The History of Storage

Session 16140

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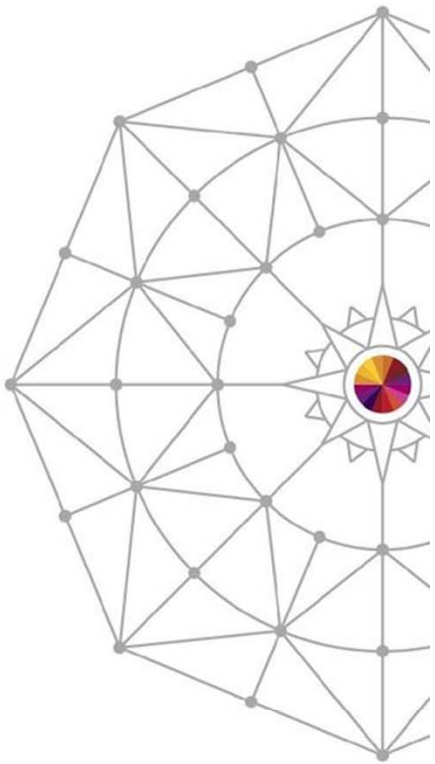

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And, In The Beginning…

March, 1956, RAMAC 305
4.4 MB usable capacity
1200 RPM
2150 pounds (975 Kilograms)
First disk drive to use vacuum tubes
Last disk drive to use vacuum tubes
AND
The fastest disk drive ever made!!

Wow, a 10MB Hard Drive

Much Progress has Been Made

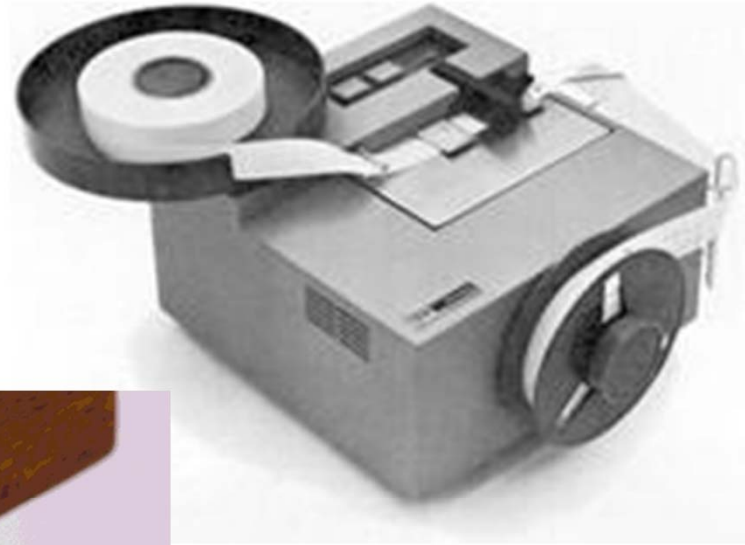
MEASUREMENT		Improvement by 2010
Aerial Density (sq. inch)		35,000,000x
Cost per capacity		27,600,000x
Volume capacity (cubic inch)		622,100,131x
Latency		8x
Seek Time		102x
Data Rate		11,719x

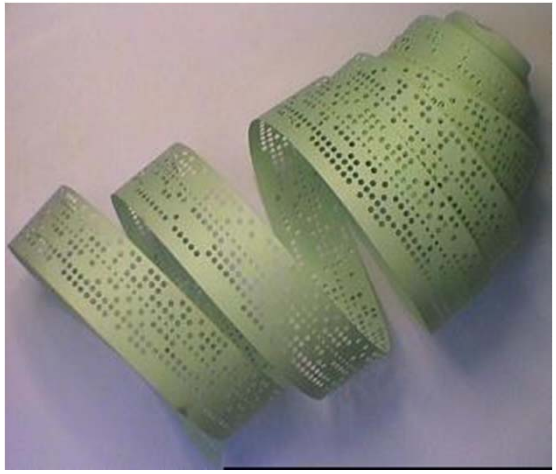
Seagate: With the transition to HAMR drives, we could* see 60TB drives within the decade

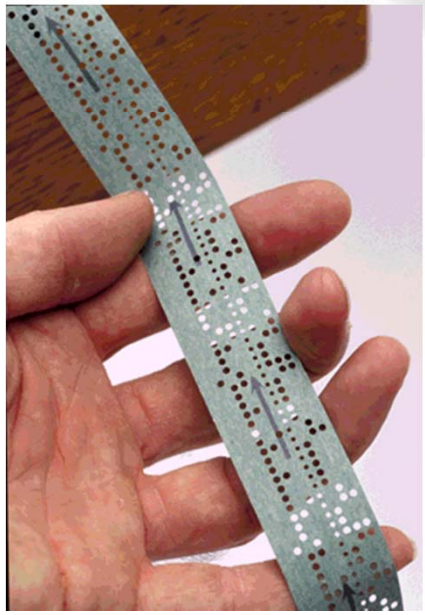
**** "could" comes with many caveats***

Early IBM Storage

- IBM 1055 Paper Tape Punch Machine
- IBM 1054 Paper Tape Reader
- IBM 1134 Paper Tape Reader

