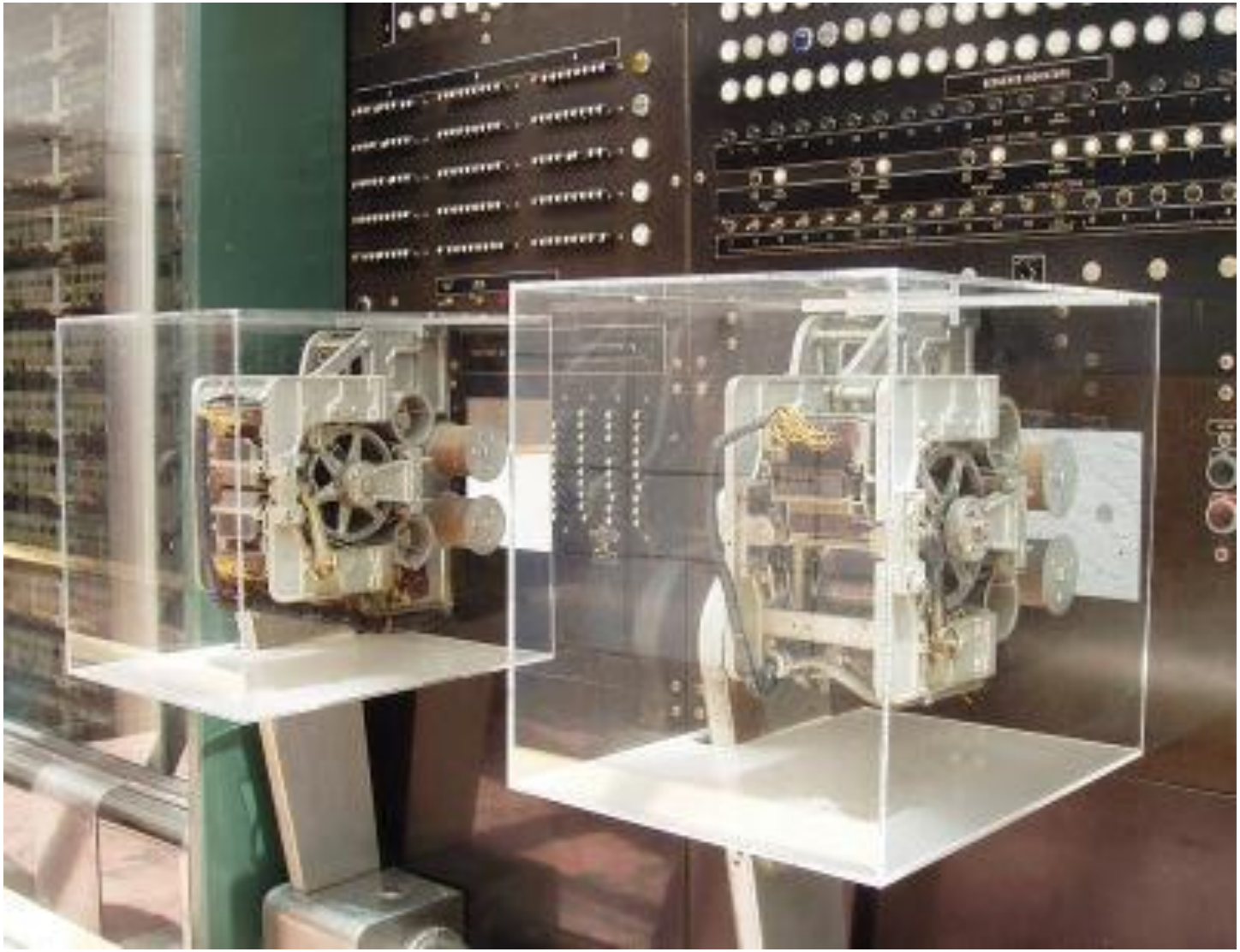
- Howard Aiken - Harvard Mark I
  - (IBM Automatic Sequence Controlled Calculator)-
  - Used to calculate mathematical tables,
  - this electromechanical (relays) computer sported
  - a storage of 72 x 23-digit decimal numbers.

- This machine provides
  - the namesake of the Harvard Architecture
  - in which instructions and data are considered separate.

- The Mark I's program was read from paper tape.
- Input was from punched cards, paper tape, or switches and output was to typewriter or punched cards.

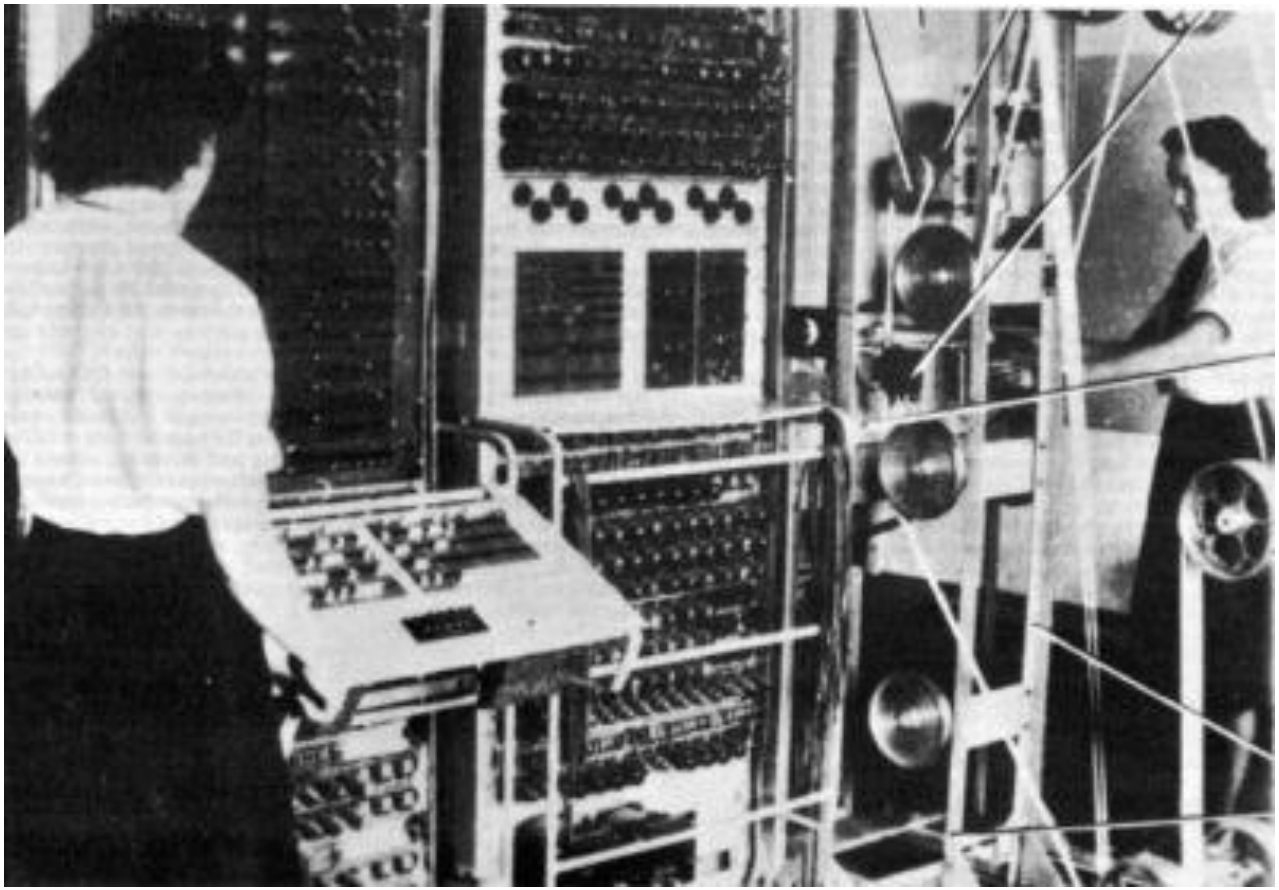
- Its design was based on Babbages Analytical Engine. (1944)

Howard Aiken - Harvard Mark I

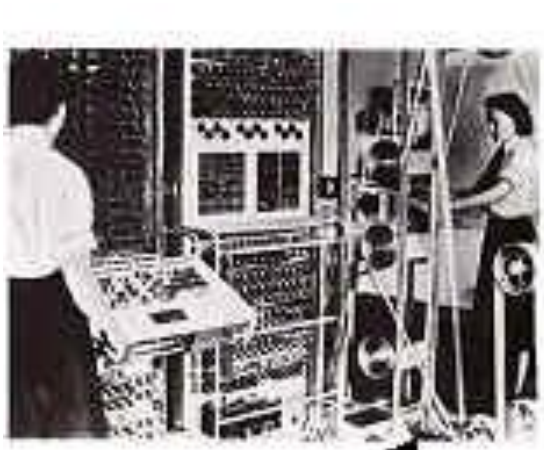


Generation 1 (1945-1955) Vacuum Tube

- **Top-secret vacuum tube computer designed to break the Lorenz SZ40 (a relative of the Enigma) intercepted cyphers.** This was a single purpose computer programmed cables and plugboards. Bletchley Park, Britain (1943)



COLOSSUS



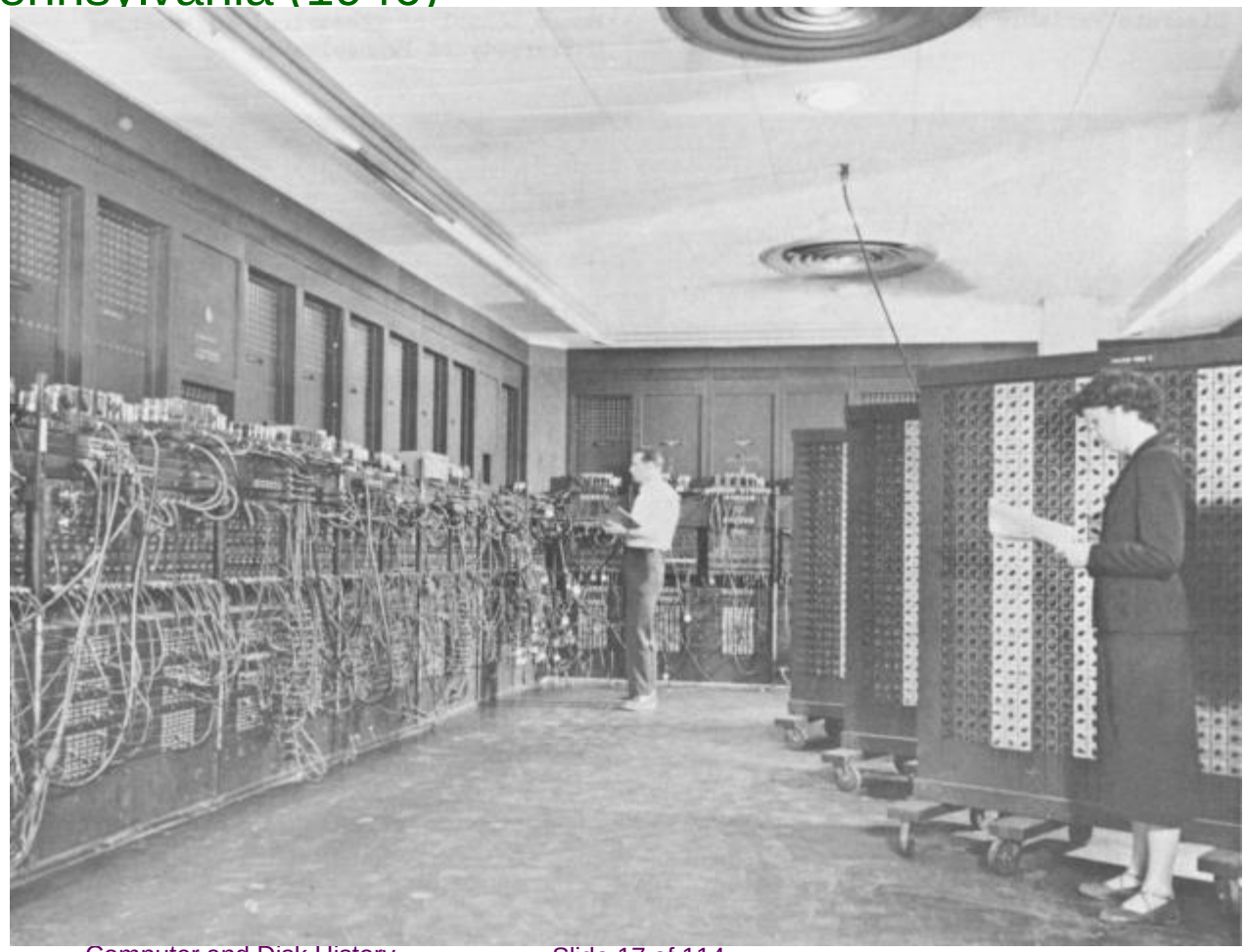
Collossus

Enigma Machine

COLOSSUS

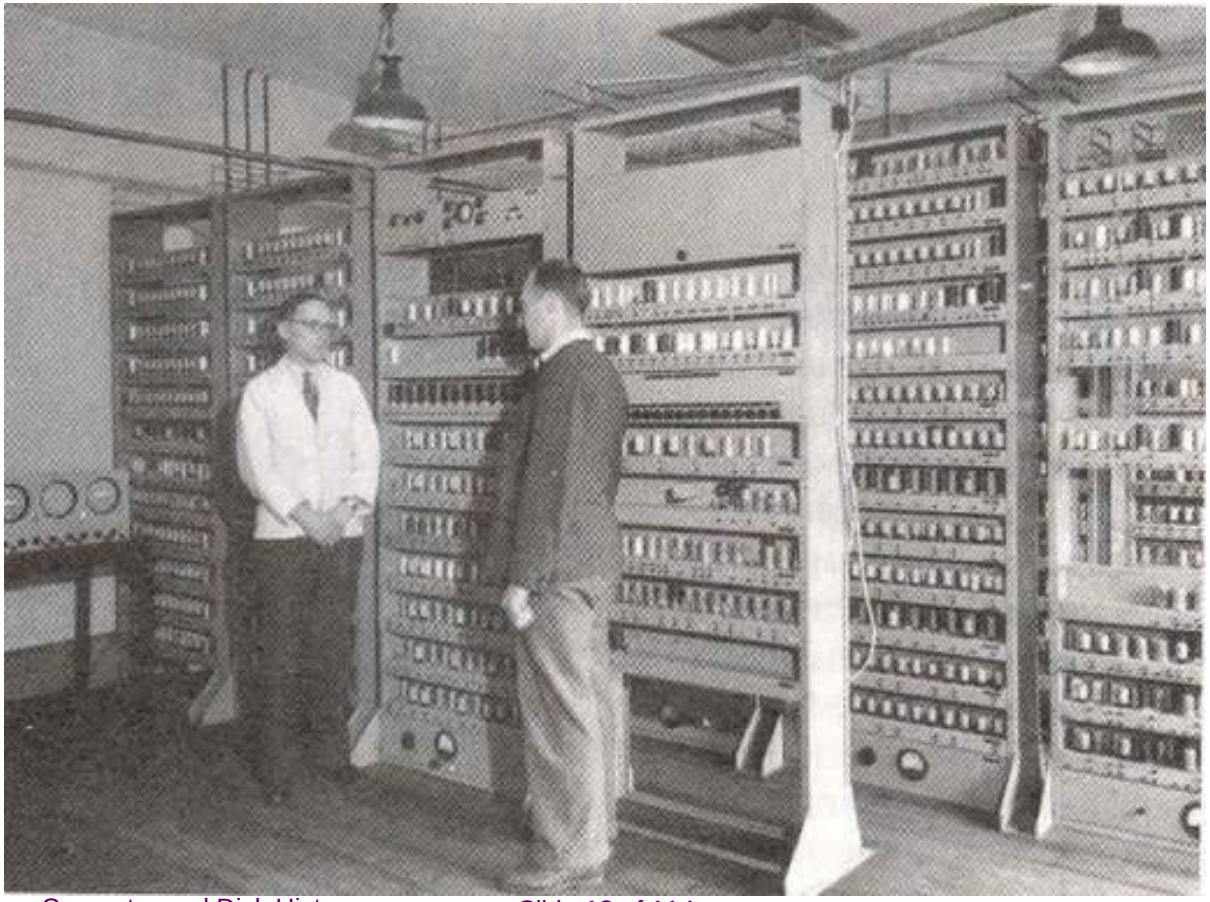
Generation 1 (1945-1955) Vacuum Tube

- **ENIAC - Electronic Numerical Integrator and Calculator - John Mauchley and J Presper Eckert -** Programmed via switches and jumper cables and utilized **20 x 10-digit** decimal registers - University of Pennsylvania (1946)



