# Lecture 26: Input/Output—Beyond Disk Arrays: Automated Data Libraries

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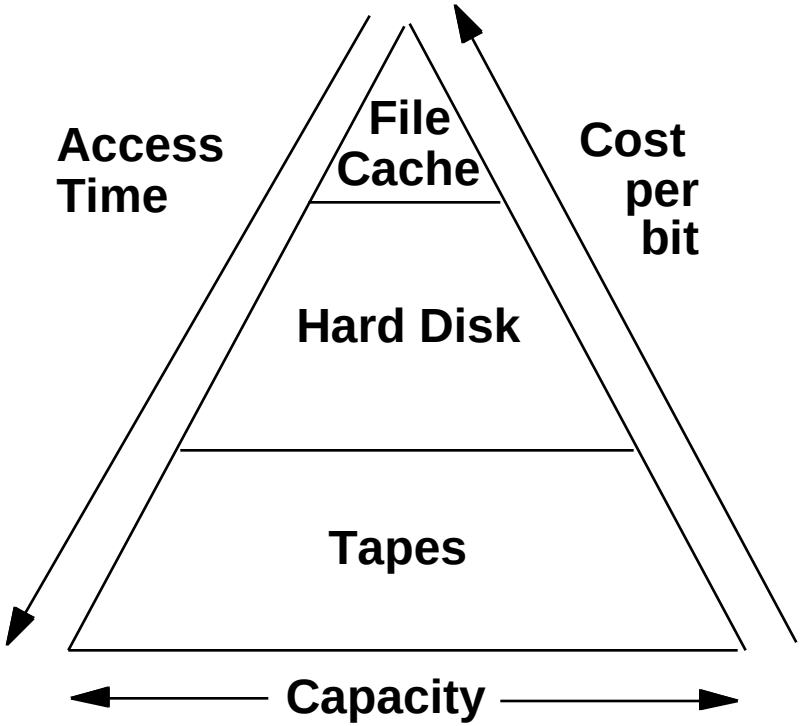
**Computer Science 252**