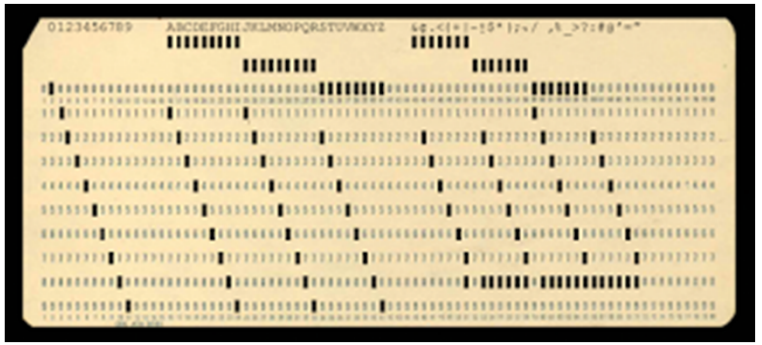


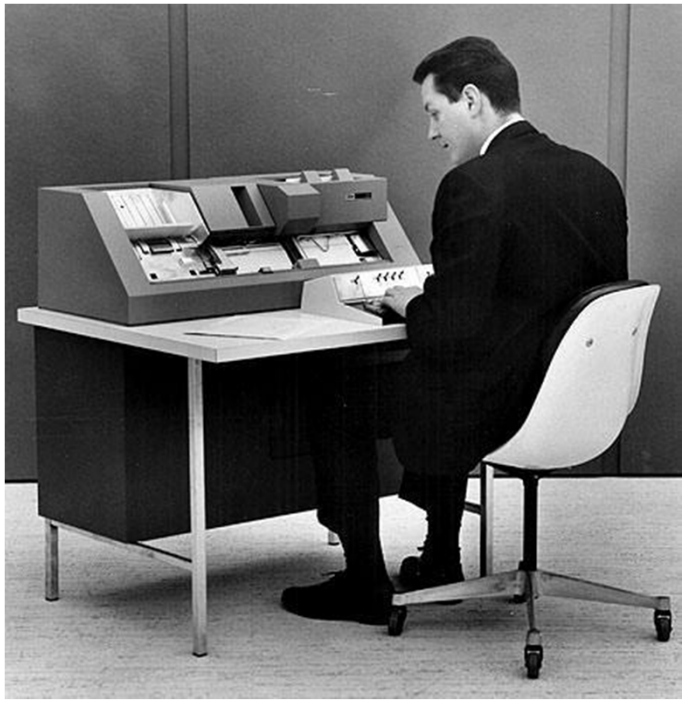




IBM Punch Cards

This stack of 62,500 punched cards, what was 5MB of data, held the control program for the giant SAGE military computer network





IBM Punch Card Equipment

IBM 026 Card Punch

IBM 083 Sorter

IBM 077 Collator

IBM 444 Tabulator

IBM 602 Calculation Punch

IBM 514 Duplicator

Accounting Operation Using IBM Punch Card Equipment

It's 1950 and these 11 men and women are operating an IBM electric accounting machine installation. On the left is an IBM 523 gang summary punch, which could process 100 cards a minute and in the middle is an IBM 82 high-speed sorter, which could process 650 punched cards a minute.

IBM NEWS SAN JOSE

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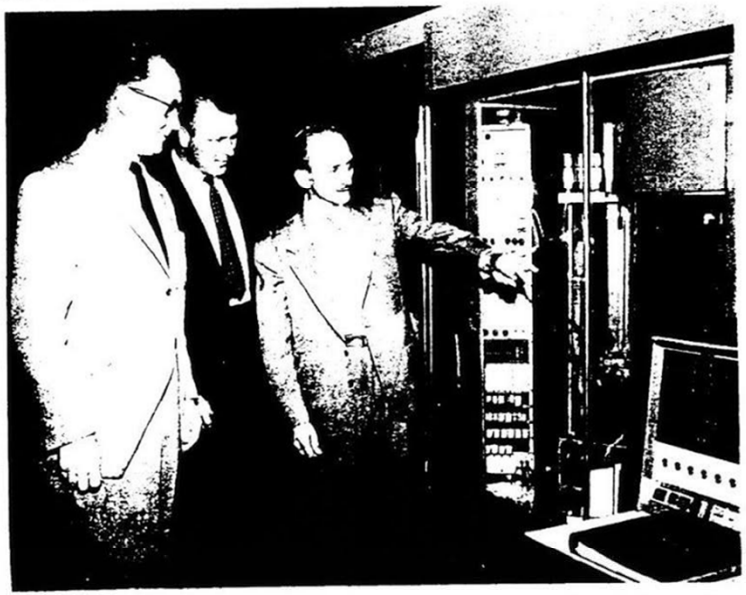
RAMAC Officially Announced

RAMAC Is First Major Achievement Of Mushrooming IBM San Jose Plant

Conceived and developed in the IBM San Jose Research and Development Laboratories, the huge electronic data processing machine equipped with the "juke box" memory file, known as RAMAC for Random Access Memory Accounting, was announced by press, radio and television September 14.

