Information Storage: Yesterday, Today and Tomorrow

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Periods
Yesterday, Today, and Tomorrow

- **Information Storage: Content is intended to be widely shared**
  - **My definition: Storage must be nonvolatile.**
  - **Memory supports information processing; the high access rates desired can favor volatile technologies.**
- **Types of information includes text, symbols, images and time signals (sound, patterns, etc)**

- **Yesterday: Printing press to WWII**
- **Today: WWII to end of 20th century**
- **Tomorrow: 2000+ perspectives**

Printing Press

- **Radically changed society by providing wide dissemination of information and knowledge**
- Moveable type printing press
  - Introduced in 15th Century by J Gutenberg, Mainz, Germany
  - Content (printed text, symbols and images)
    - Information is human readable
  - Medium: paper
  - Information transfer: by physical transport
  - Libraries: repositories for public access

Punched Card

- In 19th century the need for record keeping and computing were growing
- H. Hollerith took the punched card idea of the Jacquard loom and developed equipment for sorting, collating and tabulating census data from key-punched cards
  - "Binary coding" made the **machine processing of large amounts of data possible**.
    - Content: alphanumeric data
- IBM led in making punched cards and batch processing the basis of business data processing in first half of 20th century

Two Emerging Storage Technologies

- Photographic film for images emerged and became popular in late 19th century
  - Roll film and box camera (G. Eastman)
- ==========
- In 1898 magnetic recording was invented by V. Poulson
  - In first half of 20th century focus was on the analog recording of sound on magnetic tape
    - Technology just beginning to emerge during this period
  - Like paper, card, and film media, magnetic media was nonvolatile and in addition also reusable.

Summing up - “Yesterday”

- Printed paper became the main means for information storage
- Punched cards introduced, allowing machine processing of large quantities of data.
- Photographic film became the standard method for storing images and moving pictures
- Magnetic recording still in an early developmental stage, was focused on the tape recording of speech.

"Today"
The Seminal Event That Led to Change

The Electronic Digital Computer

- The ENIAC Computer - developed in 1940's to meet computing needs of military arising during WWII
  - Memory
    - Vacuum tubes (data volatile)
    - High speed, small capacity
  - Input/Output
    - Removable media: punched cards, paper tape
    - Slow access, low cost. Open-ended capacity
  - Data transfers were between I/O and Memory