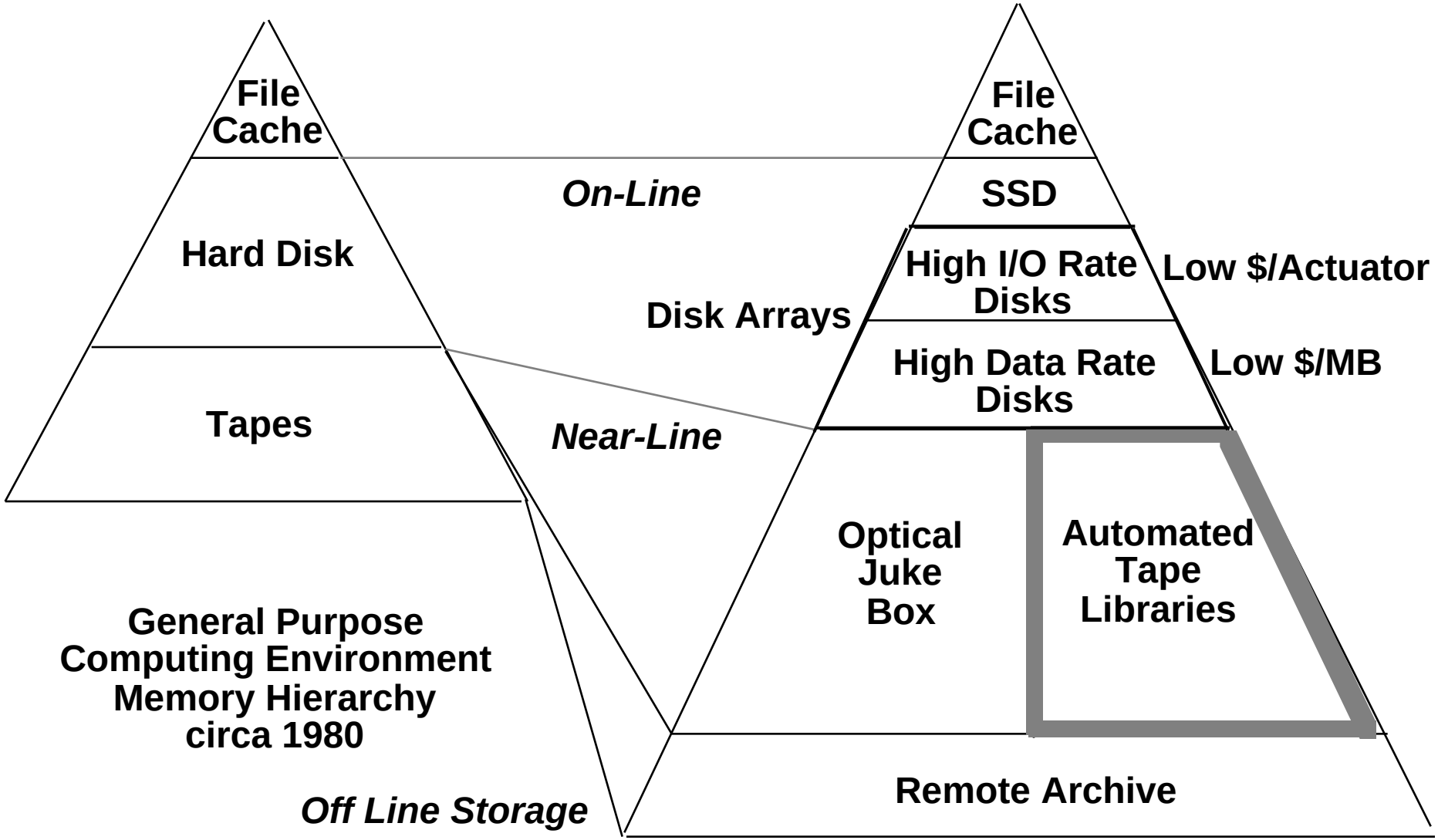
**Spring 1996**

# Memory Hierarchies



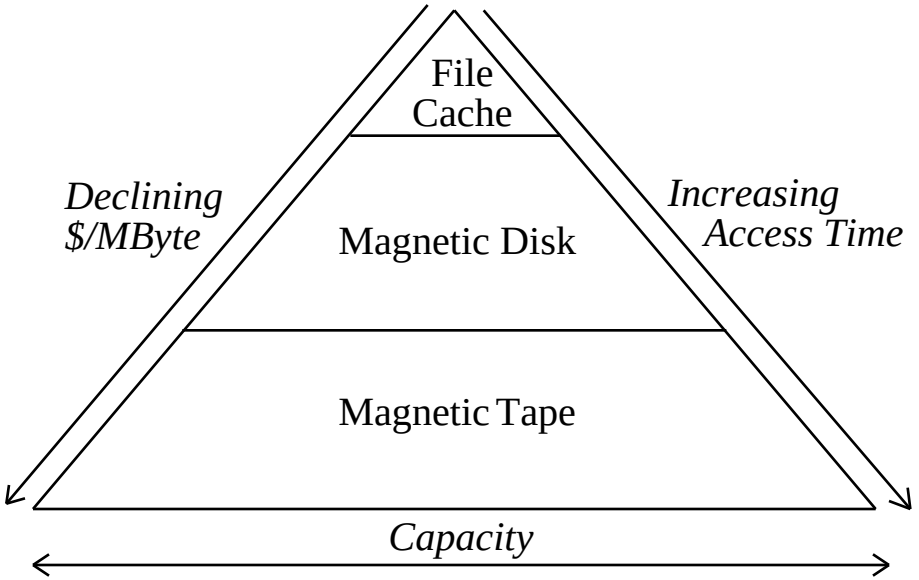

**General Purpose
Computing Environment
Memory Hierarchy
circa 1980**

# Memory Hierarchies

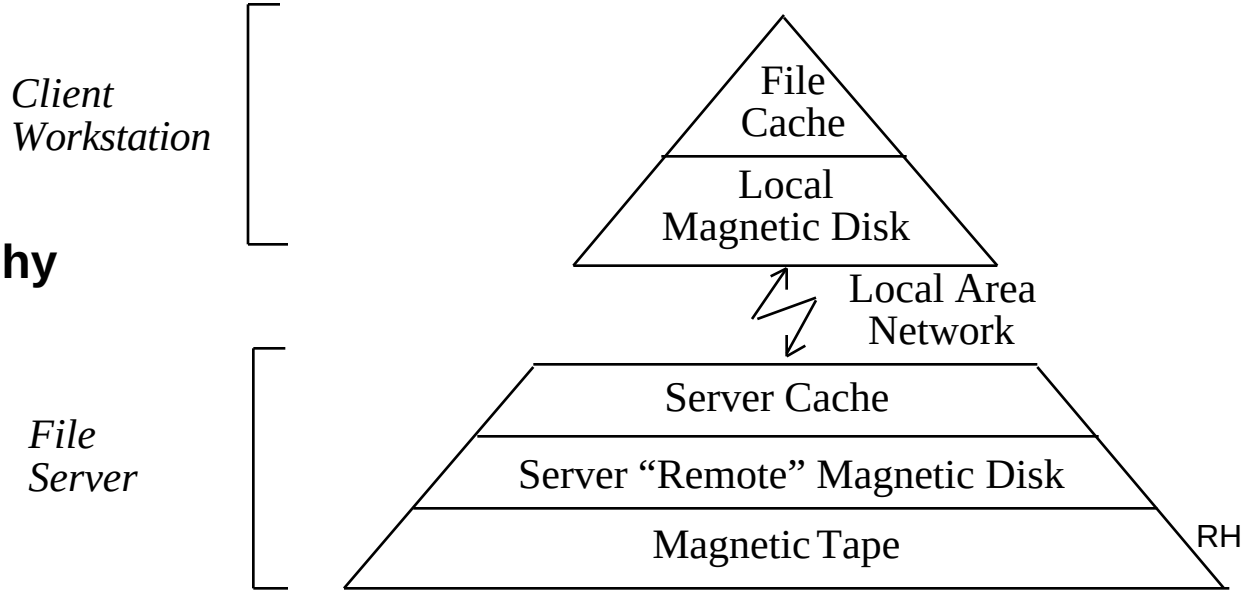


# Storage Trends: Distributed Storage

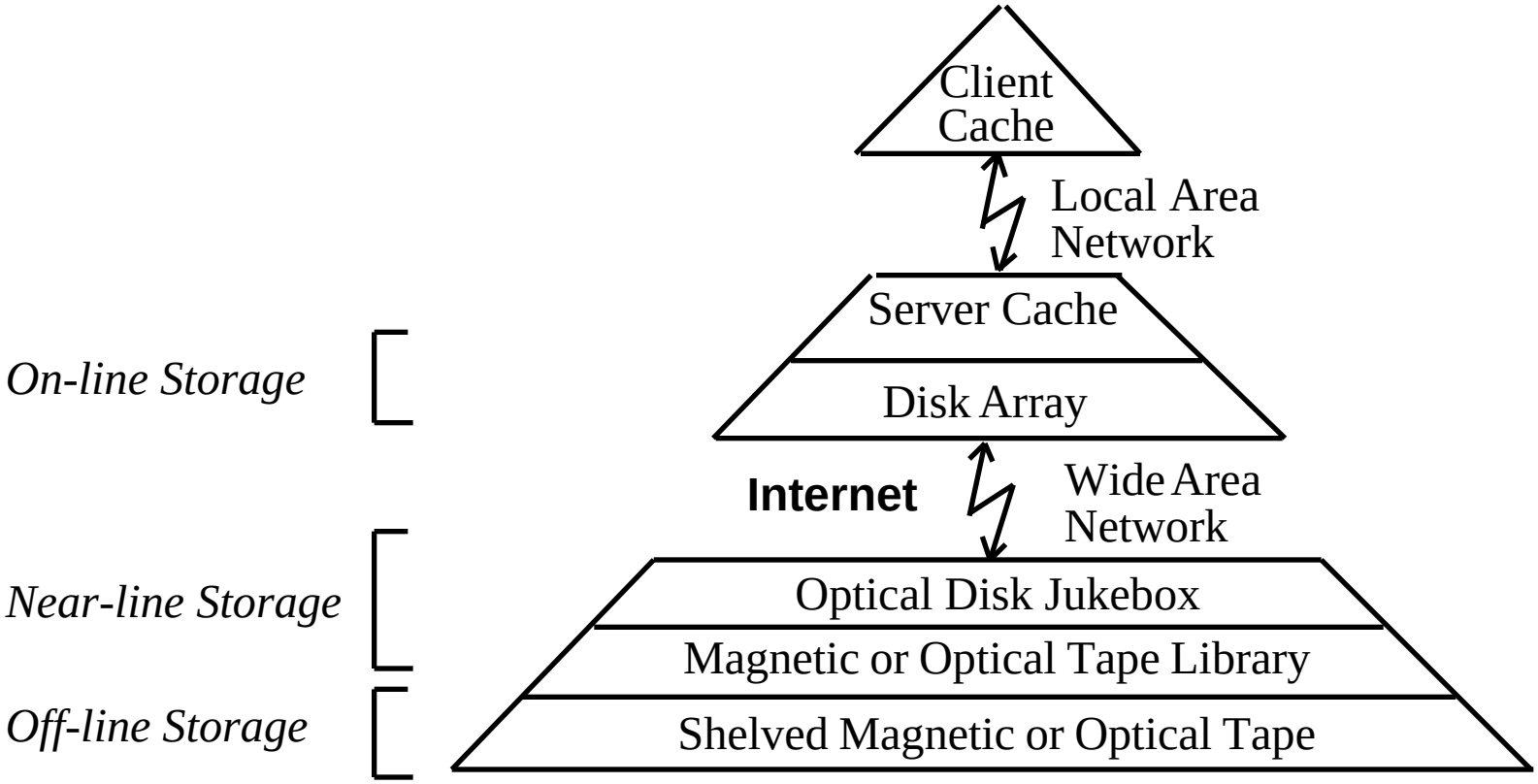
**Storage Hierarchy circa 1980**




**Storage Hierarchy circa 1990**



# Storage Trends: Wide-Area Storage




**Typical Storage Hierarchy, circa 1995**

**Conventional disks replaced by disk arrays**

**Near-line storage emerges between disk and tape**

# What's All This About Tape?

**Tape is used for:**

- **Backup Storage for Hard Disk Data**

  **Written once, very infrequently (hopefully never!) read**

- **Software Distribution**

  **Written once, read once**

- **Data Interchange**

  **Written once, read once**

- **File Retrieval**