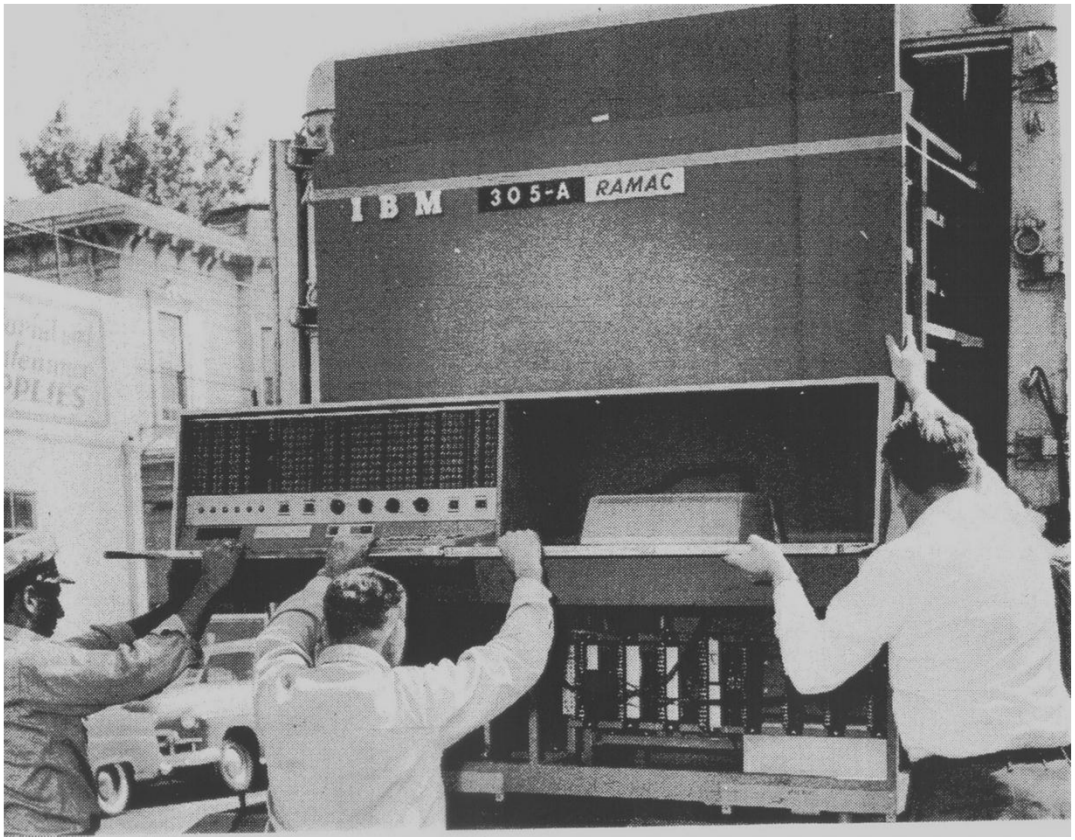
Hailed by President Thomas J. Watson, Jr., as "providing one of the most significant advancements toward business control and operation by electronics thus far," RAMAC is the result of four years of intensive research and development by upwards of 200 San Jose IBM engineers and technicians. In addition, scores of Product Planning, Test, Customer Engineering, CE School, Manufacturing and Sales personnel have collaborated to make the RAMAC electronic "brain" a reality.

RAMAC has spearheaded a tremendous growth for the IBM plant here in San Jose with several thousand persons expected to be employed at the new plant by 1960. Up-

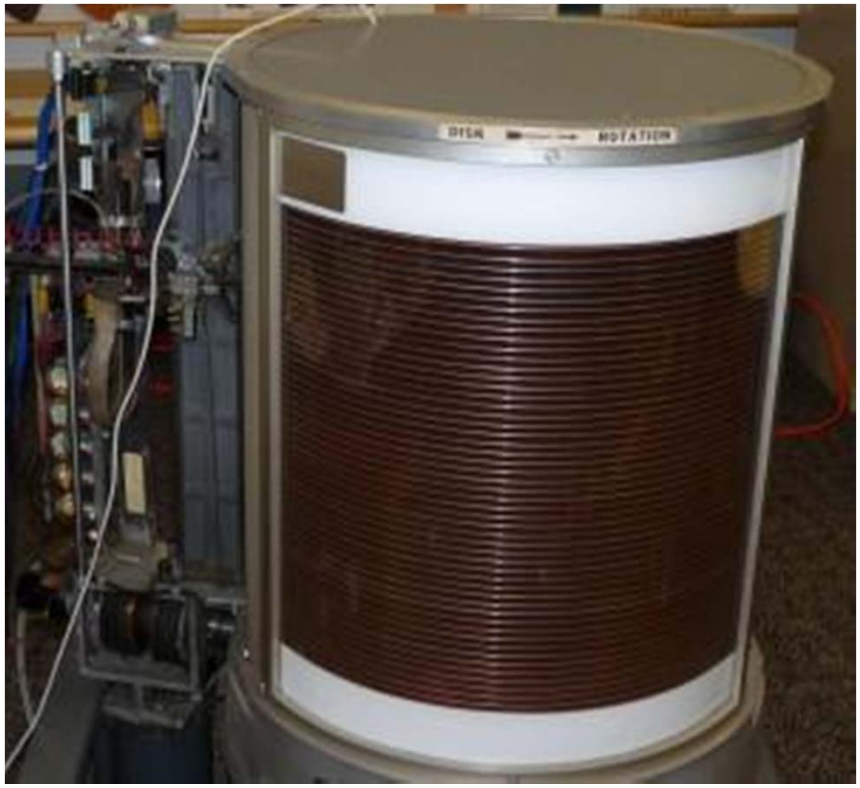


IBM's SAN JOSE BRAIN CHILD — Watching the operation of the random "juke box" memory device of the San Jose-born RAMAC are Reynold B. Johnson, left, manager of the Research Laboratory, who with his associates originated the idea of the disk file; L. D. Stevens, manager of Development Engineering, and J. D. Fernbach, Engineering Laboratory manager, who were responsible for the development and engineering of the much-publicized