Early Computer Activities

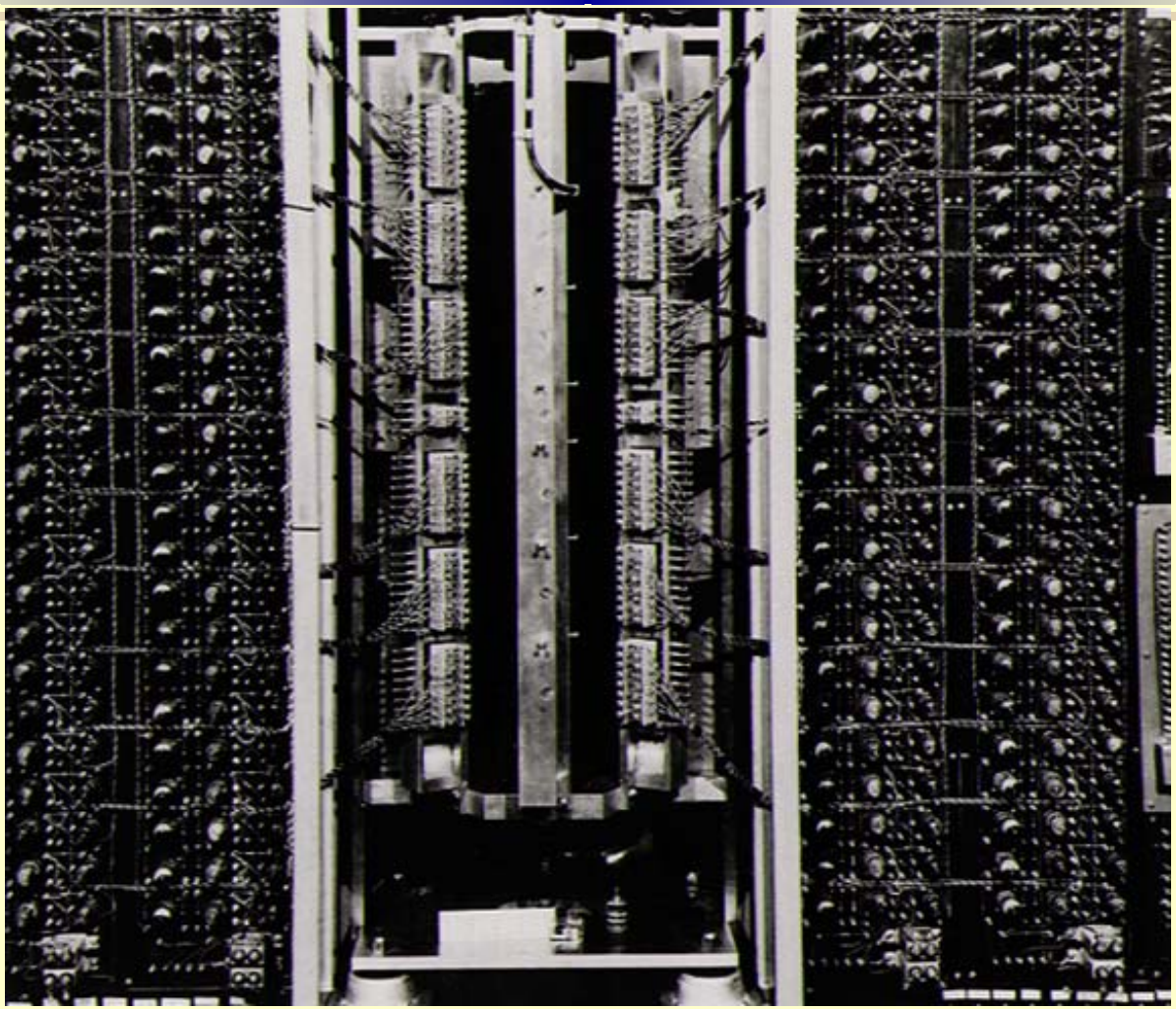
- Primary focus on scientific computation
  - Government was funding source for many early activities
  - Universities played a leading role
- High end
  - Memory evolution -- emphasis on speed, then cost
    - Vacuum tube, Mercury delay line, CRT (Williams tube), then: ***Magnetic core, Semiconductor***
- Intermediate
  - Memory evolution -- emphasis on low cost, then speed
    - Magnetic drum, then: ***Magnetic core, Semiconductor***

Magnetic Drum Memory
CALDIC at UC Berkeley (1948-1952)

- *Unlike existing magnetic tape devices, based on analog recording, having a head in contact with a slowly moving tape*

- Magnetic drum memory was based on digital magnetic recording where:
  - Could write, read and update in-place a small block of binary encoded data (saturate cell + or – direction)
- Provided fast access to any block and a high data rate, requiring a high medium velocity.
  - Needed a physical separation between head and medium to avoid wear

UC Magnetic Drum Memory



Computer Application Trends Early 1950's

- Business data processing growing in importance
  - Magnetic tape replacing paper tape and punched cards
  - Methodology still based on "batch" data processing
    - Tape sorting and sequential processing of data
- Growing interest and desire for on-line system storage that would allow direct access to any record for transaction processing to handle applications like accounting and control