  **Written/Rewritten, files occasionally read**

  **Near Line Archive**

  **Electronic Image Management**

***Relatively New Application For Tape***

# Alternative Data Storage Technologies

| Technology | Cap (MB) | BPI | TPI | BPI*TPI | Data Xfer (Million) | Data Xfer (KByte/s) | Access Time | |
|---|---|---|---|---|---|---|---|---|
| **Conventional Tape:** | | | | | | | | |
| Reel-to-Reel (.5") | | | 140 | 6250 | 18 | 0.11 | 549 | minutes |
| Cartridge (.25") | 150 | | 12000 | 104 | 1.25 | 92 | minutes | |
| **Helical Scan Tape:** | | | | | | | | |
| VHS (.5") | 2500 | | 17435 | 650 | 11.33 | 120 | minutes | |
| Video (8mm)* | 2300 | | 43200 | 819 | 35.28 | 246 | minutes | |
| DAT (4mm)** | 1300 | | 61000 | 1870 | 114.07 | 183 | 20 seconds | |
| **Disk:** | | | | | | | | |
| Hard Disk (5.25") | | | 760 | 30552 | 1667 | 50.94 | 1373 | 20 ms |
| Floppy Disk (3.5") | | | 2 | 17434 | 135 | 2.35 | 92 | 1 second |
| CD ROM (3.5") | | | 540 | 27600 | 15875 | 438.15 | 183 | 1 second |

* Second Generation 8mm: 5000 MB, 500KB/s
** Second Generation 4mm: 10000 GB

# R-DAT Technology

***Two Competing Standards***

## DDS (HP, Sony)

- **22 frames/group**
- **1870 tpi**
- **Optimized for serial writes**

## DataDAT (Hitachi, Matsushita, Sharp)

- **Two modes: streaming (like DDS) and update in place**
- **Update in place sacrifices xfer rate and capacity**

  **Spare data groups, intergroup gaps, preformatted tapes**

# R-DAT Technology

## Advantages:

- Small Formfactor, easy handling/loading
- 200X speed search on index fields (40 sec. max, 20 sec. avg.)
- 1000X physical positioning (8 sec. max, 4 sec. avg.)
- Inexpensive media ($10/GBytes)
- Volumetric Efficiency: 1 GB in 2.5 cu. in; 1 TB in 1 cu. ft.