IBM 305 RAMAC Being Shipped



IBM 305 RAMAC Specifications



- 5MB of storage
- Disk platters – 24” in diameter, 1” thick
- 50 coated aluminum disks (100 surfaces)
- 1,200 RPM’s
- 8,800 bytes transfer rate

Early History of IBM Disks for the Mainframe

- 1956 – 305A RAMAC (5MB/box, 24” disks)
- 1961 – IBM 1301 (25MB)
- 1962 – IBM 1311 (14” disk)
- 1964 – IBM 2311
- 1965 – IBM 2314 (29MB/drive, 4 drives/box, $890/MB)
- 1970 – IBM 3330-1 (200MB/box, $392/MB)
- 1973 – IBM 3330-11 (400MB/box, $279/MB)
- 1974 – IBM 3850 Mass Storage
- 1975 – IBM 3350 (635MB/box, $112/MB, non-removable)
- 1981 – IBM 3380 (2.5GB/box, $35/MB, 3MB/sec transfer rate)

IBM 1301 Disk Drive

- 25MB of storage per module
- 20 disks per module
- 1301 Model 1 had one module, the Model 2 had two modules
- 1,800 RPM's
- 90,000 bytes per second transfer rate

IBM 1311 Disk Drive

- 2MB of storage per disk pack
- 14” disk platters
- 1,500 RPM’s

IBM 2311 Disk Drive

- 7.25MB per disk pack
- 85ms average seek time
- 156KB per second data transfer rate
- 2311 Model 1 and 2 were used on the System/360 mainframes

IBM 2314 Disk Drives

- 29MB of storage per disk pack
- 14” disk platters
- 310KB data transfer rate
- 2314 Model A and B

IBM 3330 Disk Drive

Each 3330 subsystem could have from two to 16 drives, giving users fast access up to 1.6GB of online storage.

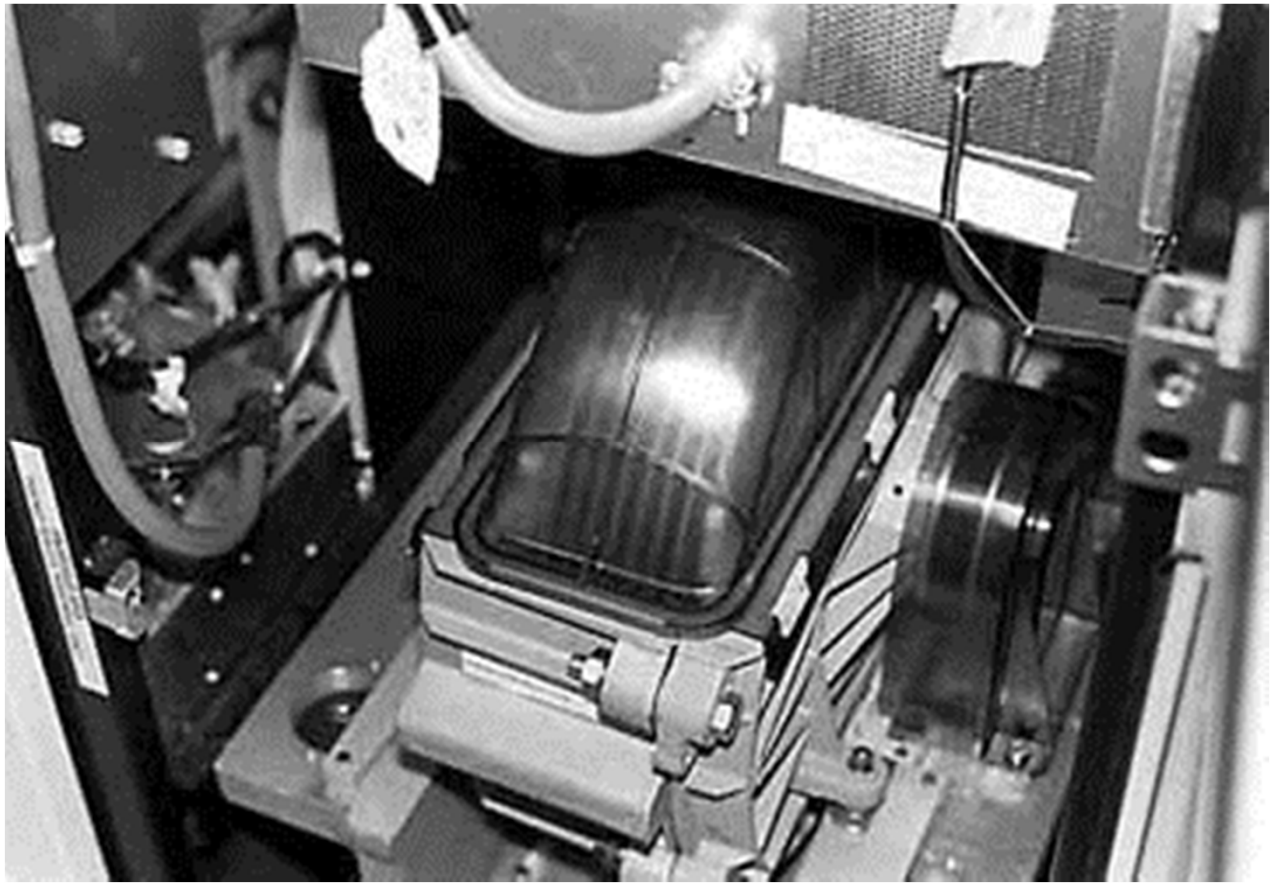
Average access time was 30ms, and the data transfer rate was 806KB/sec.