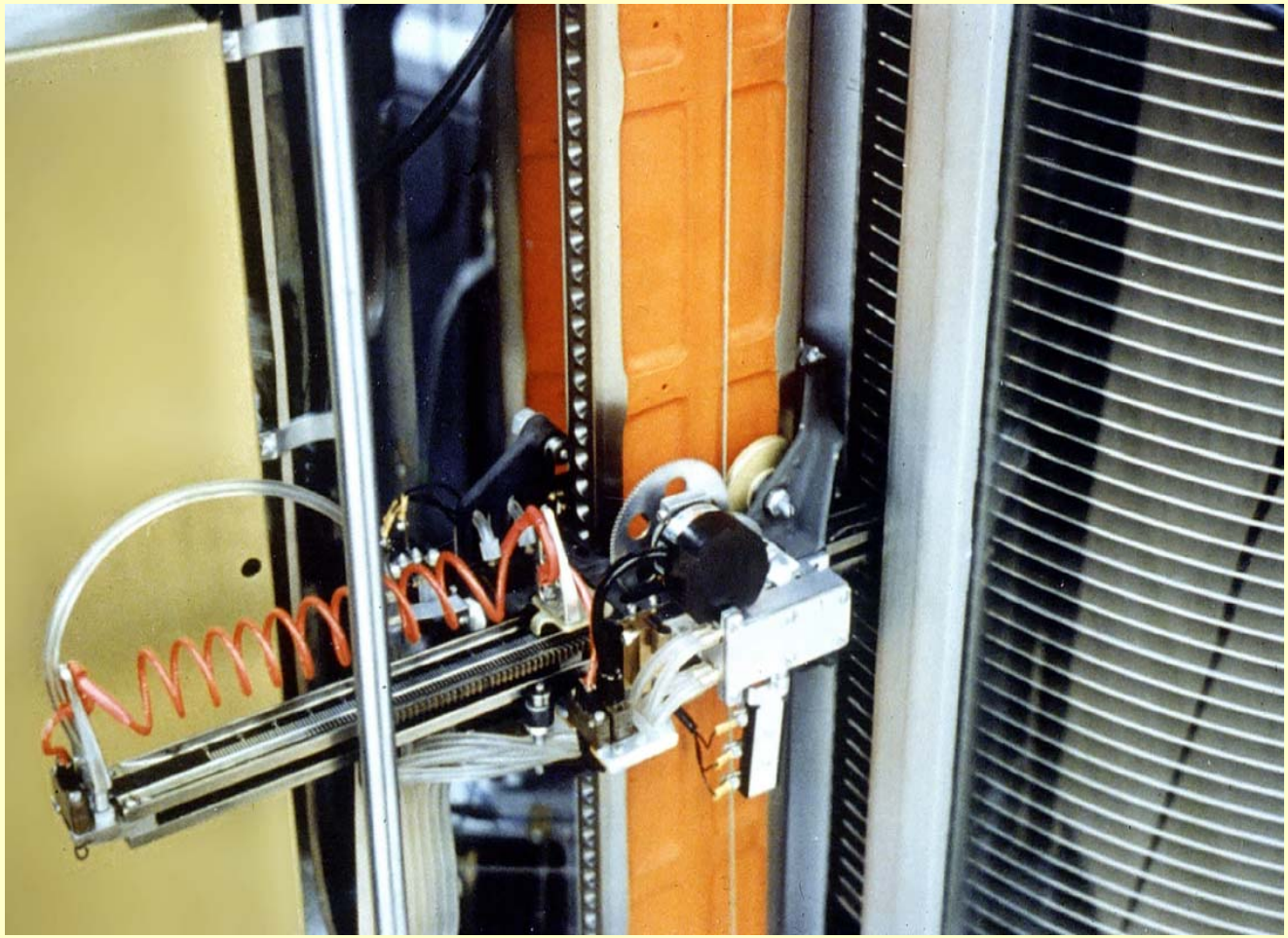
On-line Storage Characteristics Desired

- Magnetic drum digital magnetic recording features but also providing :
- Much higher capacity with a significantly lower cost/byte.