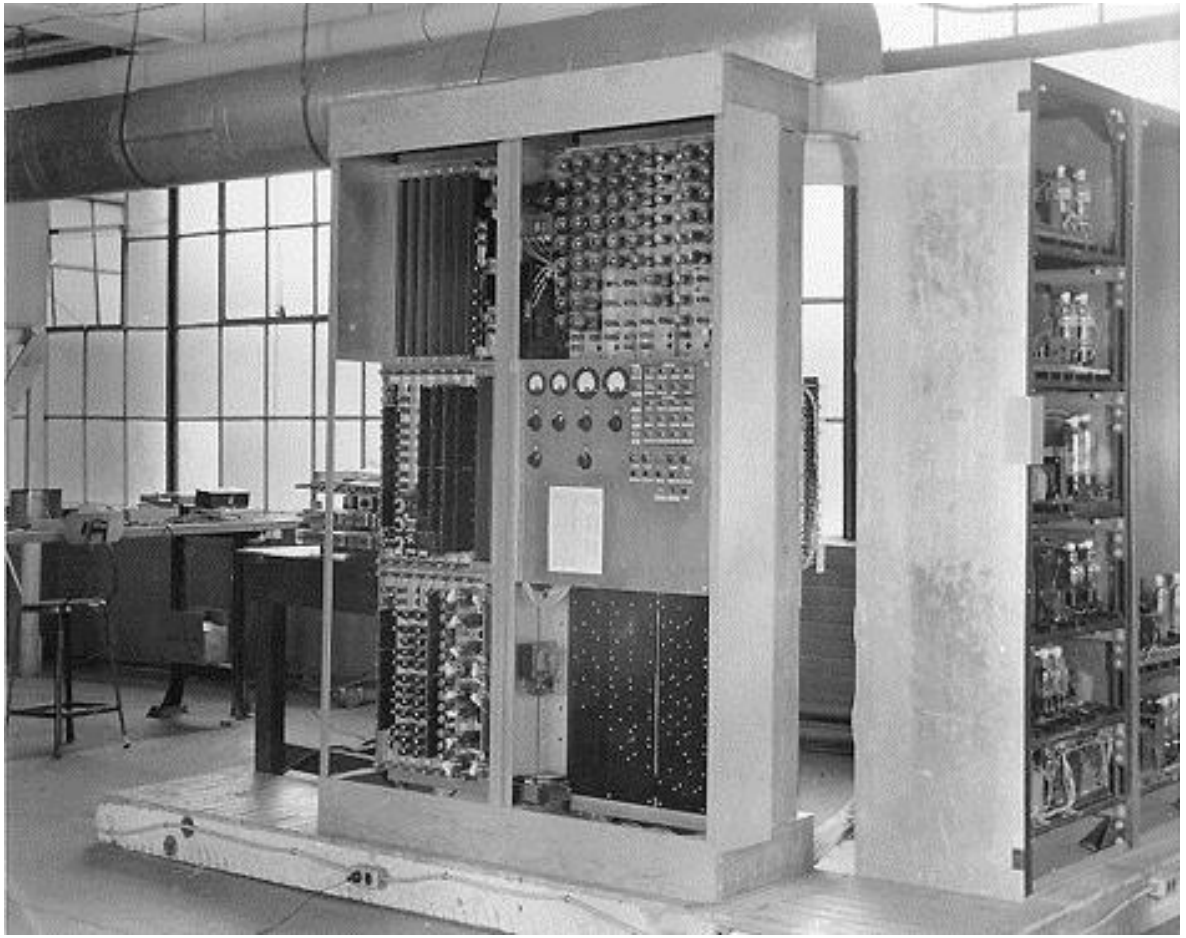
Generation 1 (1945-1955) Vacuum Tube

- **EDSAC - Electronic Delay Storage Automatic Calculator -** Maurice Wilkes - The **first general purpose stored program computer** - An example of the von Neuman Architecture in which data and instructions share a common data path. - University of Cambridge (1949)



Generation 1 (1945-1955) Vacuum Tube

- **EDVAC - Electronic Discrete Variable Automatic Computer -** Eckert/Mauchley - similar in capability and intent to the EDSAC - University of Pennsylvania (1951)



Generation 1 (1945-1955) Vacuum Tube

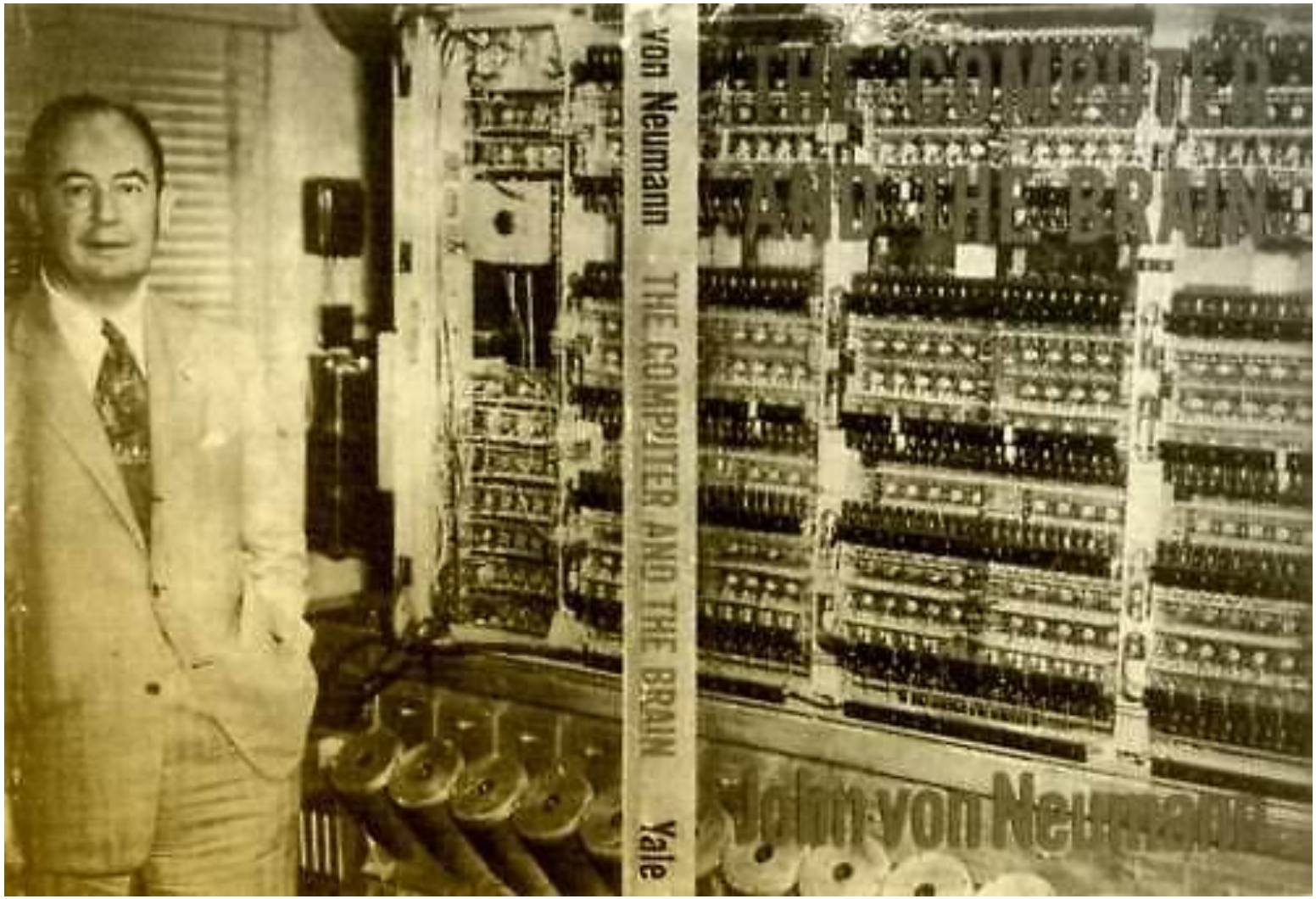
- **IAS Princeton Institute for Advanced Studies (1952) –**
- This system is the inspiration and technology base for the epidemic of similar computers mentioned next.

- This system was designed by **John von Neumann**.

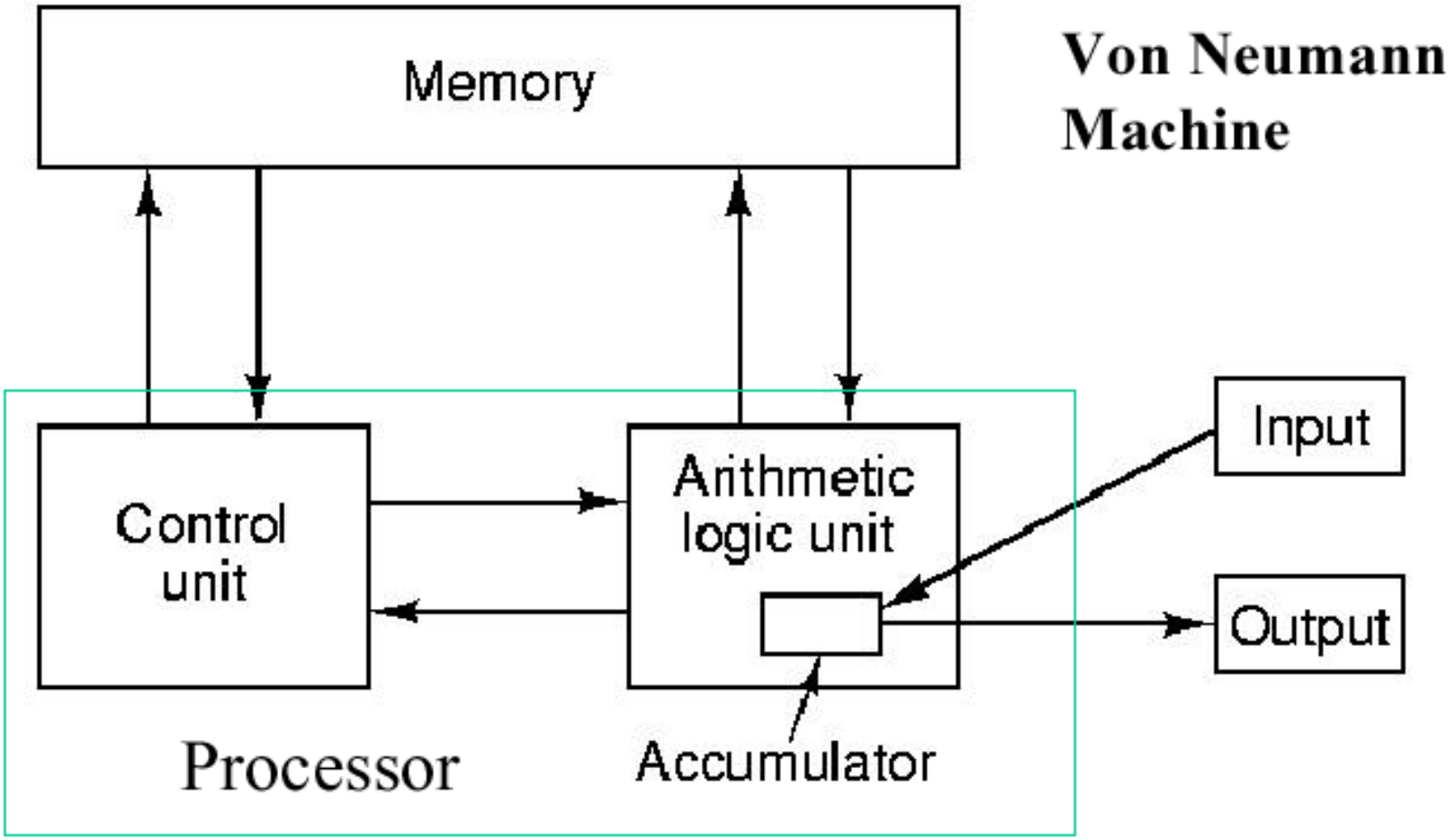
- It had a storage of 1000 x 40-bit words that held data or instructions.

- From the programmer's viewpoint, there was:
  - **the store (memory)**
  - **an accumulator (register)**
  - **a program counter**
  - **input device and output device**

IAS- John von Neumann



IAS- John von Neumann



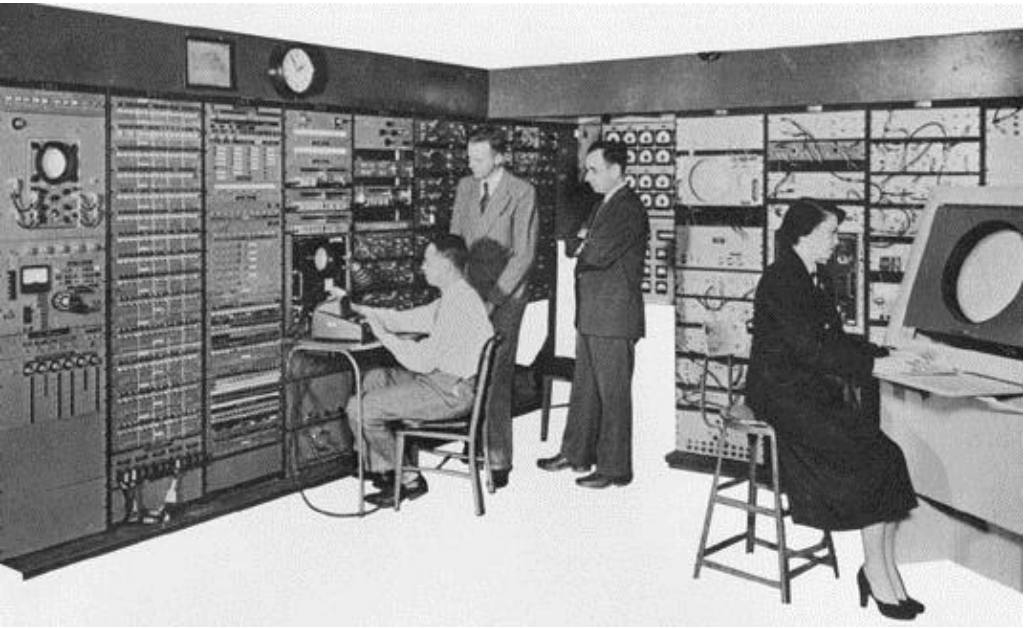
Generation 1 (1945-1955) Vacuum Tube

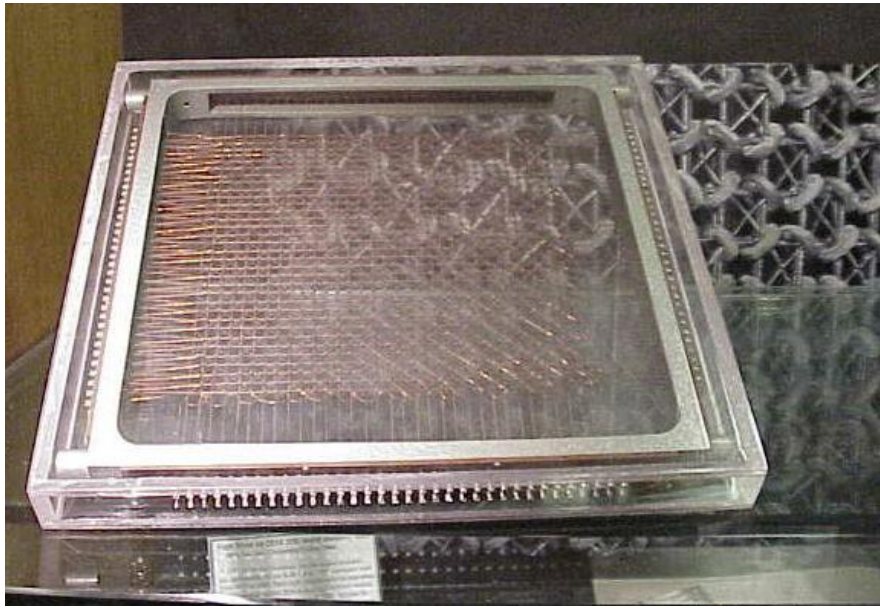
- **JOHNIAC (John Integrator and Automatic Computer, Rand Corp)**
- **ILLIAC (Univ of Illinois)**
- **SILLIAC (Sydney version of the Illinois Automatic Computer University of Sidney, Australia)**
- **MANIAC (Mathematical Analyzer, Numerical Integrator, and Computer - Los Alamos Lab)**
- **WEIZAC (Weizmann Automatic Computer, Weizmann Institute, Israel) –**
- **Other examples of similar machines developed simultaneously (1950's)**