3350 Disk Drives

- 317.5MB per drive
- 1,198KB/sec data transfer rate
- 25ms average seek time
- 8.4ms average rotational delay

- 19,069 bytes per track
- 30 tracks per cylinder
- 555 cylinders per volume

3350 Head Disk Assembly

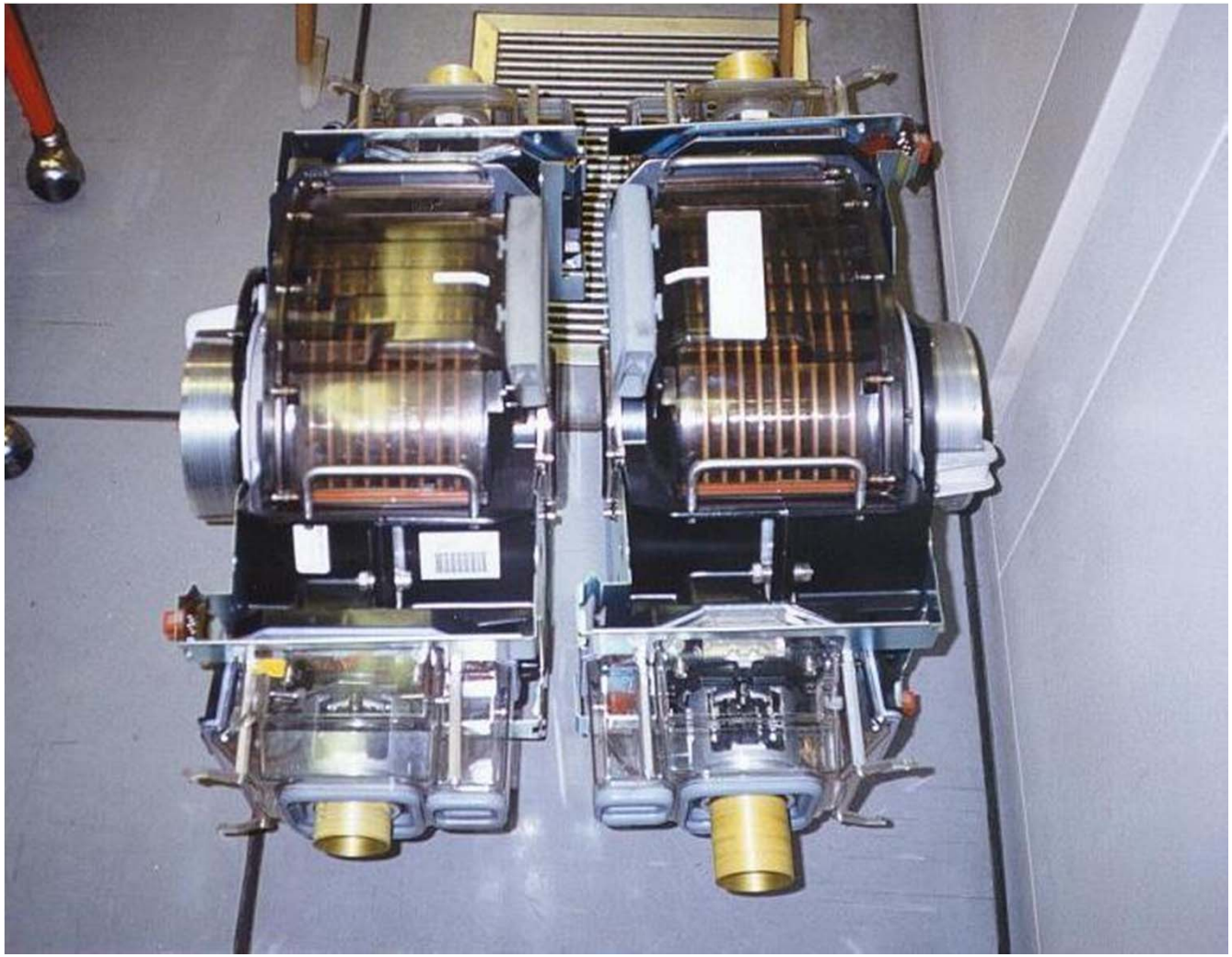


History of Mainframe Disks in the 1980's

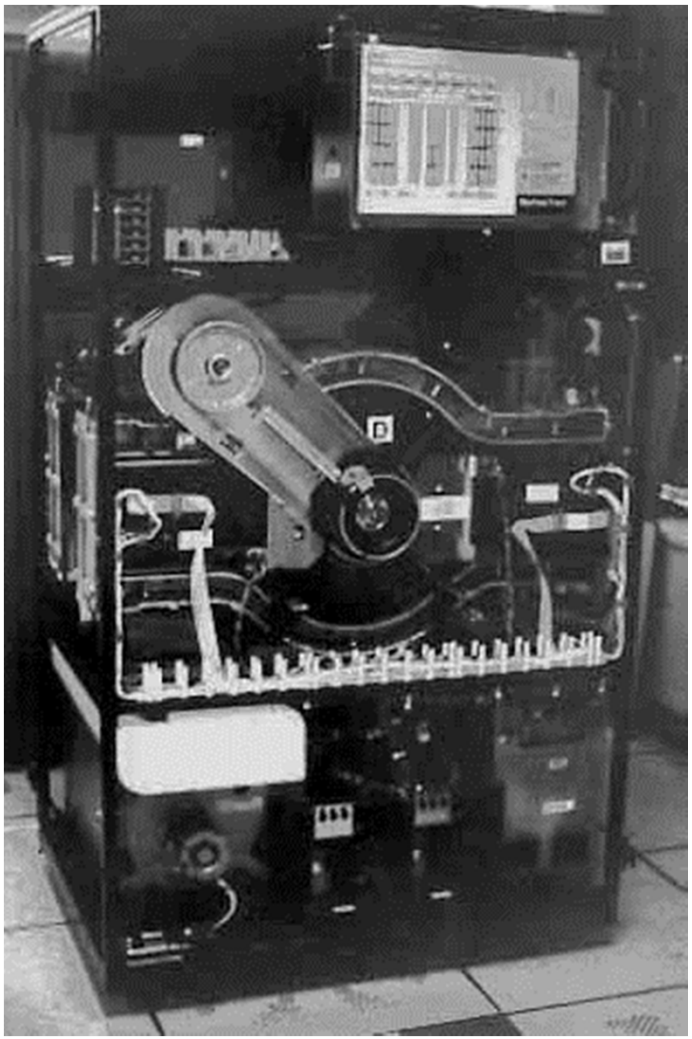
- 1980 – IBM 3380 Models A4, A4F, AA4, AAF, B4 and BF4
- 1982 – IBM 3880 Models AD4, BD4, AE4 and BE4 & controllers with 8MB cache
- 1982 – AMD 6880 controller & 6280 disk (1.2GB disks)
- 1984 – AMD 6380 (2.5GB/box)
- 1985 – IBM 3380D/E ($33.97/MB & $26.10/MB)
- 1986 – AMD 6380/E
- 1986 – AMD 6680 EDAS (64 - 256 MB)
- 1987 – IBM 3380J/K (7.5GB/box, $17/MB)
- 1987 – IBM 3880 transfer rate increases to 4.5MB/sec
- 1988 – IBM 3990 controller
- 1988 – AMD 6100 controller (512MB cache)
- 1989 – IBM 3390 (1.89GB/disk, 22.7GB/box, 10.5" disks, 4.2GB/sec transfer from disk to controller, $12.12/MB)

IBM 3380 Disk with 3880 Controller