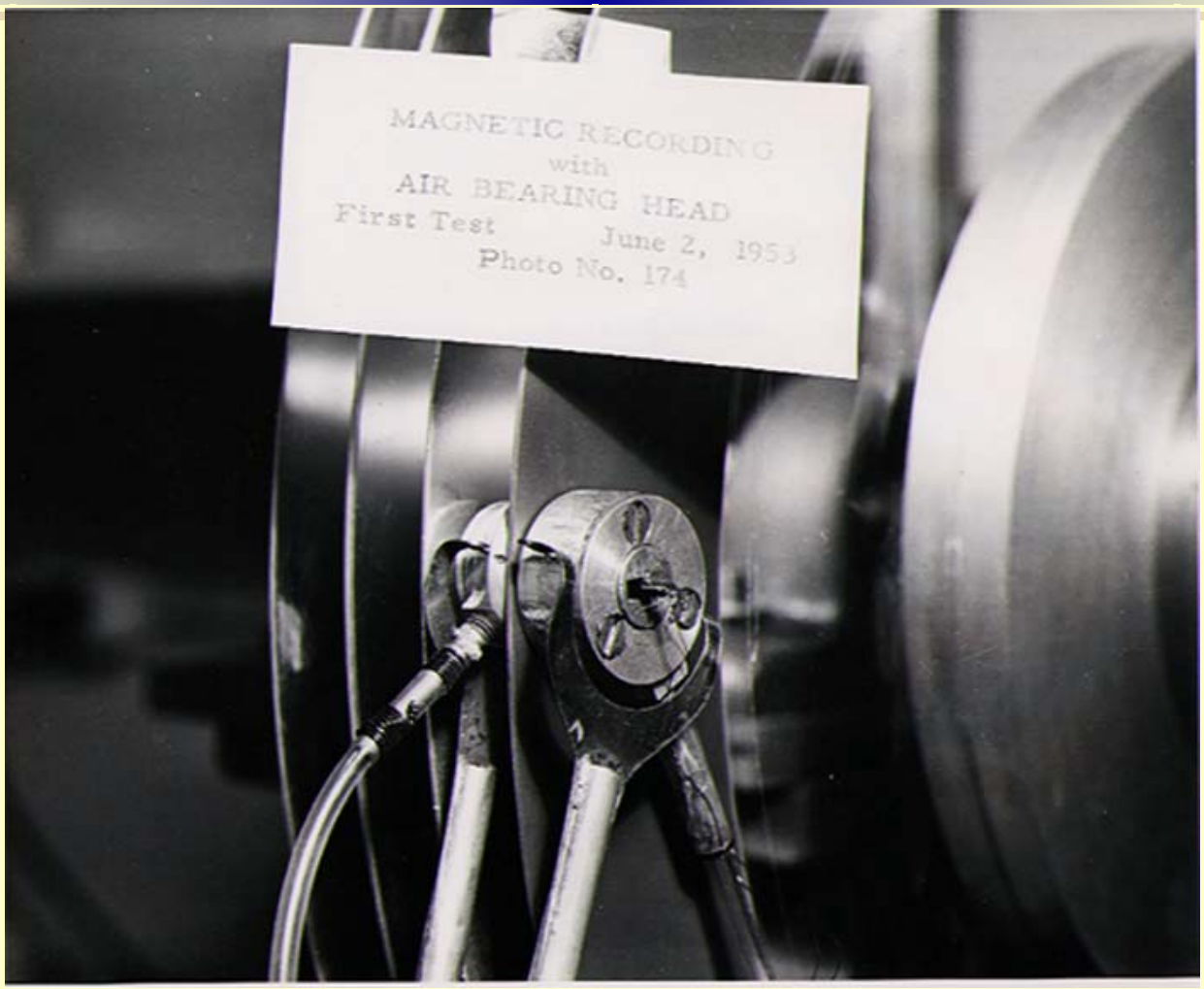
Optimum design tradeoffs

  - For Capacity: Large recording medium surface area (rotating disk stack)
  - For low cost per byte: Head positioning (each head servicing many tracks)
  - Consequence: self-clocking of data

IBM RAMAC (Announced 1956)



RAMAC Magnetic Head



RAMAC System

Emerging Perspectives

- Non-contact digital magnetic recording (1947)
  - **Able to add or update individual data blocks**
  - **High data rate and short access time from a high medium velocity, requiring physical separation between head and medium**
  - Offered possibility of storing all types of information on the same medium
- Magnetic disk data storage (1955)
  - **On-line transaction processing. Response times compatible with applications involving human interaction with large databases**
- World-wide packet switching data networks
  - Started by ARPA (created in response to Sputnik) (1957)

Next Generation Disk Drive (1301)