Generation 1 (1945-1955) Vacuum Tube

Generation 1 (1945-1955) Vacuum Tube

- **Whirlwind I - Realtime operation with innovative video display unit.** This computer was also the first to use core memory - MIT Lincoln Lab (1951)





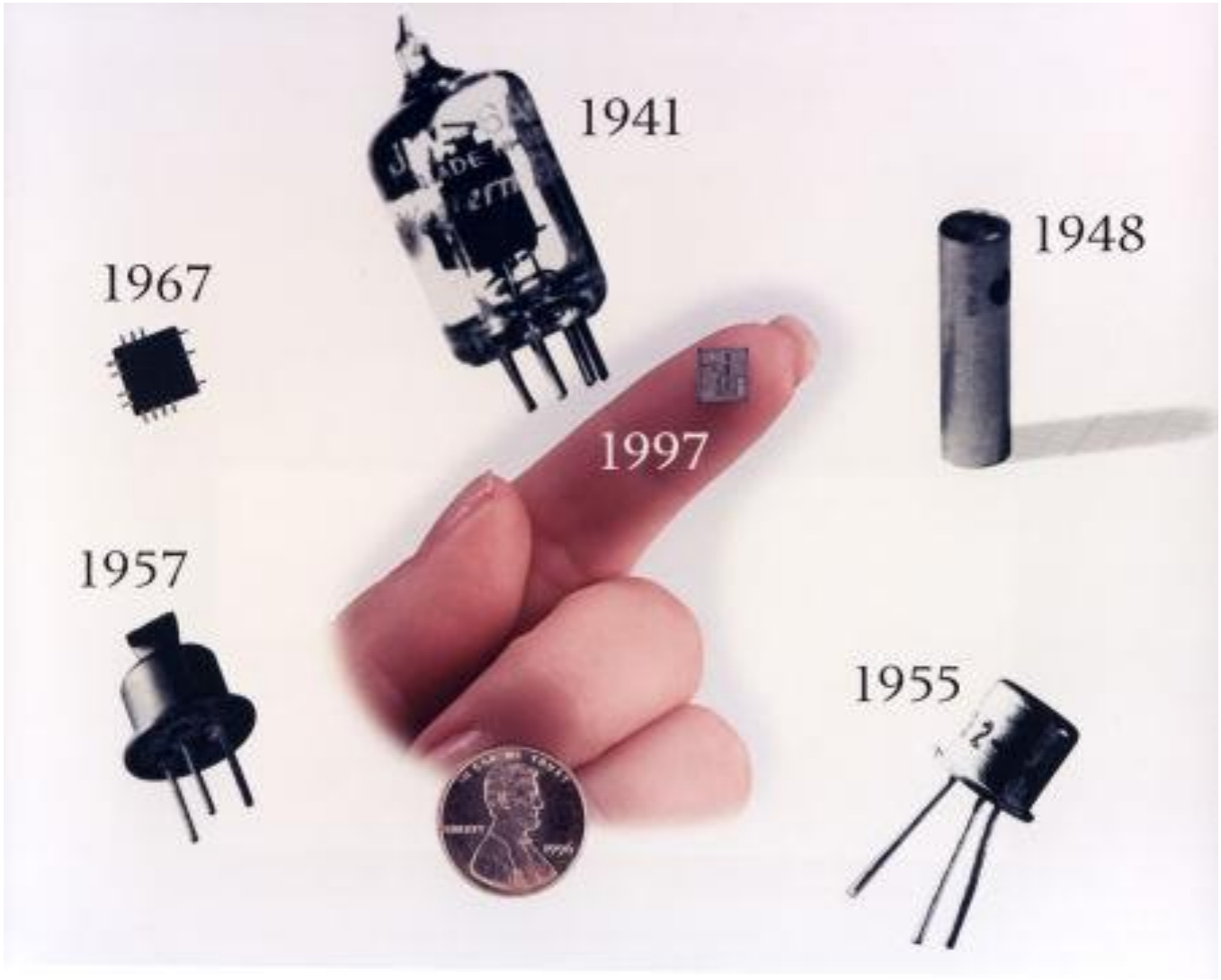
Generation 1 (1945-1955) Vacuum Tube

- **UNIVAC I (UNIVersal Automatic Computer I)- First commercial computer designed by Eckert and Mauchley.** This computer predicted the outcome of the 1952 presidential election of Eisenhower over Stevenson with a sample of 1% of the voting population. - Remington-Rand Corporation (1951)

Generation 1 (1945-1955) Vacuum Tube

- **IBM 701 - IBM's first scientific computer (1953)**

Generation 2 (1955-1965) Transistor



Generation 2 (1955-1965) Transistor

- **TX-0 - Transistorized Experimental computer zero or tixo** - The world's first transistorized computer having **64K of 18-bit words core memory**, basically a conversion of the earlier Whirlwind I - MIT Lincoln Lab (1956)

Generation 2 (1955-1965) Transistor

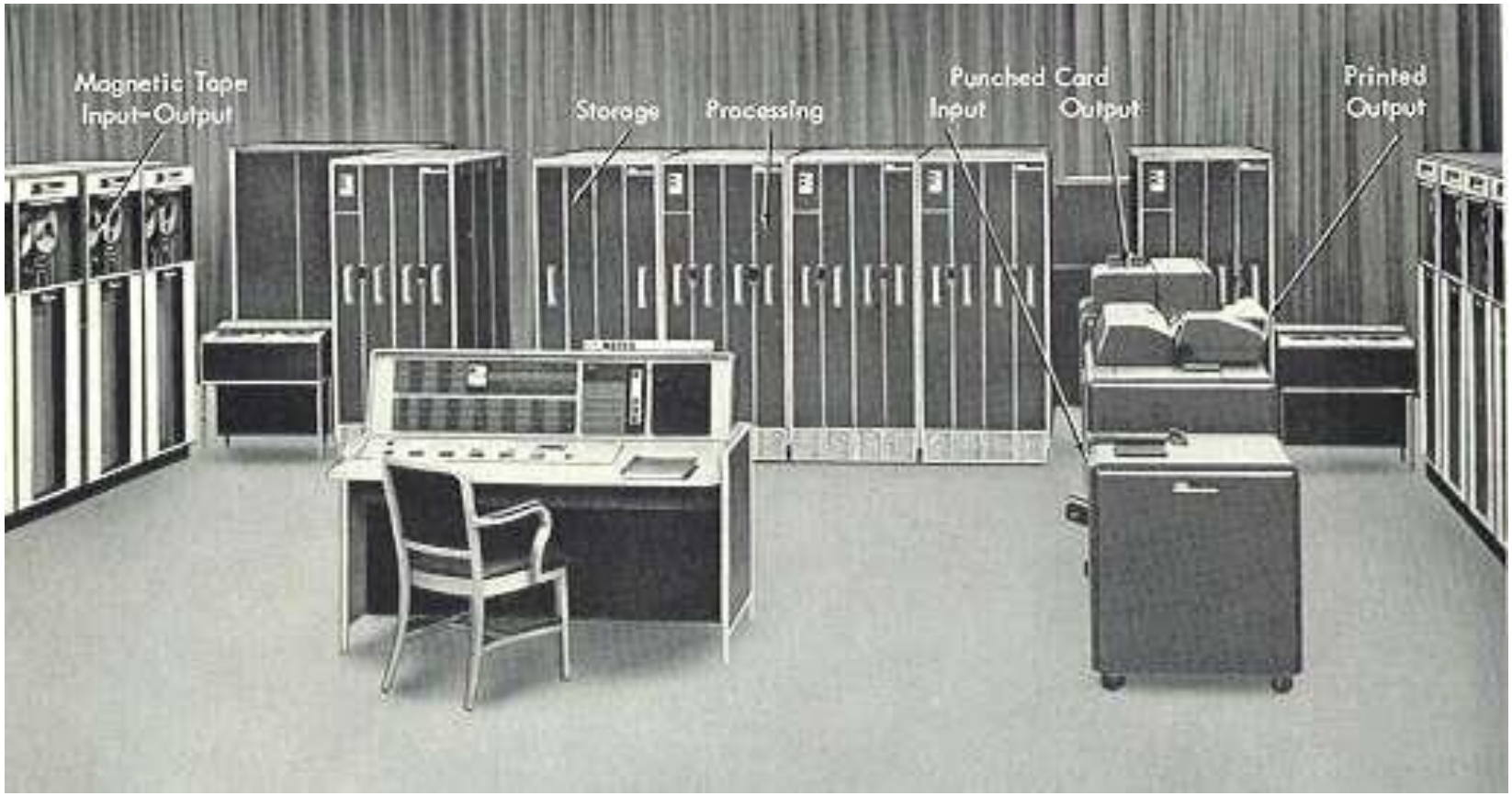
- **DEC PDP-1**
- **Programmed Data Processor**
  - 1 - 4K of 18-bit words
  - and
  - ran at 0.2 MIPS

- Ran the **first video game**, spacewar,
- and because it had a typewriter as an output device,
- it inspired the creation of text editing programs such as TECO
- (Text Editor and Corrector and Expensive Typewriter,
- the **first word processing program**.
- It was also used to play four-part music - (1960)

DEC PDP-1

Generation 2 (1955-1965) Transistor

- **IBM 7090 - The transistorized version of the 709 scientific computer having 32K of 36-bit words of magnetic core storage.** This computer was 2 times faster than the PDP-1, but cost 20 times as much. (1959)