3380 Head Disk Assembly



IBM 3380 with the Covers Off



History of Mainframe Disks from 1990 - 1993

- 1990 – HDS 6587 (35.4GB/box)
- 1990 – EMC Symmetrix 4200 (24GB RAID storage, 256MB cache)
- 1991 – IBM 3995 Optical Disk
- 1991 – ESCON Channels (17MB/sec)
- 1992 – IBM 3390-3 (2.83GB/disk, 34GB/box, $9.92/MB)
- 1992 – STK 9200 “Iceberg” is announced (virtual storage)
- 1992 – HDS 7390-3
- 1993 – IBM 3990-6 controller
- 1993 – IBM 3390-9 (8.51 GB/drive)
- 1993 – HDS 7693 (3390-3 equivalent)

History of Mainframe Disks from 1994 - 2000

- 1994 – HDS 7699 (3390-9 equivalent)
- 1994 – AMD 6395-9 (3390-9 equivalent)
- 1994 – STK 9200 “Iceberg” becomes GA
- 1994 – IBM RAMAC-1 (9337, 5.25” disks)
- 1994 – EMC Symmetrix 5500
- 1995 – IBM RAMAC-2 9337
- 1996 – IBM RAMAC-3 9337 (45 – 726 GB subsystems)
- 1996 – HDS 7600
- 1997 – IBM RAMAC Virtual Array (remarketing of STK 9200)
- 1998 – HDS 7700E
- 1999 – IBM 2105 “Shark”
- 2000 – HDS Lightening 9900