- "Prototype" for all following generations of disk drives by introducing the flying head per surface design.
  - dramatically reducing head positioning time, 1/10 of RAMAC
  - Providing path for continually reducing head/medium spacing.
  - Storage density 10 times that of RAMAC
- Provided magnetic disk performance capabilities for major applications requiring real-time on-line transaction oriented applications.
  - Signature implementation: AA Sabre Airlines Reservations System (requiring a 3 sec or less response time to inquiries) was based on 1301, and a precursor of such real-time computer systems applications

Perpendicular Magnetic Head (ADF)

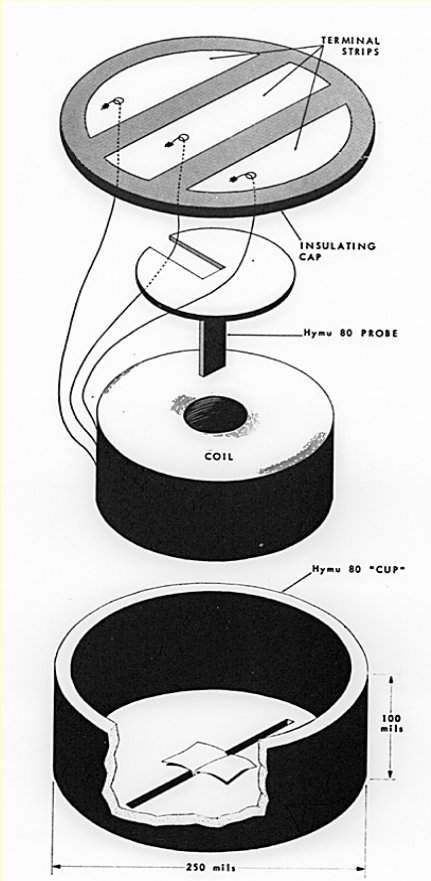
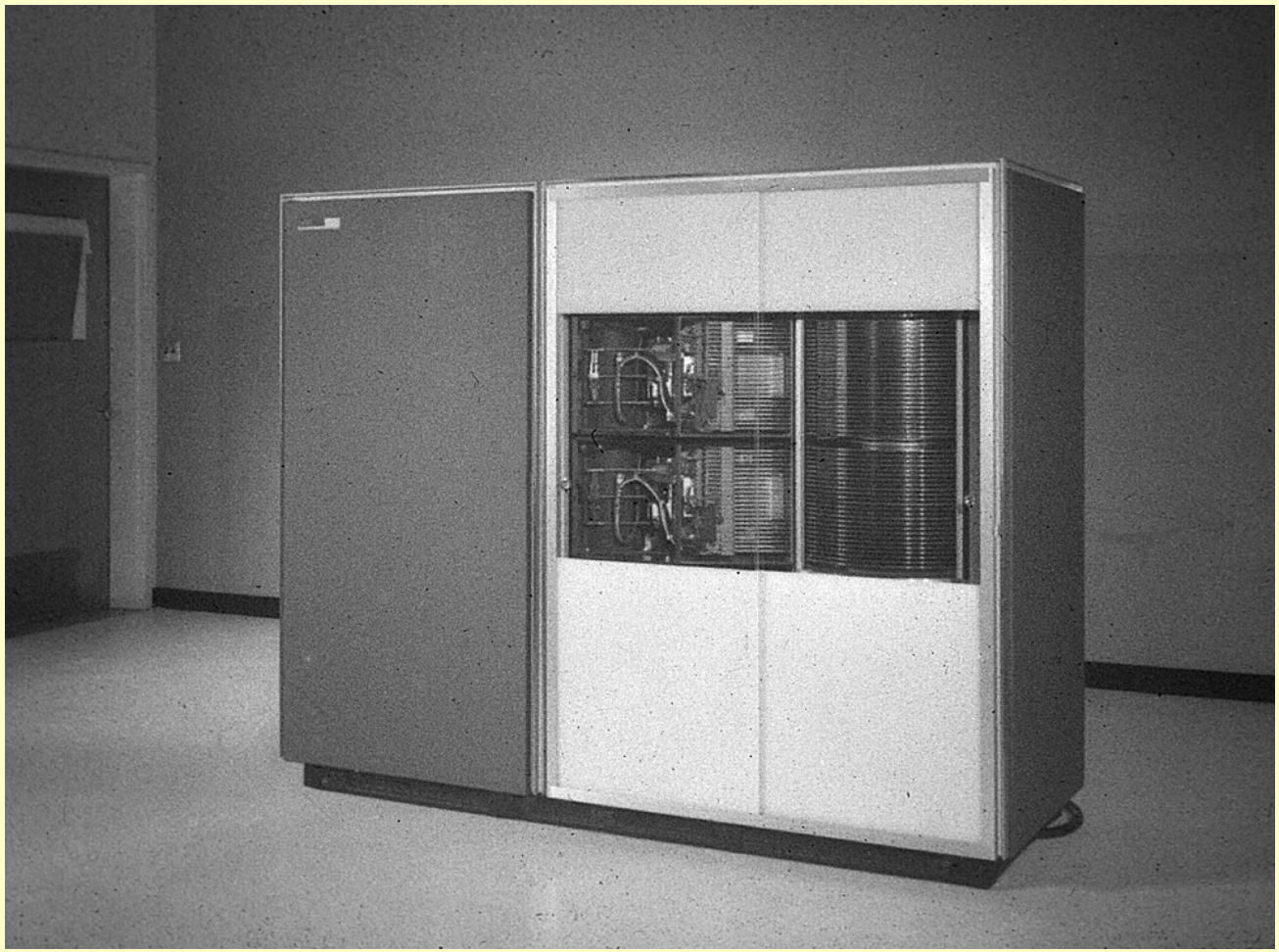