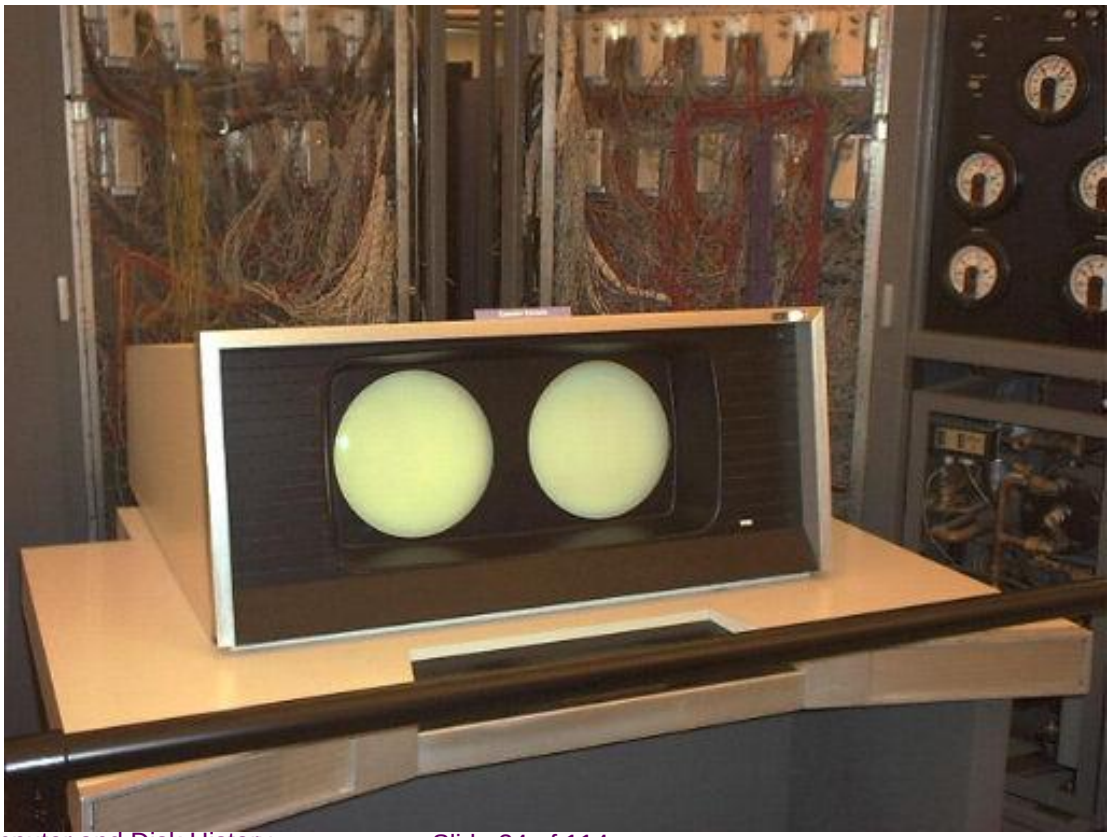


Generation 2 (1955-1965) Transistor

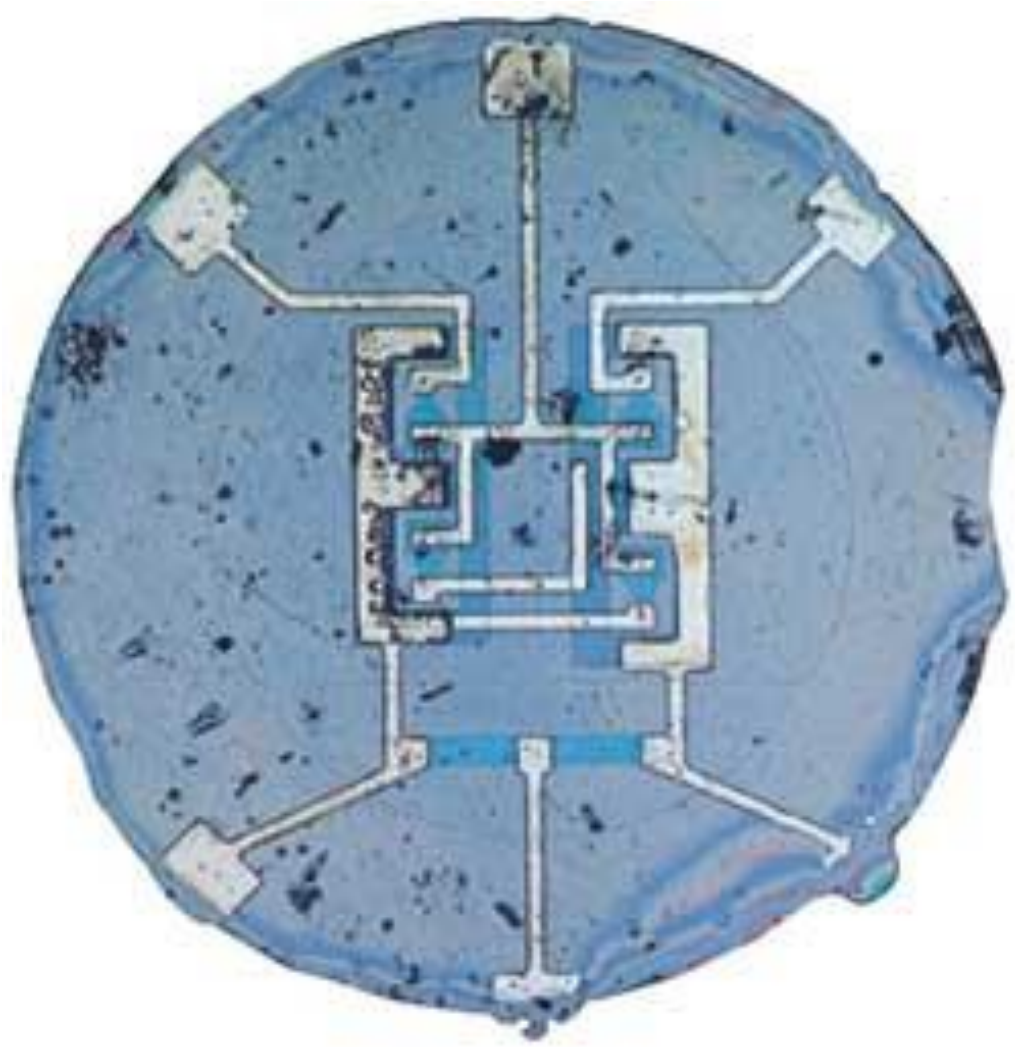
- **IBM 1401 -** A **business-oriented computer** using variable length words of **6-bit bytes holding an alphameric character**; two additional bits added parity and wordmark bits. Numbers were **represented in BCD format** (1960). The upper 2 bits of the byte were called zone bits.

Generation 2 (1955-1965) Transistor

- **CDC 6600 -** A very fast scientific computer utilizing parallel computational paths and separate processors for IO and job management. These ideas were revolutionary and formed the basis for many successful computer systems in the coming years. **Seymour Cray** was the designer of this system which was the start of the Cray supercomputer line.



Generation 3 (1965-1989) Integrated Circuits (Robert Noyce 1958)



Generation 3 (1965-1989) Integrated Circuits

- **IBM System/360 -** Abandoning its earlier two-prong marketing strategy, IBM introduced the highly successful System/360 series **using integrated circuits** and targeting scientific and business applications.
- **Avalaible in different models** (sizes and speeds), **software for one model could run on all of the others** as they shared the same machine language. Some even featured microcode emulation of the earlier machines to allow use of legacy software.
- These machines also supported multiprogramming and utilized a byte-oriented memory (instead of word oriented), **16 of 32-bit registers** using 2's complement integers, **IBM specific floating point hardware**, and the EBCDIC character set.
- Unfortunately the **memory space was limited to 16 MB** (24-bit addresses) which was more than anyone needed at the time, but later proved to be inadequate, forcing incompatibility with instruction sets in the mid-1980's. (1965)

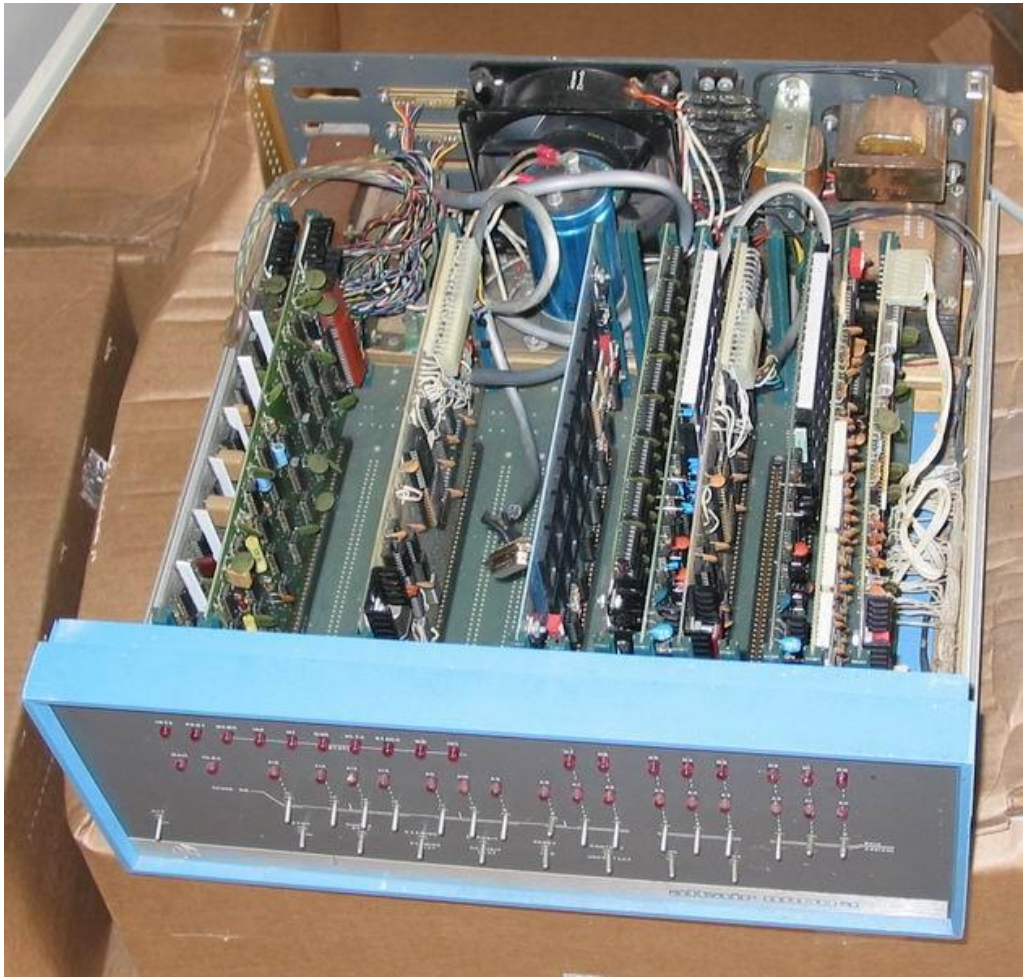
IBM 360

Generation 3 (1965-1989) Integrated Circuits

- **DEC PDP-11 - A 16-bit successor to the PDP-8 also utilizing byte addressable memory.** The PDP series was an **extremely popular** computer due to **low cost** and good performance. Its 16-bit address space caused it to decline in popularity as large memories became cheaply available with the introduction of VSLI technology. This picture is of Dennis Ritchie and Kenneth Thompson, creators of the UNIX operating system, at a PDP-11. (1970)

Generation 4 (1980-)
VLSI and Personal Computers

- **Altair 8800 -** One of the first **kit-based personal computers** based on the **Intel 8080A** chip was announced in Popular Electronics and sold thousands of kits in the first month. (1975)



Generation 4 (1980-)
VLSI and Personal Computers

- **Apple -** The **first commercially available personal computer** designed and built by Steve Wozniak and Steve Jobs. It used the MOS Technology 6502 processor and had 4K of memory. (1976)

Generation 4 (1980-)
VLSI and Personal Computers

- **Commodore PET** (personal eductional tutor) was popular in classrooms. It was based on MOS Technology 6502 processor and had 4-8K of RAM. When color and sound were added (VIC-20 and Commodore-64) it became a popular home computer (1977)

Generation 4 (1980-)
VLSI and Personal Computers

- **Coleco ADAM - A** largely unsuccessful addition to the home computer line. This computer came with a builtin word processor (SmartWriter), a daisy-wheel (letter quality) printer, and dual high-speed tape drives for program and data storage. It was based on the Zilog Z80 and included 3 additional Motorola 6801 processors. Although this venture lasted only 2 years, there are still annual conventions of ADAM enthusiasts. (1983)

Generation 4 (1980-)
VLSI and Personal Computers

- **Atari 800 -** Also based on the MOS 6502, this machine was a popular game computer. (1979)

Generation 4 (1980-)
VLSI and Personal Computers

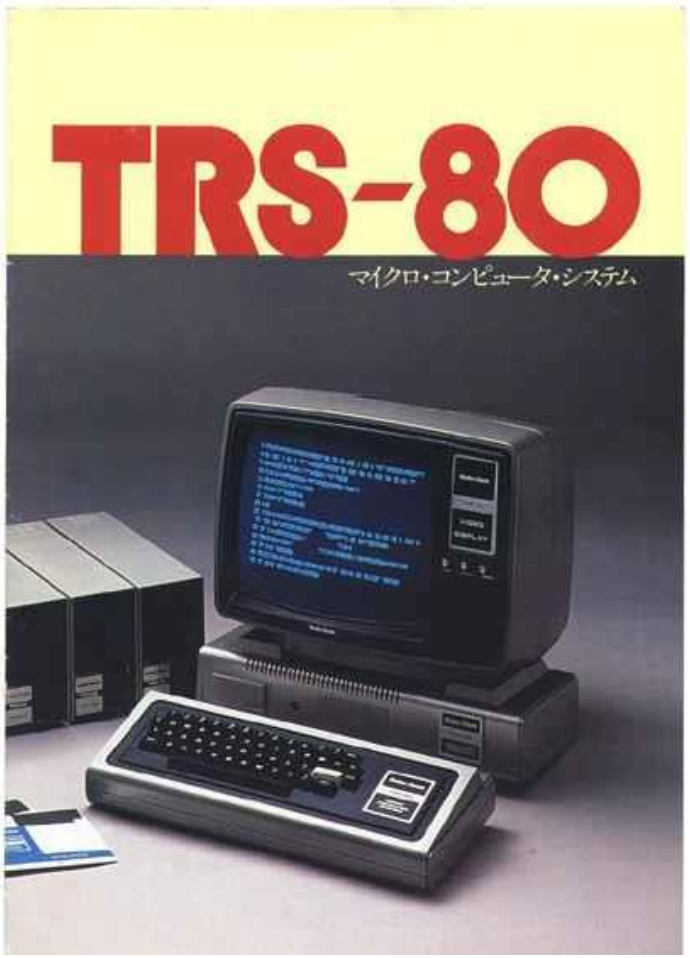
- **TI-99/4A -** Utilizing the Texas Instruments TMS9900 processor (a 16-bit processor) and 256 bytes of RAM (There was an additional 16K associated with the video display unit) this computer was sold in 1983 for **$150** at a loss in order to compete with more popular systems. (1981)

Generation 4 (1980-)
VLSI and Personal Computers

- **Timex Sinclair ZX81** - Sold for under $100, used a television for display and a standard audio cassette tape recorder for data storage. It used the NEC Zilog Z80 processor. You can play with one online in this Java Applet. (1981)

Generation 4 (1980-)
VLSI and Personal Computers

- **TRS-80 by Tandy** - Affectionately known as the trash-eighty was sold through Radio Shack outlets. The TRS-80 used a Zilog Z80 processor. This computer is available online. (1977)

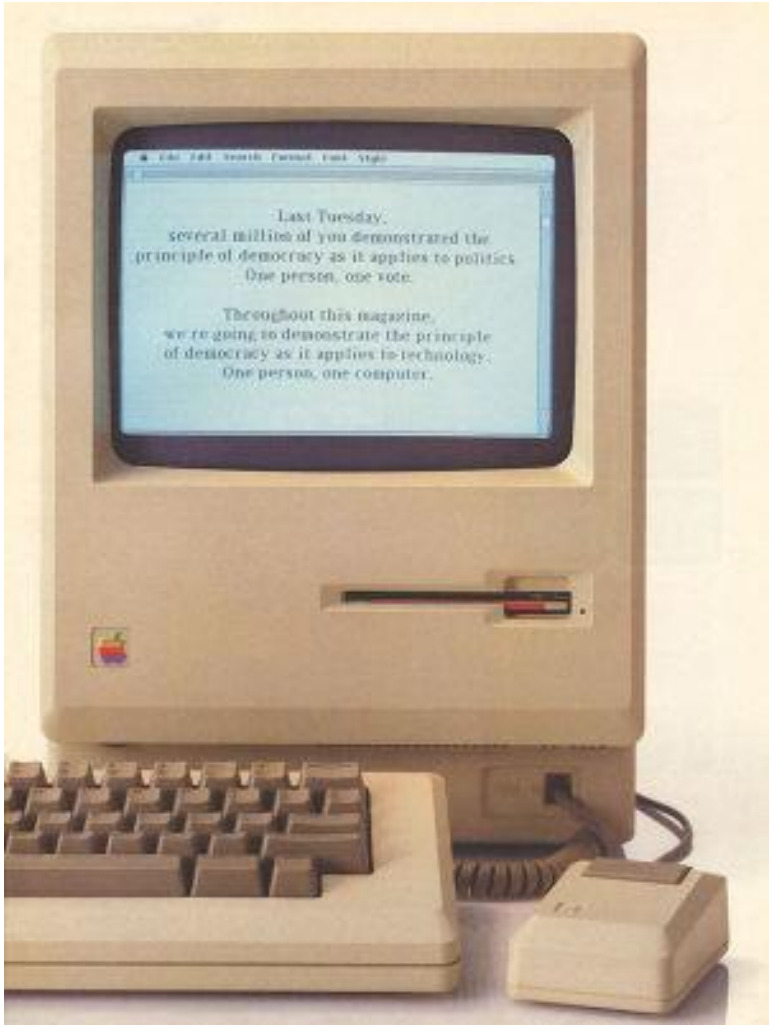


Generation 4 (1980-)
VLSI and Personal Computers

- **IBM PC -** Based on the Intel 8088 processor, the IBM PC revolutionized the personal computer market. IBM released plans for this system giving rise to many PC clones. The IBM PC shipped with the PC-DOS operating system while the clones utilized MS-DOS. (1981)

Generation 4 (1980-)
VLSI and Personal Computers

- **Apple Macintosh -** Made the GUI operating environment the envy of all personal computer users. (1984