Physical DASD Characteristics for CKD Devices

Disk Type	Data cylinders	Alternate cylinders	Tracks per cylinder	Bytes per track	Bytes per cylinder
2305-1	48	6	8	14,136	113,088
2305-2	96	12	8	14,660	117,280
2311	200	2	10	3,625	36,250
2314	200	3	20	7,294	145,880
3330-1	404	7	19	13,030	247,570
3330-11	808	7	19	13,030	247,570
3340-35	348	1	12	8,368	100,416
3340-70	696	2	12	8,368	100,416
3350	555	5	30	19,069	572,070
3375	959	1	12	35,616	427,392
3380 A/B/D/J	885	1	15	47,476	712,140
3380 E	1,770	2	15	47,476	712,140
3380 K	2,655	3	15	47,476	712,140
EMC338O K+	3,339	3	15	47,476	712,140
EMC338O K+ +	3,993	3	15	47,476	712,140
3390-1	1,113	1	15	56,664	849,960
3390-2	2,226	1	15	56,664	849,960
3390-3	3,339	1	15	56,664	849,960
3390-9	10,017	3	15	56,664	849,960

Tape Storage History

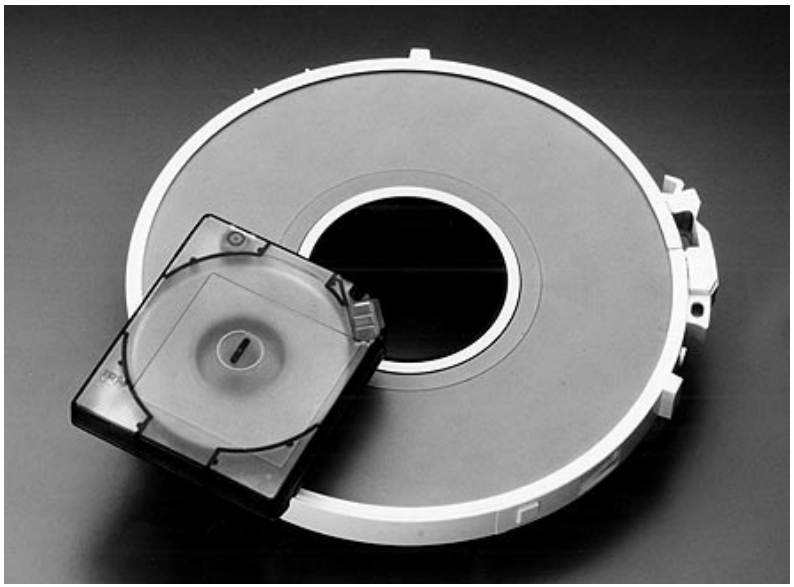
Available	Media Type	Capacity	Transfer Rate	Length	Tracks
1970	3420-3,5,7	42 MB	60 – 160 KB/s	2,400	6
1973	3420-4,6,8	150 MB	47KB/s - 1.25MB/s	2,400	9
1984	3480	200 MB	3.0 MB/s	550	18
1989	3490	200 MB	3.0 MB/s	550	18
1991	3490E	400 MB	3.0 – 4.5 MB/s	550	36
1992	3490E	800 MB	3.0 – 4.5 MB/s	1,100	36
1995	3590	10 GB	9.0 MB/s	1,100	128
1998	9840	20 GB	10.0 MB/s	900	288
1999	3590E	20/40/60 GB	14.0 MB/s	2,070	256

IBM 3420 Tape Drives

- First 3420 tape drives recorded data on 9 tracks at 800 bpi and 1,600 bpi
- Next generation 3420 tape drives recorded at 6,250 bpi

3420 Tape Library

IBM 3420 to 3480 Conversion



- Closed cartridge design
- More compact media (4”x5”x1” in size)
- Recording media used chromium dioxide
- Initial 3480 cartridges could hold 200MB of data
- IDRC provided the capability to store 400MB of data
- 3490E cartridges could store 800MB of data