Figure 12 **Design of probe-type recording head.**

IBM 1301 (1961)

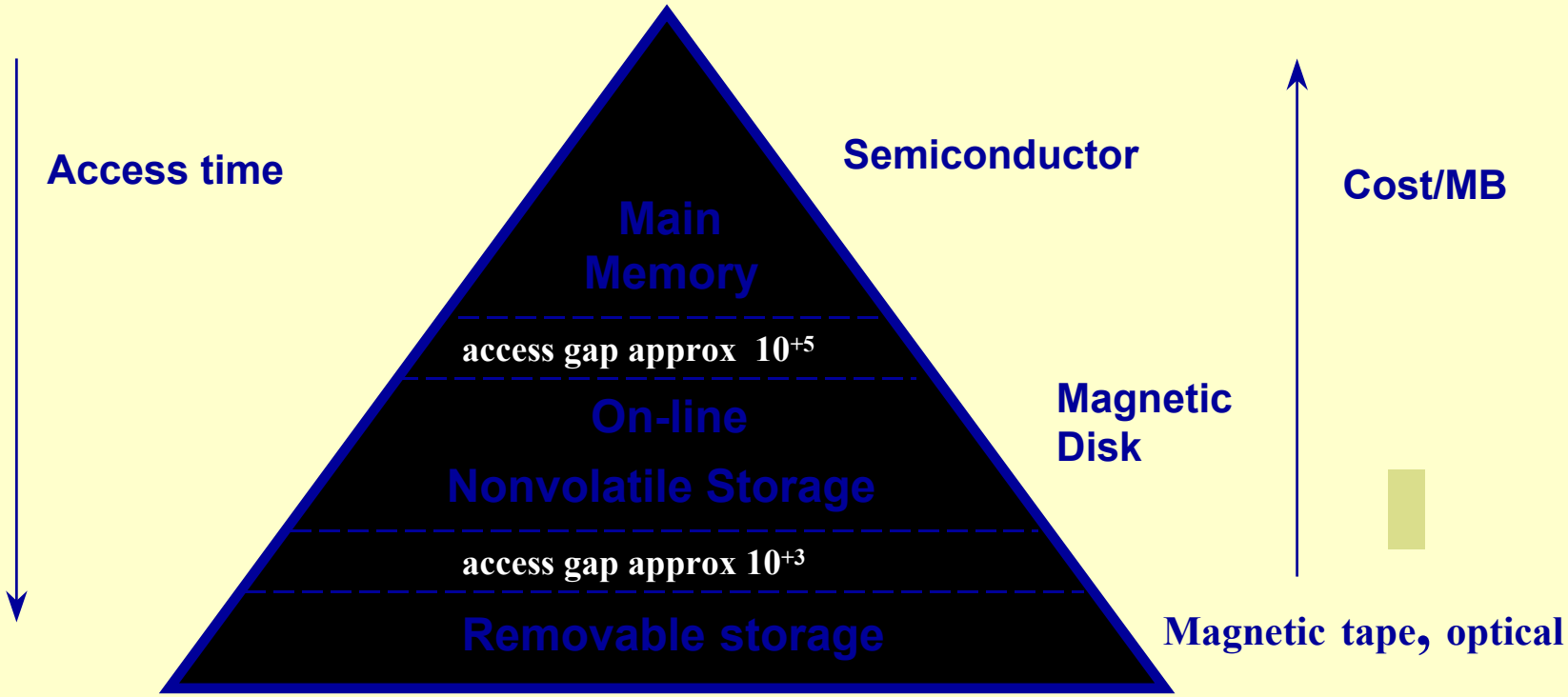


Magnetic Disk "Design Milestones"

- Rotating disk stack with cylindrical tracks and a head/arm assembly for track positioning (RAMAC) *
- Air bearing head per surface, dramatically reducing seek time (1301) *
- Head-track registration (for high tpi) using servo information from disk *
- Rotary actuator
- Multi-layer thin film magnetic media
- GMR head technology
- Sophisticated ("RAID") disk storage systems for 24/7 storage and retrieval of information that is instantly accessible from networks

* Projects initiated under Rey Johnson in downtown San Jose

Memory/Storage Hierarchy Computer Systems



Removable Storage & Archival Requirements?

- Computer systems primarily have magnetic tape for removable storage, although paper still used for human readable storage.
- The continuously lower costs of memory and magnetic disk storage leads to the upward percolation of data from removable to on-line storage
  - Removable storage forces backward compatibility and limits the rate of technological change that can be made.
    - Migration of data to more advanced media is costly and time consuming
- Assurance of retrieving archived information that is very infrequently accessed.?
  - Life of medium and read/write hardware?

Summing Up - "Today"

- Magnetic disk storage has taken over the role of providing the storage, retrieval and the world-wide distribution of information and knowledge in our society through the Internet (which is dependent on magnetic disk storage and data networks)
- The magnetic disk is rapidly being being used to store all "types" of information with a single medium
  - Replaced punched cards and now replacing film.

Epilogue

- The origin of magnetic disk data storage occurred in San Jose, at **99 Notre Dame**, with the **RAMAC,** developed at a small IBM Laboratory started in ***1952*** and led by **Rey Johnson.** The high-technology disk drive industry revolutionized information storage by enabling real-time on-line transaction processing.