Generation 5 (?) Invisible Ubiquitous Pervasive Computing

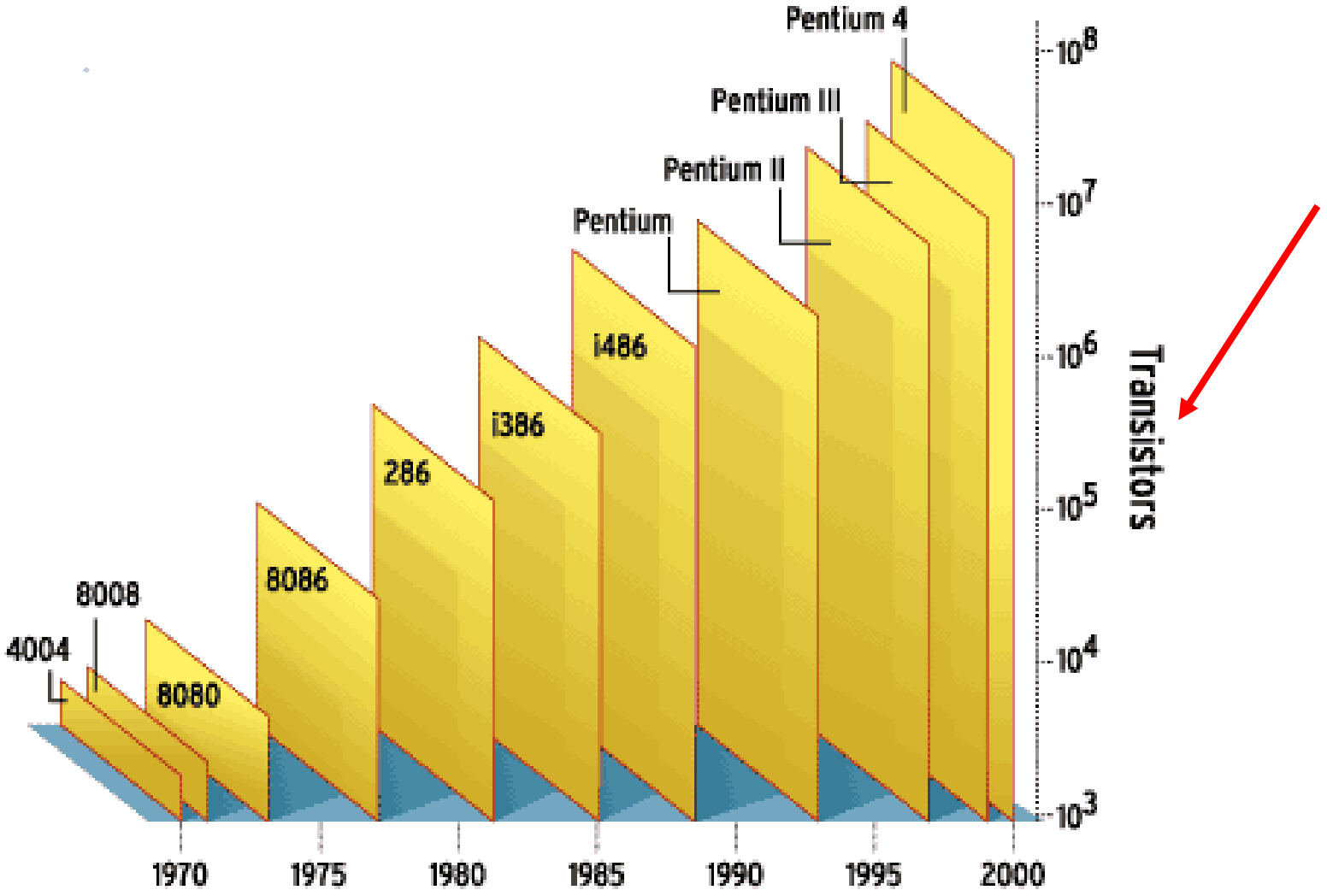
- **Palm 5000 - PDA's (1996)**

Nevidljiv

Sveprisutan

Prožimajući

Generation 5 (?) Invisible Ubiquitous Pervasive Computing



Generation 5 (?) Invisible Ubiquitous Pervasive Computing

- **Embedded computers**

Part 02.

- **Disk History**

Prvi disk

- Priča o hard-disku počinje sredinom prošlog veka
  - u gradu San Jose (USA, CA),
  - gde je u jednoj od najznačajnijih **IBM**-ovih R&D laboratorija
  - tim inženjera pod vođstvom Reynolda Johnsona
  - razvio ***mainframe* računarski sistem IBM 350** with **RAMAC 305**
  - (*Random Access Method of Accounting and Control*).

- Ovaj sistem, baziran na elektronskim cevima
  - proizveden u više od hiljadu primeraka tokom narednih pet godina,
  - bio je specifičan po tome što je
  - po **prvi put koristio hard disk** umesto
  - - za to vreme - **uobičajenih bušača kartica**.

IBM RAMAC 305

- Iako je sâm IBM 350 (hard-disk jedinica RAMAC 305 sistema)
- prezentovan javnosti nekoliko dana ranije,
- RAMAC je zvanično postao dostupan tek **13. septembra 1956. godine**.

IBM 350- RAMAC 305

- IBM 350 izgledao je kao ogromni ormar
- sa svojim neverovatnim dimenzijama za današnje pojmove:
  - **152,4 cm dugačak**
  - **172,7 cm visok**
  - **73,7 cm širok**
  - **težio je nešto preko jedne tone**!
- Ni izbliza nalik današnjim hard-diskovima...

IBM 350

- IBM 350 se sastojao iz:
  - 50x 24-inčnih dvostranih ploča
  - koje su se rotirale brzinom od **1200 rpm**
  - čiji je ukupni kapacitet iznosio **4,375 MB**
  - (tačnije, pet miliona 7-bitnih karaktera).

- Podacima se pristupalo uz pomoć
  - dve (kasnije opciono tri) glave
  - koje su kontrolisane uz pomoć servo mehanizama.
  - Glave su koristile aluminijumske vazdušne ležajeve (ABS)
  - koje su radile pod pritiskom iz **eksternog kompresora**,
  - što je obezbedilo **stabillno odstojanje** između glava i ploča
  - od **20 mikrometara**.

- Upravo je otkriće **beskontaktnog načina** upisivanja i čitanja
  - podataka sa magnetne ploče
  - dovelo do konstrukcije prvog komercijalnog RAMAC,
  - odnosno hard-disk sistema.

IBM 1301

- Tokom narednih nekoliko godina
  - IBM je usavršavao postojeći dizajn
  - ali je čitav koncept napušten 1962.
  - kada je IBM po prvi put predstavio **hidrodinamičke "leteće glave"**
  - (***flying heads***).

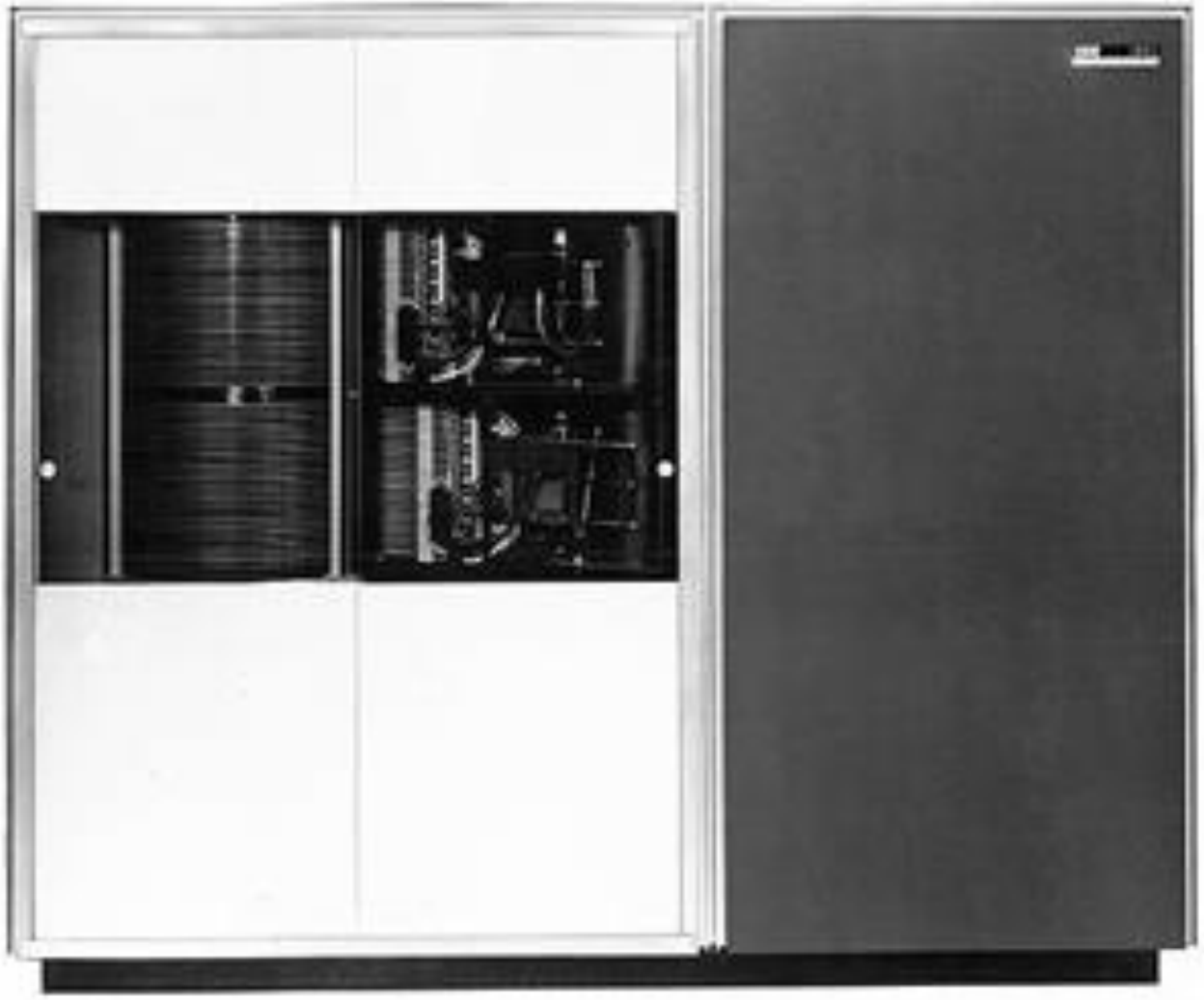
- IBM 1301 bio je opremljen glavama
  - sa specijalnim aerodinamički konstruisanim
  - čeličnim fluidnim ležajevima
  - koji su održavali fiksno odstojanje iznad magnetnih ploča
  - uz pomoć kompresovanog vazduha tj. vazdušnih struja
  - koje su nastajale tokom same rotacije.

IBM 1301

- Ovaj koncept je omogućio:
  - da se rastojanje između glava i površi ploča
  - smanji na svega **6,35** mikrometara
  - bez upotrebe eksternog kompresora
  - i na taj način **višestruko uveća gustina zapisa dragocenih bita**.

- Model 1301 doneo je i još **jednu revoluciju** u dizajnu tadašnjih diskova.
  - Umesto samo jednog ili dva nosača glava
  - koji bi se kretali po visini tokom promene ploča
  - IBM je predstavio **ram sa jednakim brojem glava**
  - **koliko i snimajućih površina**
  - **postavljanih na zajedničku osovinu (aktuator).**
- U kombinaciji sa povećanom brzinom rotacije (1800 rpm)
  - 1301 je doneo višestruko uvećanje
  - u brzini pristupa i gustini zapisa
  - u odnosu na prvobitni IBM 350.

IBM 1301



model 2314

- **1965.** godine IBM predstavlja model 2314
  - koji po prvi put koristi **glave sa feritnim jezgrom**
  - tip koji će kasnije pronaći primenu
  - i kod prvih diskova u personalnim računarima.

- U međuvremenu, tokom **1970.**
  - osnovana je kompanija General Digital Corporation
  - naredne godine preimenovana u **Western Digital**
  - Inicijalno, kompanija nije imala veze sa proizvodnjom hard-diskova
  - (**bavila se proizvodnjom kontrolera za iste**)
  - ali ostavićemo kompaniju WD za trenutak...

model 3340

- Marta 1973. godine IBM predstavlja svoj legendarni model 3340,
  - poznatiji po svom kodnom imenu "**Winchester**".
  - Ovaj disk se smatra temeljem savremene HDD industrije,
  - jer je omogućio gustinu zapisa od 1.7 miliona bita po kvadratnom inču.
  - Zahvaljujući radikalno izmenjenom dizajnu u konstrukciji glava,
  - **masa glave** iznosila je **nepunih 20 grama**,
  - dok je rastojanje između površi ploča i glava
  - smanjeno na red veličine **nanometra**!
- IBM 3340 je za svoje vreme posedovao **neverovatni kapacitet**
  - od 35 (ili **70 MB**) uz upotrebu dve ili četiri 14" ploče.
  - Sve do samog kraja sedamdesetih, diskovi su koristili "**14-ice**"
  - (standard koji je predstavljen tokom 1963. i koji je vladao tokom sedamdesetih),
  - ali koje su jednostavno bile ogromne za kompaktnije računarske sisteme.
- Tek 1979. IBM po prvi put predstavlja 3310 model
  - koji koristi 8-inč ploče,
  - značajno redukujući dimenzije tadašnjih hard-diskova.

IBM 3340 "Winchester"

Seagate ST-506

- 1979. godina je, međutim,
- bila veoma značajna i zbog jedne sasvim druge stvari.

- Gospodin **Alan Shugart**,
  - otac hard-diska, tokom 1950-tih radio kao inžinjer u IBM-u
  - kada je dizajnirao originalni RAMAC
  - i veliki vizionar po svojoj prirodi (delom zaslužan i za floppy disk),
  - te godine zajedno sa svojim partnerom **Finis Conner**-om osniva
  - kompaniju Shugart Technologies,
  - kasnije preimenovana u svima znani **Seagate**

- Conner kasnije napušta Shugarta
  - i osniva Conner Peripherals 1986.
  - koji se 1996. ponovo spojio sa Seagate-om.