## Disadvantages:

- Two incompatible standards (DDS, DataDAT)
- Slow XFER rate
- Lower capacity vs. 8mm tape
- Small bit size (13 x 0.4 sq. micron) effect on archive stability

# RDAT Technical Challenges

## *Tape Capacity*

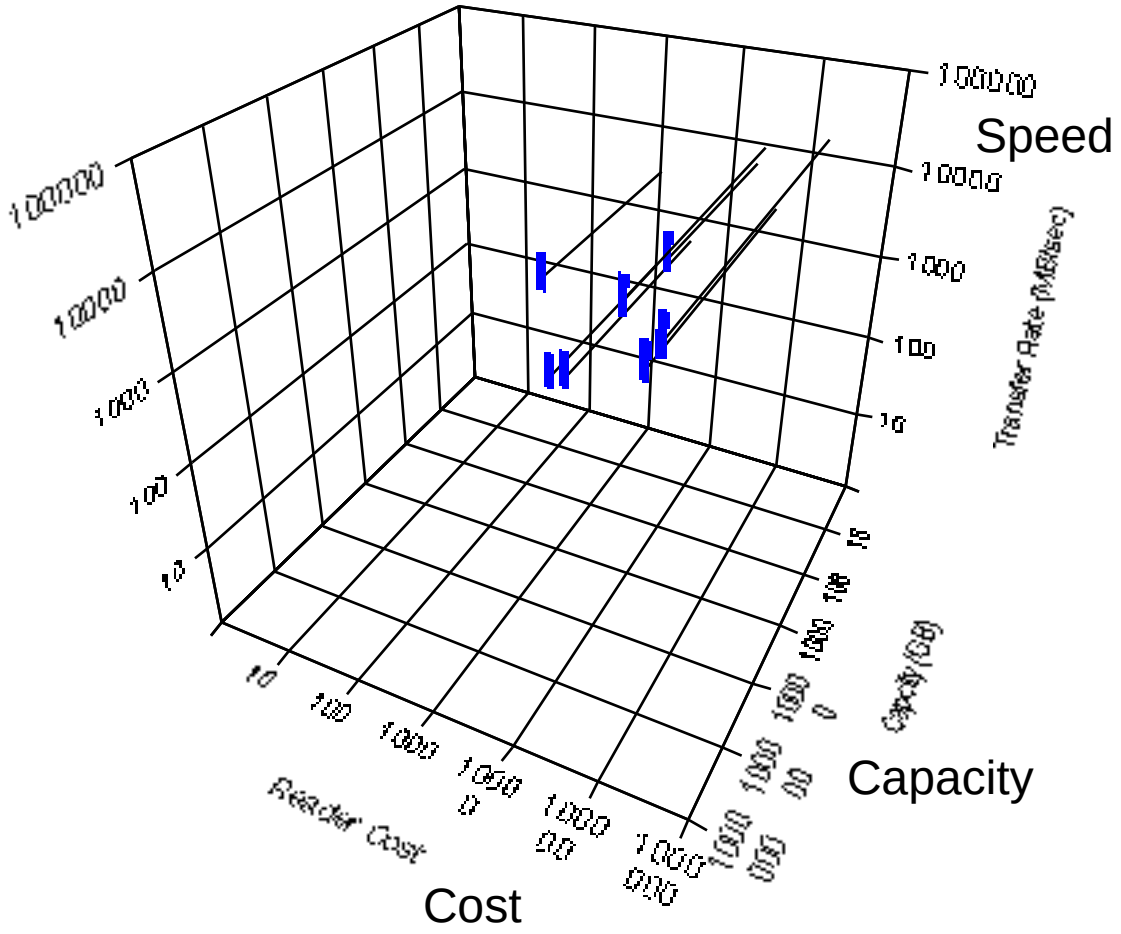
- **Data Compression is key**

## *Tape Bandwidth*

- **Data Compression**