Magnetic Disk Heritage Center

Santa Clara University

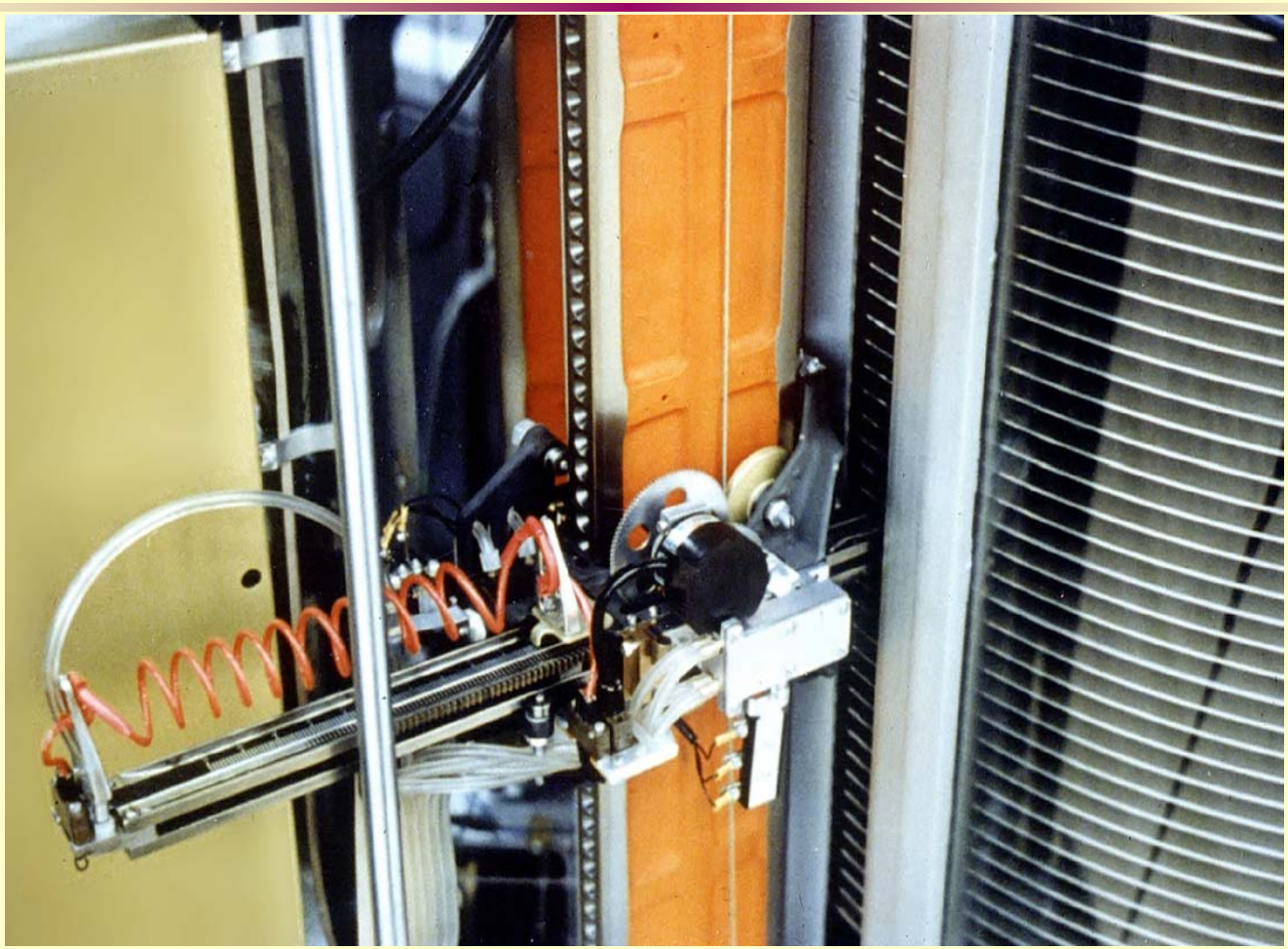
Mission: To Preserve the Historic Legacy of Magnetic Disk Storage

www.mdhc.scu.edu

99 Notre Dame, A City Landmark
2002 picture → 50th anniversary

The original building!

IBM RAMAC (Announced 1956)



Rey Johnson receiving the Medal of Technology from President Reagan (1986)

“Tomorrow” > Magnetic Disk (1)

- Magnetic disk storage will be around at least through this century.
  - Relative simplicity and elegance of technology and design
  - Performance tradeoff options that are superior to alternatives
  - Major technical advances still to be exploited
    - *If perpendicular magnetic recording (currently being aggressively pursued as next advance) is eventually adopted, the first prototype drive based on its use will be identified as led by Rey Johnson in downtown San Jose

Areal Density: Magnetic Recording 101

- **Scaling** applies with spacing key parameter
  - How close can you space without wear has been biggest uncertainty since the beginning in predicting future densities
- RAMAC spacing was 1 mil = 1000 micro-inches
  - Today's spacing is approximately ½ micro-inch or 2000 times closer.
- For today's spacing, based on RAMAC design (and signal processing techniques) and using a scaling factor of (2000x2000) times the RAMAC density of 2000 bits/in2, an areal density of 8 gigabits/in2 could have been predicted fifty years ago.

  Note: In my career I have seen a density increase of 100 million (800 bits/in2 on CALDIC to 100 gigabits/in2 on drives now in pipeline)

“Tomorrow” > Magnetic Disk (2)

- The magnetic disk drive has become a very low-cost commodity component
  - High volume, supply adjusts to demand
    - No significant proprietary limitations to market entry
    - Used in turn in commodity products
  - User value is associated with the stored content and supported applications

The Far Future