Seagate ST-506

- Kako bi Shugart izbegao sudski spor sa kompanijom Xerox
- zbog svoje ranije kompanije kratkog veka *Shugart Associates*,
  - tražeći reč u rečniku
  - koja počinje na S
  - završava se sa T
  - i sadrži slovo G
- Alan Shugart menja naziv kompanije u **Seagate Technologies.**

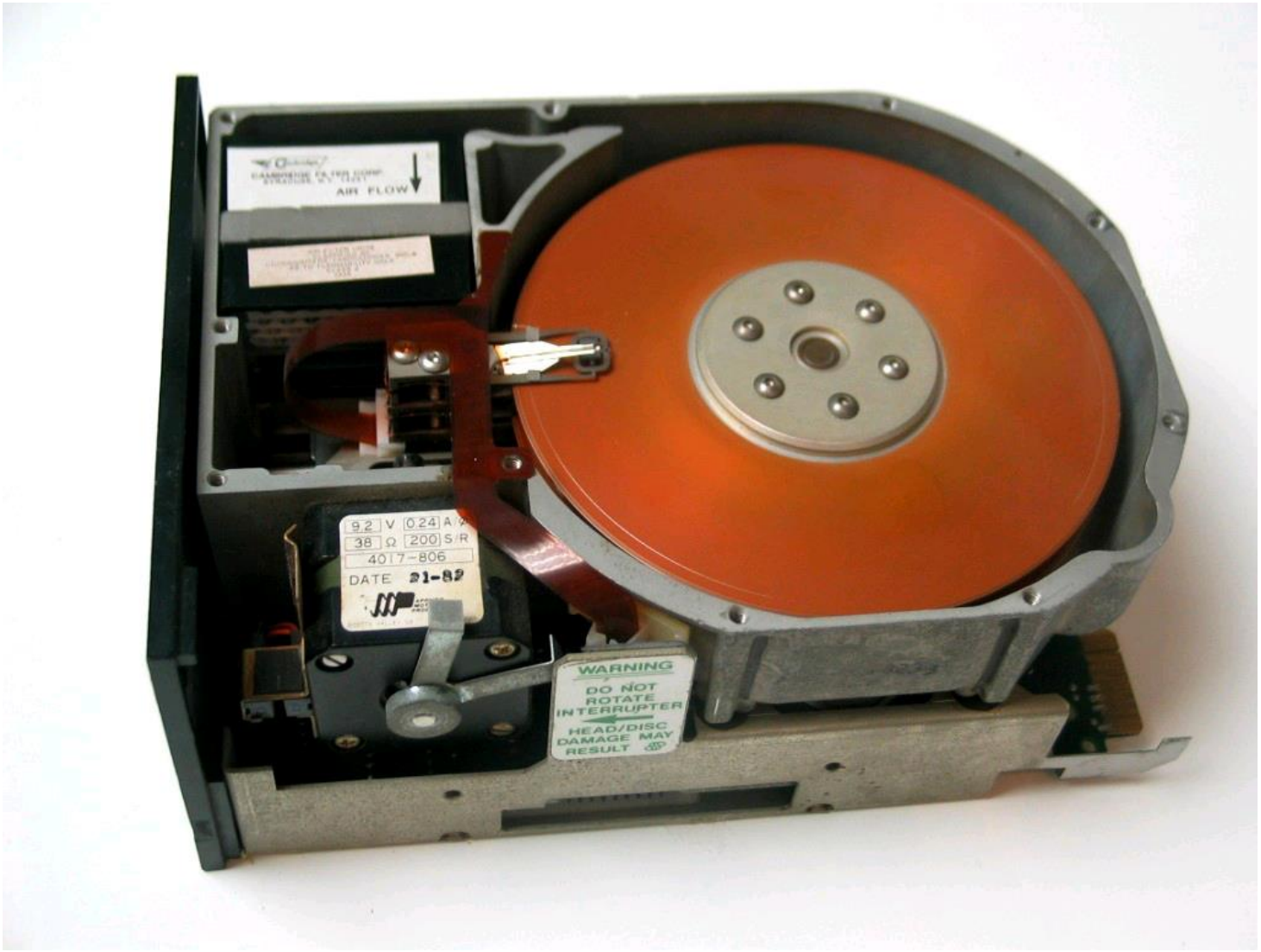
- Ovaj genije je svoju viziju o pristupačnom
  - **5.25" hard-disku**
  - realizovao i predstavio tokom naredne 1980. godine
  - u vidu ST-506 full-height modela
  - koji je koštao neverovatnih **1500$!**

Seagate ST-506

- **ST-506**
  - ukupnog kapaciteta od 5 megabajta
  - je posedovao dve ploče
  - koje su se rotirale brzinom od 3600 rpm,
  - brzina transfera iznosila je 5 MB/s
  - sa prosečnim vremenom pristupa od oko 200 ms.
- Model je, doslovno rečeno,
  - postao pravi hit koji je već naredne 1981.
  - doživeo inkarnaciju u modelu ST-412 dvostruko većeg kapaciteta.
- Kompanija Apple bila je prva velika mušterija,
  - ali je tokom 1983.
  - Seagate sklopio važan ugovor sa kompanijom IBM
  - o snabdevanju svojih ekstremno popularnih PC-XT mašina ST-412 diskovima.
- Ostalo je praktično istorija, Seagate Technologies postaje No.1.

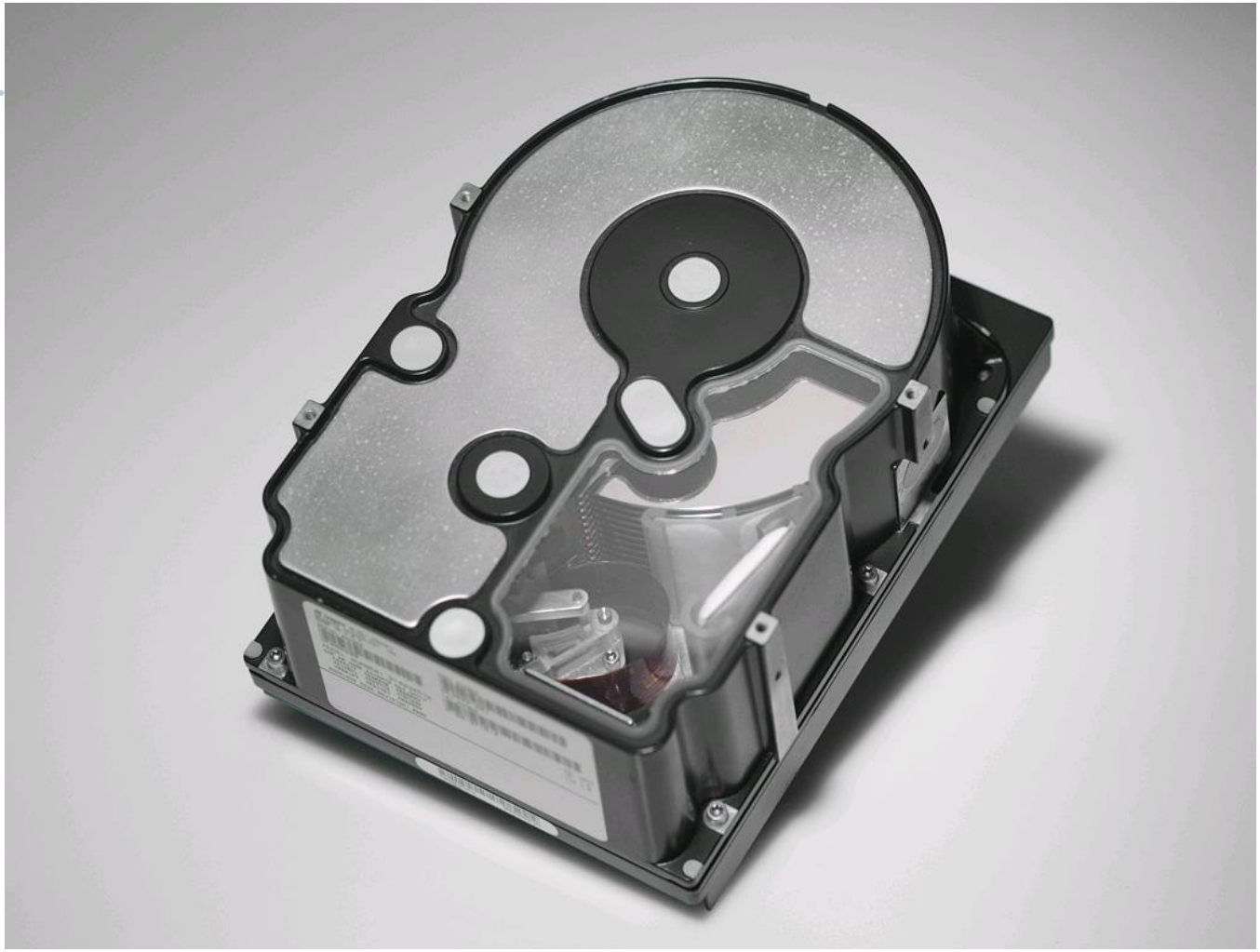
Seagate ST-506

ST506 - 1980: First 5.25-inch hard drive



ST225 - 1984: First high-volume hard drive

Elite 1 - 1990: First 1GB 5400 RPM hard drive



Barracuda 2 - 1992: First 7200 RPM hard drive

Barracuda 4FC - 1994:
First fibre channel hard drive

Cheetah X15 - 2000:
First 15K SCSI hard drive

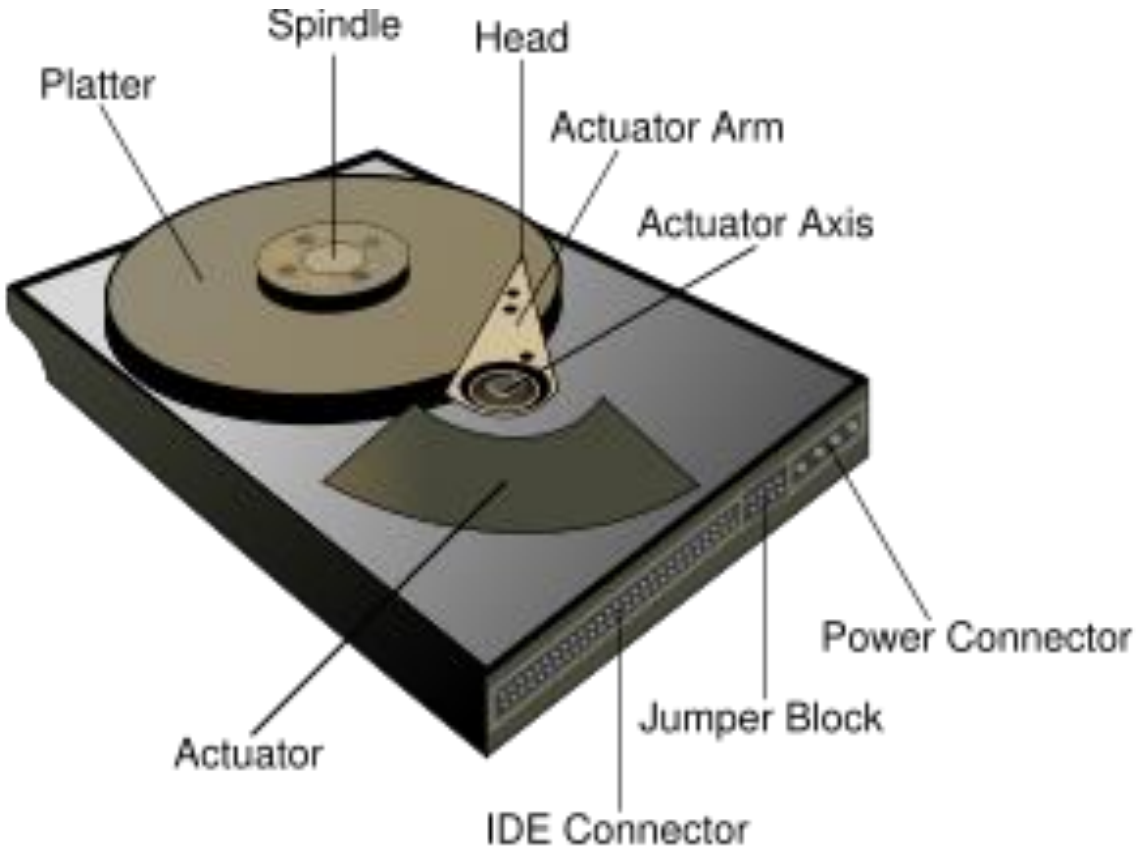
Savvio - 2004:
First 2.5-inch enterprise-class hard drive

Momentus - 2005:
First 7200 RPM notebook hard drive

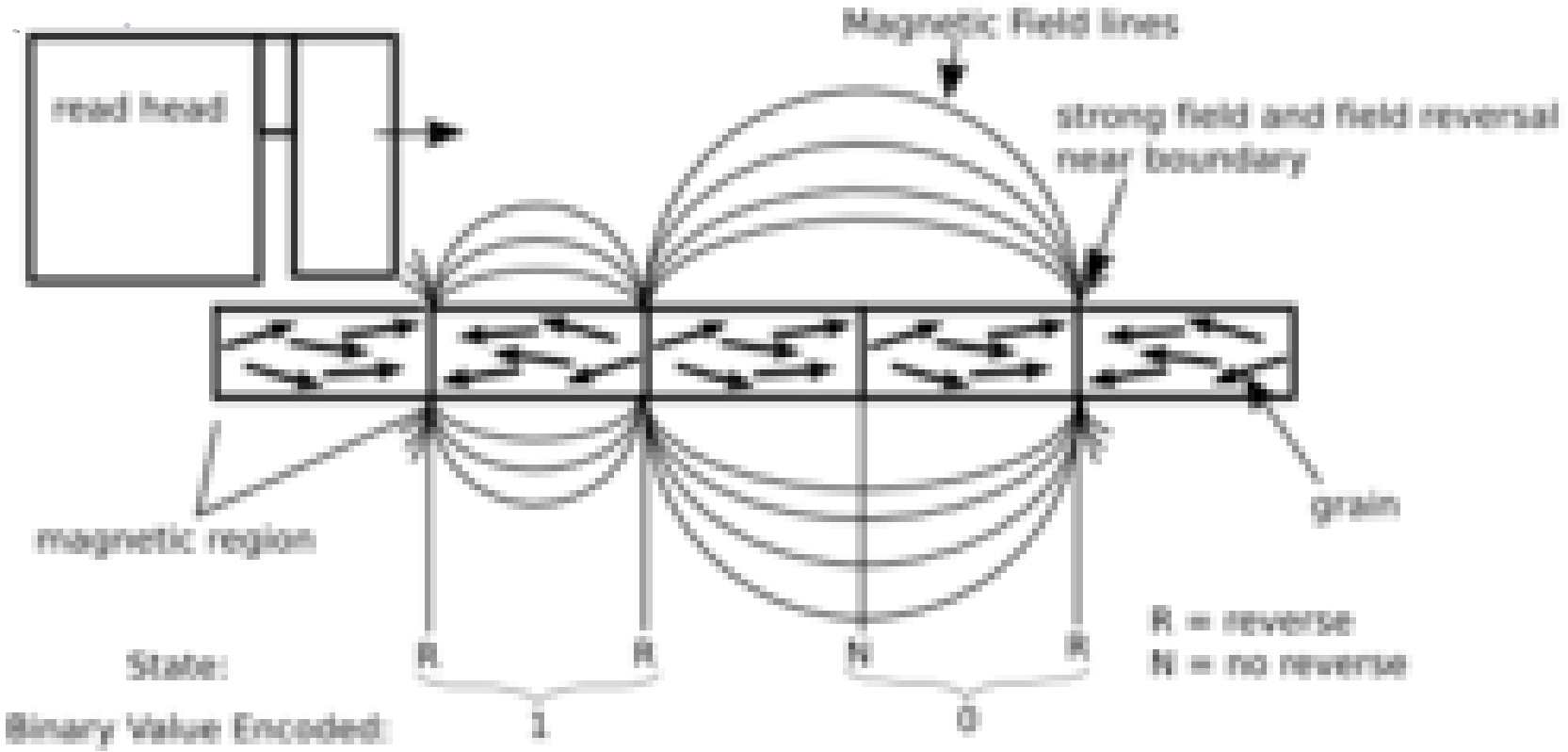
ST1 - 2005: First 1-inch hard drive

1-inch hard drive

Technology


Spindle
Head
Platter
Actuator Arm
Actuator Axis
Power Connector
Jumper Block
Actuator
IDE Connector

Magnetic


Magnetic field lines
read head
strong field and field reversal near boundary
magnetic region
grain
R = reverse
N = no reverse
State:
R
R
N
R
Binary Value Encoded:
1
0

Form factor

Form factor	Width	Largest capacity	Platters (Max)
5.25" FH	146 mm	47 GB[19] (1998)	14
5.25" HH	146 mm	19.3 GB[20] (1998)	4[21]
3.5"	102 mm	1.5 TB[12] (2008)	5
2.5"	69.9 mm	500 GB[22] (2008)	3
1.8" (PCMCIA)	54 mm	160 GB[23] (2007)	
1.8" (ATA-7 LIF)	53.8 mm		
1.3"	36.4 mm	40 GB[24] (2008)	1

disassembled and labeled 1997 hard drive

Six hard drives with 8", 5.25", 3.5", 2.5", 1.8", and 1" disks

Six hard drives with 8", 5.25", 3.5", 2.5", 1.8", and 1" disks

- **8 inch:** (9.5 in x 4.624 in x 14.25 in = 241.3 mm x 117.5 mm x 362 mm)
  In 1979, Shugart Associates' SA1000 was the first form factor compatible HDD, having the same dimensions and a compatible interface to the 8" FDD. Both "full height" and "half height" (2.313 in) versions were available.