3480 Tape Drives

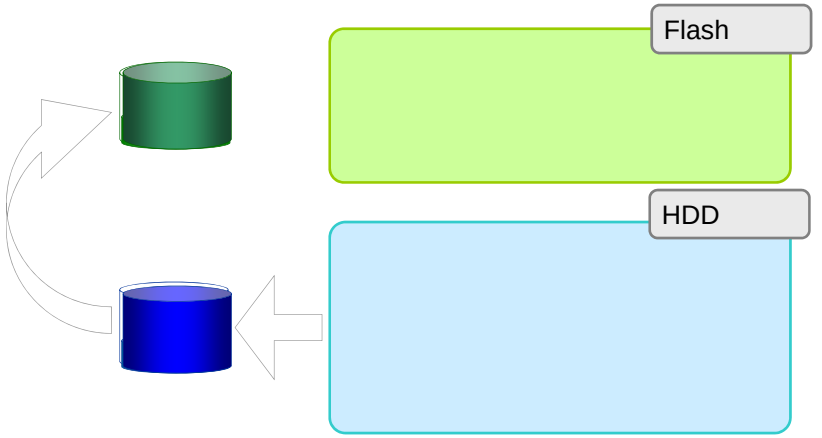
IBM 3590 and 3590E Tape Cartridges

- Native capacities were 10GB/20GB, 20GB/40GB or 30GB/60GB

Flash Disks

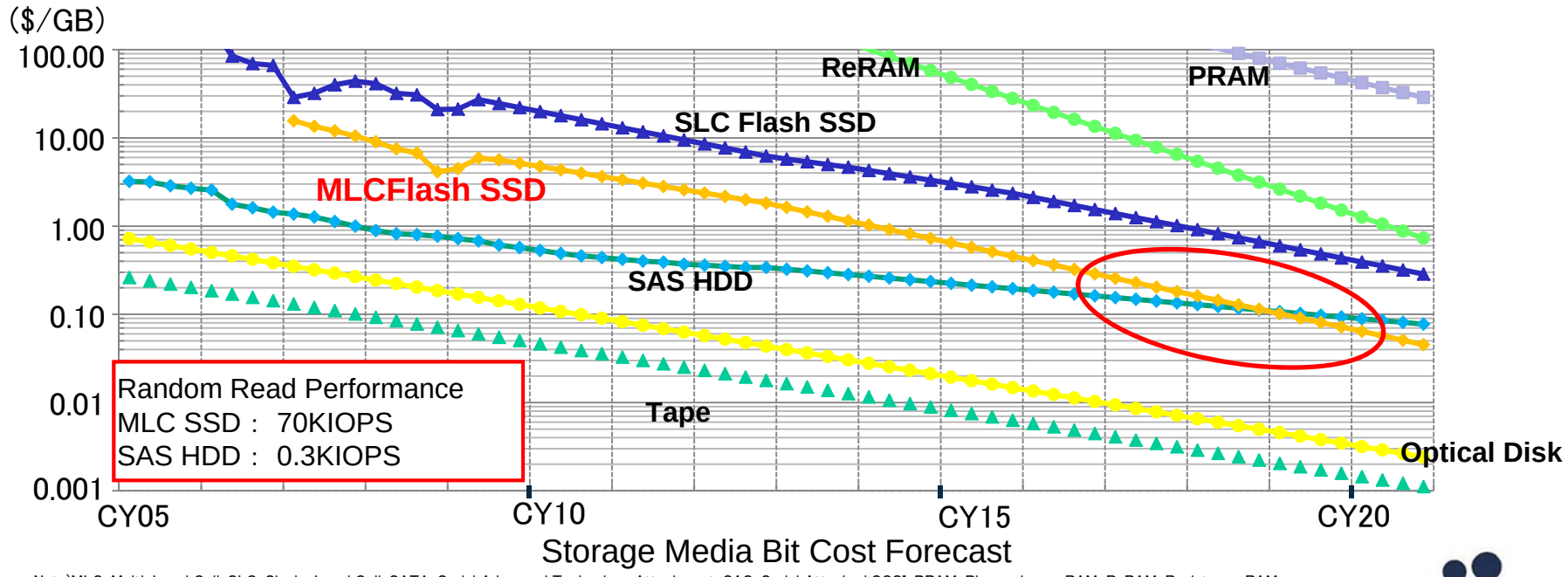
- Very High Performance for Critical applications
  - 70x random reads, 14x random writes
- 50% reduction in power and cooling
- Enterprise SLC Flash has 100,000 Write/Format cycles
  - Wear leveling, error recovery, spares
- Currently higher cost than HDD

- Optimize use of Flash with dynamic tiering
- Eliminate waste of allocated unused Flash capacity with Dynamic Provisioning
- But how much data benefits?



Flash Media Technology Trends

- Volumes in the consumer market will continue to drive down MLC Flash prices
- The durability of MLC will be a concern for the enterprise market
- Durability of MLC can be managed with wear leveling, aggressive sparing, and consolidating writes



Note)MLC: Multi-Level Cell, SLC: Single-Level Cell, SATA: Serial Advanced Technology Attachment, SAS: Serial Attached SCSI, PRAM: Phase change RAM, ReRAM: Resistance RAM

Intelligent Storage – Changing the Landscape

- **Prior to 1992, storage was a commodity**
  - **Pack 14-inch disk packs in a box and sell them to customers**
  - **Vendors (HDS, IBM, and EMC) tried to compete on performance, reliability, and price. Customers heard price, price, and price**
- **1992 brought Concurrent Copy, the first intelligent function to storage controllers**
  - **This was pre-RAID**
  - **New functionality brought never before heard software licenses and required professional services**
  - **From there, years of additional functionality, networked storage, and quickly, no one knew what storage actually cost.**
  - **And with todays capacity efficiency products, what's a terabyte?**

Some More Background…

- Early 1980's
  - Largely distributed and departmental systems
  - DASD utilization rates were very, VERY low, generally < 10%
  - DASD was running about $15/MB, or
    - $15,000/GB or $15,000,000 a TB
    - Anyone wanna petabyte?
- Motivation to develop System Managed Storage from 2 sources
  - Road Warriors spreading the gospel of data management and consolidation
    - Best practices and utilities
    - Consolidation of departmental systems
    - Increase utilization rate
  - "Ivory Tower"
    - Designated to rewrite the MVS device code
    - Focus on Automation
    - Address the Access Density problem
  - Result? Ivory Tower, meet the Road Warriors….and thousands of bar napkins later, SMS was born!!!

Much Progress has been made, meaning….If the aircraft industry had progressed as fast as the storage industry…

- Assume a 787 Dreamliner were flying in 1956 (OK, let's go for the DC7), if a DC7, flying in 1956, carried 120 passengers, and was traveling at 360 mph, if compared to the storage industry, it would be today (if there are any DC7's left in the world) be:
  - Traveling at 4.3 million MPH, and
  - Would be carrying 74.5 TRILLION passengers.
  - And their ticket price would be .000018 cents, all 74 trillion of them

- Is that progress, or what!!! GO STORAGE!!!

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