- **5.25 inch:** (5.75 in x 1.63 in x 8 in = 146.1 mm x 41.4 mm x 203 mm)
  This smaller form factor, first used in an HDD by Seagate in 1980, was the same size as full height 5¼-inch diameter FDD, i.e., 3.25 inches high. This is twice as high as commonly used today; i.e., 1.63 in = 41.4 mm ("half height"). Most desktop models of drives for optical 120 mm disks (DVD, CD) use the half height 5¼" dimension, but it fell out of fashion for HDDs. The Quantum Bigfoot HDD was the last to use it in the late 1990s, with "low-profile" (~25 mm) and "ultra-low-profile" (~20 mm) high versions.

- **3.5 inch** (4 in x 1 in x 5.75 in = 101.6 mm x 25.4 mm x 146 mm)
  This smaller form factor, first used in an HDD by Rodime in 1984, was the same size as the "half height" 3½ FDD, i.e., 1.63 inches high. Today has been largely superseded by 1-inch high "slimline" or "low-profile" versions of this form factor which is used by most desktop HDDs.

Six hard drives with 8", 5.25", 3.5", 2.5", 1.8", and 1" disks

- **2.5 inch:** (2.75 in x 0.374 in x 3.945 in = 69.85 mm x 9.5–15mm mm x 100 mm)
  This smaller form factor was introduced by PrairieTek in 1988; there is no corresponding FDD. It is widely used today for hard-disk drives in mobile devices (laptops, music players, etc.) and as of 2008 replacing 3.5 inch enterprise-class drives. Today, the dominant height of this form factor is 9.5 mm for laptop drives, but high capacity drives have a height of 12.5 mm. Enterprise-class drives can have a height up to 15 mm.

- **1.8 inch:** (54 mm × 8 mm × 71 mm)
  This form factor, originally introduced by Integral Peripherals in 1993, has evolved into the ATA-7 LIF with dimensions as stated. It is increasingly used in digital audio players and subnotebooks. An original variant exists for 2–5 GB sized HDDs that fit directly into a PC card expansion slot. These became popular for their use in iPods and other HDD based MP3 players.

- **1 inch:** (42.8 mm × 5 mm × 36.4 mm)
  This form factor was introduced in 1999 as IBM's Microdrive to fit inside a CF Type II slot. Samsung calls the same form factor **"1.3 inch" drive** in its product literature.

- **0.85 inch:** (24 mm × 5 mm × 32 mm)
  Toshiba announced this form factor in January 2004 for use in mobile phones and similar applications, including SD/MMC slot compatible HDDs optimized for video storage on 4G handsets. Toshiba currently sells a 4 GB (MK4001MTD) and 8 GB (MK8003MTD) version[4] and holds the Guinness World Record for the smallest harddisk drive.

Minimizing hard disk drive failure and data loss

- Most major hard disk and motherboard vendors now support self-monitoring, analysis and reporting technology (**S.M.A.R.T.),** which attempts to alert users to impending failures.
- However, not all failures are predictable. Normal use eventually can lead to a breakdown in the inherently fragile device, which makes it essential for the user to periodically back up the data onto a separate storage device. Failure to do so will lead to the loss of data. While it may sometimes be possible to recover lost information, it is normally an extremely costly procedure, and it is not possible to guarantee success. A 2007 study published by Google suggested very little correlation between failure rates and either high temperature or activity level; however, the correlation between manufacturer/model and failure rate was relatively strong. Google did not publish the manufacturer's names along with their respective failure rates. While several S.M.A.R.T. parameters have an impact on failure probability, a large fraction of failed drives do not produce predictive S.M.A.R.T. parameters. S.M.A.R.T. parameters alone may not be useful for predicting individual drive failures
- A common misconception is that a colder hard drive will last longer than a hotter hard drive. The **Google study** showed the reverse -- "lower temperatures are associated with higher failure rates". Hard drives with S.M.A.R.T.-reported average temperatures below 27 C had failure rates worse than hard drives with the highest reported average temperature of 50 C, failure rates at least twice as high as the optimum S.M.A.R.T.-reported temperature range of 36 C to 47 C.

Disk Interfaces

- Hard disk drives are accessed over one of a number of bus types, including parallel ATA (PATA, also called IDE or EIDE), Serial ATA (SATA), SCSI, Serial Attached SCSI (SAS), and Fibre Channel. Bridge circuitry is sometimes used to connect hard disk drives to buses that they cannot communicate with natively, such as IEEE 1394 and USB.
- Back in the days of the ST-506 interface, the data encoding scheme was also important. The first ST-506 disks used Modified Frequency Modulation (MFM) encoding, and transferred data at a rate of 5 megabits per second. Later on, controllers using *2,7 RLL* (or just "RLL") encoding increased the transfer rate by 50%, to 7.5 megabits per second; this also increased disk capacity by fifty percent.
- Many ST-506 interface disk drives were only specified by the manufacturer to run at the lower MFM data rate, while other models (usually more expensive versions of the same basic disk drive) were specified to run at the higher RLL data rate. In some cases, a disk drive had sufficient margin to allow the MFM specified model to run at the faster RLL data rate; however, this was often unreliable and was not recommended. (An RLL-certified disk drive could run on a MFM controller, but with 1/3 less data capacity and speed.)
- Enhanced Small Disk Interface (ESDI) also supported multiple data rates (ESDI disks always used 2,7 RLL, but at 10, 15 or 20 megabits per second), but this was usually negotiated automatically by the disk drive and controller; most of the time, however, 15 or 20 megabit ESDI disk drives weren't downward compatible (i.e. a 15 or 20 megabit disk drive wouldn't run on a 10 megabit controller). ESDI disk drives typically also had jumpers to set the number of sectors per track and (in some cases) sector size.

Disk Intrefaces

TYPES OF HARD DISKS			
Type of Interface	Encoding Method**	Transfer Rate (Per sec)	Range of Capacities
SATA (IDE)	RLL	150-300MB	40GB-1.2TB
PATA (IDE)	RLL	3-133MB	500MB-400GB
SCSI	RLL	5-320MB	20MB-300GB
Older Interfaces			
IPI	RLL	10-25MB	200MB-3GB
ESDI	RLL	1-3MB	80MB-2GB
SMD	RLL	1-4MB	200MB-2GB
IDE	RLL	1-8MB	40MB-1GB
ST506 RLL	RLL	937KB	30MB-200MB
ST506	MFM	625KB	5MB-100MB

Disk Interfaces

Acronym or abbreviation	Meaning	Description
SASI	Shugart Associates System Interface	Historical predecessor to SCSI.
SCSI	Small Computer System Interface	Bus oriented that handles concurrent operations.
SAS	Serial Attached SCSI	Improvement of SCSI, uses serial communication instead of parallel.
ST-506		Historical Seagate interface.
ST-412		Historical Seagate interface (minor improvement over ST-506).
ESDI	Enhanced Small Disk Interface	Historical; backwards compatible with ST-412/506, but faster and more integrated.
ATA	Advanced Technology Attachment	Successor to ST-412/506/ESDI by integrating the disk controller completely onto the device. Incapable of concurrent operations.
SATA	Serial ATA	Modification of ATA, uses serial communication instead of parallel.

Disk Interfaces

- Modern hard drives present a consistent interface to the rest of the computer, no matter what data encoding scheme is used internally. Typically a DSP in the electronics inside the hard drive takes the raw analog voltages from the read head and uses PRML and Reed–Solomon error correction [30] to decode the sector boundaries and sector data, then sends that data out the standard interface. That DSP also watches the error rate detected by error detection and correction, and performs bad sector remapping, data collection for Self-Monitoring, Analysis, and Reporting Technology, and other internal tasks.

- SCSI originally had just one speed, 5 MHz (for a maximum data rate of five megabytes per second), but later this was increased dramatically. The SCSI bus speed had no bearing on the disk's internal speed because of buffering between the SCSI bus and the disk drive's internal data bus; however, many early disk drives had very small buffers, and thus had to be reformatted to a different interleave (just like ST-506 disks) when used on slow computers, such as early IBM PC compatibles and early Apple Macintoshes.

Disk Interfaces

- ATA disks have typically had no problems with interleave or data rate, due to their controller design, but many early models were incompatible with each other and couldn't run in a master/slave setup (two disks on the same cable). This was mostly remedied by the mid-1990s, when ATA's specification was standardised and the details began to be cleaned up, but still causes problems occasionally (especially with CD-ROM and DVD-ROM disks, and when mixing Ultra DMA and non-UDMA devices).

- Serial ATA does away with master/slave setups entirely, placing each disk on its own channel (with its own set of I/O ports) instead.

- FireWire/IEEE 1394 and USB(1.0/2.0) HDDs are external units containing generally ATA or SCSI disks with ports on the back allowing very simple and effective expansion and mobility. Most FireWire/IEEE 1394 models are able to daisy-chain in order to continue adding peripherals without requiring additional ports on the computer itself.

Disk interface families used in personal computers

- Notable families of disk interfaces include:
- Historical **bit serial interfaces** — connected to a hard disk drive controller with three cables, one for data, one for control and one for power. The HDD controller provided significant functions such as serial to parallel conversion, data separation and track formatting, and required matching to the drive in order to assure reliability.
  - ST506 used MFM (Modified Frequency Modulation) for the data encoding method.
  - ST412 was available in either MFM or RLL (Run Length Limited) variants.
  - Enhanced Small Disk Interface (ESDI) was an interface developed by Maxtor to allow faster communication between the PC and the disk than MFM or RLL.

Modern bit serial interfaces

- Modern **bit serial interfaces** — connect to a host bus adapter (today typically integrated into the "south bridge") with two cables, one for data/control and one for power.
  - Fibre Channel (FC), is a successor to parallel SCSI interface on enterprise market. It is a serial protocol. In disk drives usually the Fibre Channel Arbitrated Loop (FC-AL) connection topology is used. FC has much broader usage than mere disk interfaces, it is the cornerstone of storage area networks (SANs). Recently other protocols for this field, like iSCSI and ATA over Ethernet have been developed as well. Confusingly, drives usually use *copper* twisted-pair cables for Fibre Channel, not fibre optics. The latter are traditionally reserved for larger devices, such as servers or disk array controllers.
  - Serial ATA (SATA). The SATA data cable has one data pair for differential transmission of data to the device, and one pair for differential receiving from the device, just like EIA-422. That requires that data be transmitted serially. The same differential signaling system is used in RS485, LocalTalk, USB, Firewire, and differential SCSI.
  - Serial Attached SCSI (SAS). The SAS is a new generation serial communication protocol for devices designed to allow for much higher speed data transfers and is compatible with SATA. SAS uses serial communication instead of the parallel method found in traditional SCSI devices but still uses SCSI commands.

Word serial interfaces (parallel)

- **Word serial interfaces** — connect to a host bus adapter (today typically integrated into the "south bridge") with two cables, one for data/control and one for power. The earliest versions of these interfaces typically had a 16 bit parallel data transfer to/from the drive and there are 8 and 32 bit variants. Modern versions have serial data transfer. The word nature of data transfer makes the design of a host bus adapter significantly simpler than that of the precursor HDD controller.
  - Integrated Drive Electronics (IDE), later renamed to ATA, and then later to PATA ("parallel ATA", to distinguish it from the new Serial ATA). The original name reflected the innovative integration of HDD controller with HDD itself, which was not found in earlier disks. Moving the HDD controller from the interface card to the disk drive helped to standardize interfaces, including reducing the cost and complexity. The 40 pin IDE/ATA connection of PATA transfers 16 bits of data at a time on the data cable. The data cable was originally 40 conductor, but later higher speed requirements for data transfer to and from the hard drive led to an "ultra DMA" mode, known as UDMA, which required an 80 conductor variant of the same cable; the other conductors provided the grounding necessary for enhanced high-speed signal quality. The interface for 80 conductor only has 39 pins, the missing pin acting as a key to prevent incorrect insertion of the connector to an incompatible socket, a common cause of disk and controller damage.
  - EIDE was an unofficial update (by Western Digital) to the original IDE standard, with the key improvement being the use of direct memory access (DMA) to transfer data between the disk and the computer without the involvement of the CPU, an improvement later adopted by the official ATA standards. By directly transferring data between memory and disk, DMA does not require the CPU/program/operating system to leave other tasks idle while the data transfer occurs.
  - Small Computer System Interface (SCSI), originally named SASI for Shugart Associates System Interface, was an early competitor of ESDI. SCSI disks were standard on servers, workstations, and Apple Macintosh computers through the mid-90s, by which time most models had been transitioned to IDE (and later, SATA) family disks. Only in 2005 did the capacity of SCSI disks fall behind IDE disk technology, though the highest-performance disks are still available in SCSI and Fibre Channel only. The length limitations of the data cable allows for external SCSI devices. Originally SCSI data cables used single ended data transmission, but server class SCSI could use differential transmission, either low voltage differential (LVD) or high voltage differential (HVD).

Part 03.

- **Disk History - 1**

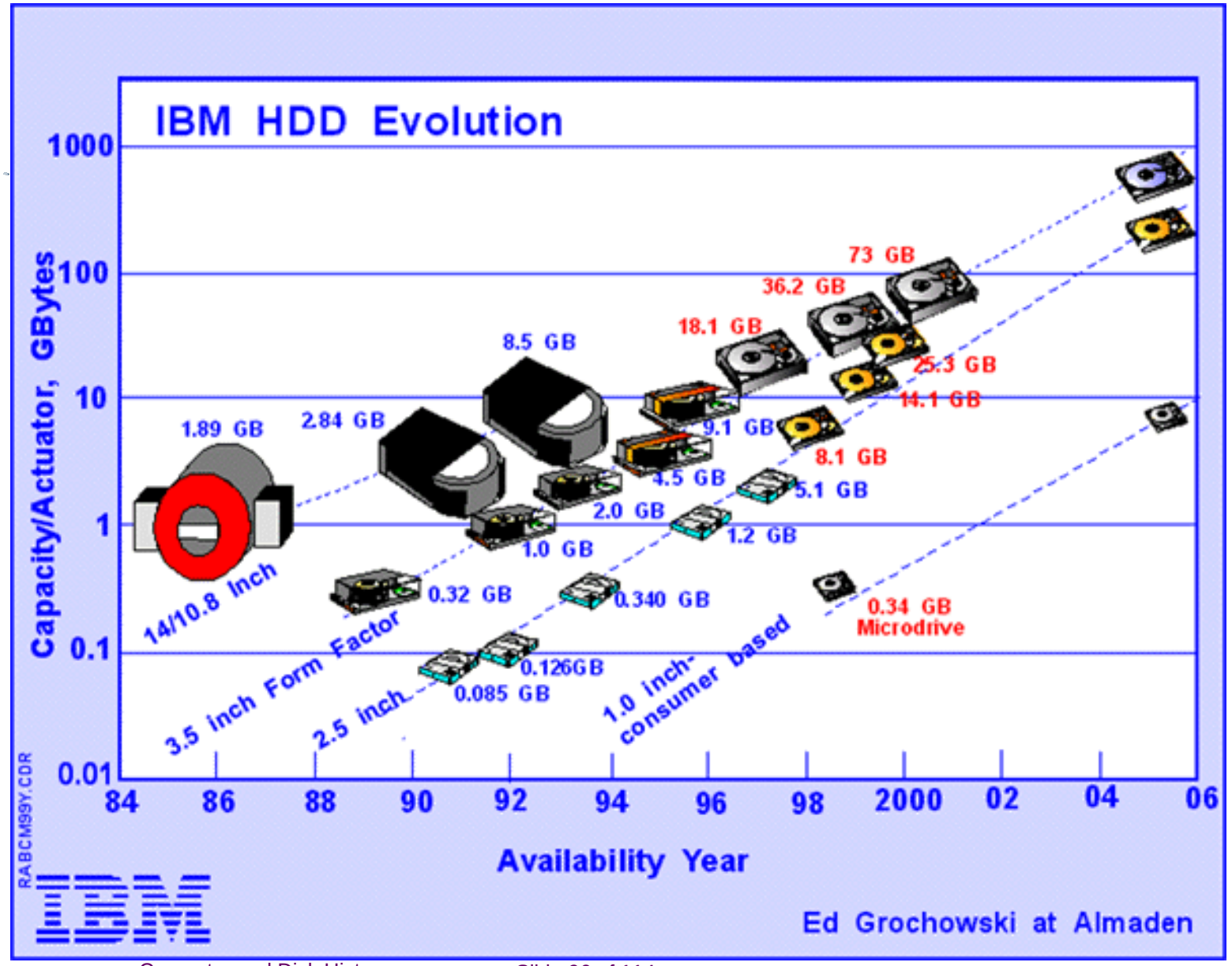
Brief History of the Hard Disk Drive

- Hard disks are one of the most important and also one of the most interesting components within the PC.
- They have a long and interesting history dating back to the early 1950s.
- Perhaps one reason that find disks so fascinating is how well engineers over the last few decades have done at **improving** them in **every respect:**
  - reliability
  - capacity
  - speed
  - power usage
  - and
  - more

Evolution of IBM hard disks over past 15 years

- This excellent chart shows the **evolution** of IBM **hard disks** over the past 15 years.
- Several different **form factors** are illustrated
  - showing the progress
  - that they have made over the years in terms of capacity
  - along with projections for the future.
- 250 GB hard disks in laptops in five years?
- Based on past history, there's a good chance that it will in fact happen!
- Note that the scale on the left is logarithmic, not linear, and PC hard disks have one **actuator.**

Evolution of IBM hard disks over past 15 years



First storage medium: paper

- The **first storage medium** used on computers was actually **paper**.

- **Programs** and **data** were recorded using holes punched into **paper tape** or **punch cards**. A **special reader** used a beam of light to scan the cards or tape; where a hole was found it read a "1", and where the paper blocked the sensor, a "0" (or vice-versa).

- This was a pretty simple arrangement. I remember using a punch station, which was like a workstation where you typed characters and the machine punched the holes into the cards. While a great improvement over nothing, these cards were still very **inconvenient to use**. You basically had to write the entire program from scratch on paper, and get it working in your mind before you started trying to put it onto cards, because if you made a mistake you had to re-punch many of the cards. It was very hard to visualize what you were working with.

- The card readers had a tendency to **jam** (the old one at my high school was nicknamed the "IBM 1443 card chewer".) And heaven help you if you dropped a stack of cards on the floor... :^) Still however, paper was used as the primary storage medium for many years.

Second storage medium: magnetic tape

- The next big advance over paper was the creation of **magnetic tape.**
- Almost everyone has at least seen pictures of the **large reels** of **tape** used in older computers.
- Recording information in a way similar to how audio is recorded on a tape, these magnetic tapes were much more flexible, durable and faster than paper tape or punch cards.
- Of course, tape is still used today on modern computers, but as a form of *offline* or secondary storage.
- Before hard disks, they were the primary storage for some computers. Their primary disadvantage is that they **must be** read linearly; it can take minutes to move from one end of the tape to the other, making *random access* impractical.

Personel Computer: none, cassette tape, floppy

- Personal computers developed much later than the early, large mainframes, and were therefore the beneficiaries of advancements in **storage technologies** fairly early on in their existence. My first computer was purchased for me by my parents in 1980: an Apple][. A great little machine for learning on, using it gave me a profound appreciation for the importance of storage: because it had ***none***! No hard disk drive, not even a floppy disk drive. My choices were to **type in programs by hand** (which I did sometimes) or try to load them from a **cassette tape**. Yes, an audio cassette tape. If you thought modern computer tape drives were unreliable, you should have tried getting that to work! :^) (Oh, and I also had to walk barefoot through three feet of snow to get to school... uphill both ways!)

- I later purchased a low-density, **single-sided floppy disk drive** for my Apple. Boy, what a feeling of freedom that was! I could load and save programs and data easily, something I could never do before. That disk drive cost C$700 (back when the Canadian dollar was worth not much less than the U.S. dollar.) The biggest advantages of floppy disks over tapes are the ability to randomly access the data, and much better portability. They don't have nearly as much capacity however.

- The first **IBM PCs** also **had no hard disk drive**, but rather employed one or two floppy disk drives. While of course far better than nothing, floppy disk drives were slow, small in capacity and relatively unreliable compared to even the earliest hard disks.

Early Disk Drives

- The very first disk drives were of course experiments. Researchers, particularly those at IBM, were working with a number of different technologies and concepts to try to develop a disk drive that would be feasible for commercial development.
- In fact, the very first drives were not "disk drives" at all--they used **rotating cylindrical drums**, upon which the magnetic patterns of data were stored. The drums were large and hard to work with.
- **The earliest "true"** hard disks:
  - had the heads of the hard disk
  - in **contact with** the surface of the disk
- This was done to allow the low-sensitivity electronics of the day to be able to better read the magnetic fields on the surface of the disk.
- Unfortunately, manufacturing techniques were not nearly as sophisticated as they are now, and it was not possible to get the disk's surface as smooth as would be necessary to allow the head to slide smoothly over the surface of the disk at high speed while in contact with it.
- Over time the **heads would wear out**,
- or **wear out the magnetic coating** on the surface of the disk.

First disk, IBM 350

- The key technological breakthrough that enabled the creation of the modern **hard disk** came in the 1950s.
- IBM engineers realized that with the proper design the heads could be suspended above the surface of the disk and read the bits as they passed underneath.
- With this critical discovery that **contact with the surface of the disk was not necessary,** the **basis for the modern hard disk was born.**

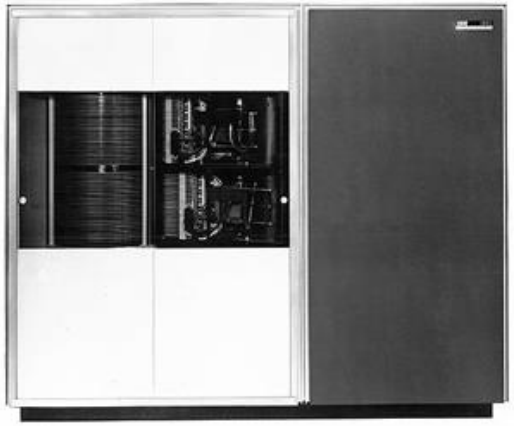
- The very first production hard disk was the IBM 305 RAMAC (Random Access Method of Accounting and Control), introduced on September 13, 1956.

First disk, IBM 350

- This beastie stored **5 million characters**
  - (approximately five megabytes, but a "character" in those days was only seven bits, not eight)
  - **on a whopping *50* disks**,
  - each 24 inches in diameter! (head **20 mikrometars)**
  - Its areal density was about 2,000 bits per square inch;
  - in comparison, today's drives have areal densities measured in billions of bits per square inch.
  - The data transfer rate of this first drive was an **impressive 8,800 bytes per second.**

First disks, IBM 1301

- Over the succeeding years, the technology improved incrementally:
  - areal density
  - capacity
  - performance
- all increased.



- In 1962,
- IBM introduced the **model 1301 Advanced Disk File**.

- The key advance of this disk drive was:
  - the creation of heads that floated (or flew)
  - above the surface of the disk
  - on an "**air bearing**"
  - reducing the distance from the heads to the surface of the disks
  - from 800 to 250 microinches.

IBM 3340

- **In 1973, IBM introduced the model 3340 disk drive**,
  - which is commonly considered
  - to be the **father of the modern hard disk**.
- This unit had two separate spindles,
  - one permanent and the other removable,
  - each with a capacity of 30 MB.
- For this reason the disk was sometimes referred to as the "30-30".
- This name led to its being nicknamed the "Winchester" disk drive, after the famous "30-30" Winchester rifle.
- Using the first sealed internal environment and
  - vastly improved "air bearing" technology,
  - the Winchester disk drive greatly reduced the flying height of the disk:
  - to only **17 microinches** above the surface of the disk.
- Modern hard disks today
  - still use many concepts
  - first introduced in this early drive
  - and for this reason are sometimes still called "Winchester" drives

Seagate ST-506

- The first hard disk drive
  - designed in the 5.25" form factor
  - used in the first PCs
  - was the Seagate ST-506.

- It featured:
  - **four heads**
  - **5 MB capacity**

- IBM bypassed the ST-506 and chose the ST-412
  - a 10 MB disk in the same form factor
  - for the IBM PC/XT
  - making it the first hard disk drive
  - widely used in the PC and PC-compatible world.

Key Technological Firsts

- There have been a number of **important "firsts"**
- in the world of hard disks over their first 40 or so years.

- The following is a list, in chronological order, of some of the products developed during the past half-century that introduced key or important technologies in the PC world.

- Note the **dominance of IBM in** the **list**; in this author's opinion Big Blue does not get nearly as much credit as it deserves for being the main innovator in the storage world.

- Note also how many years it took for many of these technologies to make it to the PC world (sometimes as much as a decade, due to the initial high cost of most new technologies).

"firsts" in the world of hard disks

- **First Hard Disk (1956): IBM's RAMAC** is introduced. It has a capacity of about 5 MB, stored on 50 24" disks. Its areal density is a mere 2,000 bits per square inch and its data throughput 8,800 bits/s.

- **First Air Bearing Heads (1962): IBM's model 1301** lowers the flying height of the heads to 250 microinches. It has a 28 MB capacity on half as many heads as the original RAMAC, and increases both areal density and throughput by about 1000%.

- **First Removable Disk Drive (1965):** IBM's model 2310 is the first disk drive with a removable disk pack. While many PC users think of removable hard disks as being a modern invention, in fact they were very popular in the 1960s and 1970s.

- **First Ferrite Heads (1966):** IBM's model 2314 is the first hard disk to use ferrite core heads, the first type later used on PC hard disks.

"firsts" in the world of hard disks

- **First Modern Hard Disk Design (1973):** IBM's model 3340, nicknamed the "Winchester", is introduced. With a capacity of 60 MB it introduces several key technologies that lead to it being considered by many the ancestor of the modern disk drive.

- **First Thin Film Heads (1979):** IBM's model 3370 is the first with thin film heads, which would for many years be the standard in the PC industry.

- **First Eight-Inch Form Factor Disk (1979):** IBM's model 3310 is the first disk drive with 8" platters, greatly reduced in size from the 14" that had been the standard for over a decade.

- **First 5.25" Form Factor Disk (1980):** Seagate's ST-506 is the first drive in the 5.25" form factor, used in the earliest PCs.

- **First 3.5" Form Factor Disk Drive (1983):** Rodime introduces the RO352, the first disk drive to use the 3.5" form factor, which became one of the most important industry standards.

"firsts" in the world of hard disks

- **First Expansion Card Disk Drive (1985):** Quantum introduces the *Hardcard*, a 10.5 MB hard disk mounted on an ISA expansion card for PCs that were originally built without a hard disk. This product put Quantum "on the map" so to speak.
- **First Voice Coil Actuator 3.5" Drive (1986):** Conner Peripherals introduces the CP340, the first disk drive to use a voice coil actuator.
- **First "Low-Profile" 3.5" Disk Drive (1988):** Conner Peripherals introduces the CP3022, which was the first 3.5" drive to use the reduced 1" height now called "low profile" and the standard for modern 3.5" drives.
- **First 2.5" Form Factor Disk Drive (1988):** PrairieTek introduces a drive using 2.5" platters. This size would later become a standard for portable computing.
- **First Drive to use Magnetoresistive Heads and PRML Data Decoding (1990):** IBM's model 681 (Redwing), an 857 MB drive, is the first to use MR heads and PRML.
- **First Thin Film Disks (1991):** IBM's "Pacifica" mainframe drive is the first to replace oxide media with thin film media on the platter surface.
- **First 1.8" Form Factor Disk Drive (1991):** Integral Peripherals' 1820 is the first hard disk with 1.8" platters, later used for PC-Card disk drives.
- **First 1.3" Form Factor Disk Drive (1992):** Hewlett Packard's C3013A is the first 1.3" drive.

Hard Disk Trends

- The most amazing thing about hard disks is that they both change and don't change more than most other components. In terms of their basic design, today's hard disks aren't a lot different than the 10 MB clunkers installed in the first IBM PC/XTs in the early 1980s. However, in terms of their capacity, storage, reliability and other characteristics, hard drives have probably improved more than any other PC component.

- Let's take a look at some of the trends in various important hard disk characteristics:

- **Areal Density**: The areal density of hard disk platters continues to increase at an amazing rate even exceeding some of the optimistic predictions of a few years ago. Densities in the lab are now exceeding **35 Gbits/in2**, and modern disks are now packing as much as **20 GB of data onto a single 3.5**" platter!

- **Capacity**: Hard disk capacity continues to not only increase, but increase at an accelerating rate. From 10 MB in 1981, we are now well over 10 GB in 2000 and will probably hit 100 GB within a year for consumer drives

Hard Disk Trends

- **Spindle Speed**: The move to faster and faster spindle speeds continues. Since increasing the spindle speed improves both random-access and sequential performance, this is likely to continue. Once the domain of high-end SCSI drives, 7200 RPM spindles are now standard on mainstream IDE/ATA drives. A 15,000 RPM SCSI drive was announced by Seagate in early 2000.

- **Form Factor**: The trend in form factors is downward: to smaller and smaller drives. 5.25" drives have now all but disappeared from the mainstream PC market, with 3.5" drives dominating the desktop and server segment. In the mobile world, 2.5" drives are the standard with smaller sizes becoming more prevalent; IBM in 1999 announced its Microdrive which is a tiny 170 MB or 340 MB device only an inch in diameter and less than 0.25" thick! Over the next few years, desktop and server drives are likely to transition to the 2.5" form factor as well. The primary reasons for this "shrinking trend" include the enhanced rigidity of smaller platters, reduction of mass to enable faster spin speeds, and improved reliability due to enhanced ease of manufacturing.

Hard Disk Trends

- **Performance**: Both positioning and transfer performance factors are improving. The speed with which data can be pulled from the disk is increasing more rapidly than positioning performance is improving, suggesting that over the next few years addressing seek time and latency will be the areas of greatest value to hard disk engineers.

- **Reliability**: The reliability of hard disks is improving slowly as manufacturers refine their processes and add new reliability-enhancing features, but this characteristic is not changing nearly as rapidly as the others above. One reason is that the technology is constantly changing, and the performance envelope constantly being pushed; it's much harder to improve the reliability of a product when it is changing rapidly.

Hard Disk Trends

- **RAID**: Once the province of only high-end servers, the use of multiple disk arrays to improve performance and reliability is becoming increasingly common, and is now even seen in consumer desktop machines. Over the next few years I predict that RAID will become the "next big thing" as the thirst for performance increases, and in five years we may see new PCs commonly shipping with multiple hard disks configured as an array.

- **Interfaces**: Despite the introduction to the PC world of new interfaces such as IEEE-1394 and USB (universal serial bus) the mainstream interfaces in the PC world are the same as they were through the 1990s: IDE/ATA and SCSI. The interfaces themselves continue to create new and improved standards with higher maximum transfer rates, to match the increase in performance of the hard disks themselves.

areal density

- This chart shows the progress of areal density over the last 43 years. The red line is drawn as a best-fit through the blue diamonds which are actual products. Key hard disk head technology developments are indicated. Note that the scale on left is logarithmic, not linear.