- **Striped Tape**

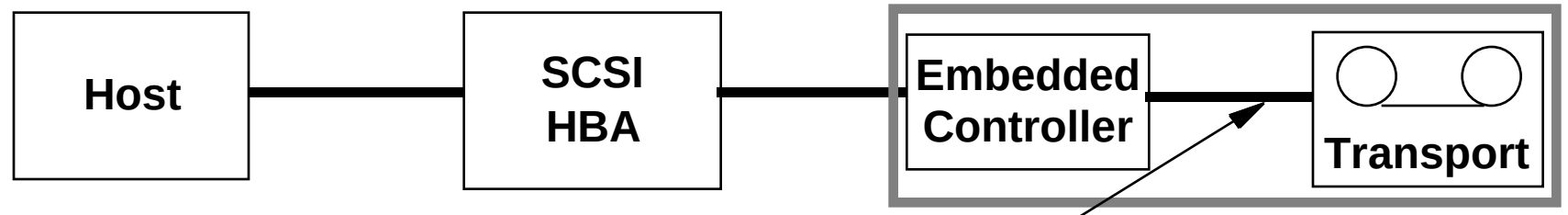
# MSS Tape: No “Perfect” Tape Drive

- **Best 2 out of 3 Cost, Size, Speed**
- **Expensive (Fast & big)**
- **Cheap (Slow & big)**



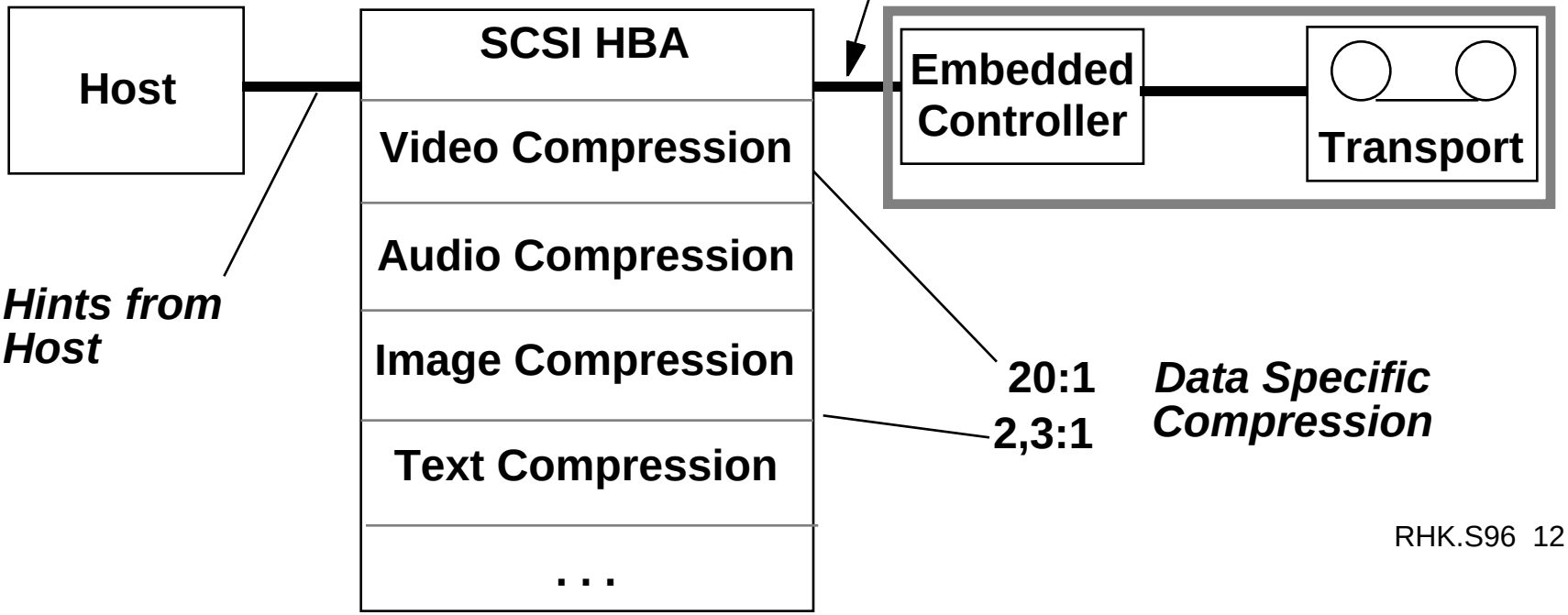
# Data Compression Issues

**Peripheral Manufacturer Approach:**

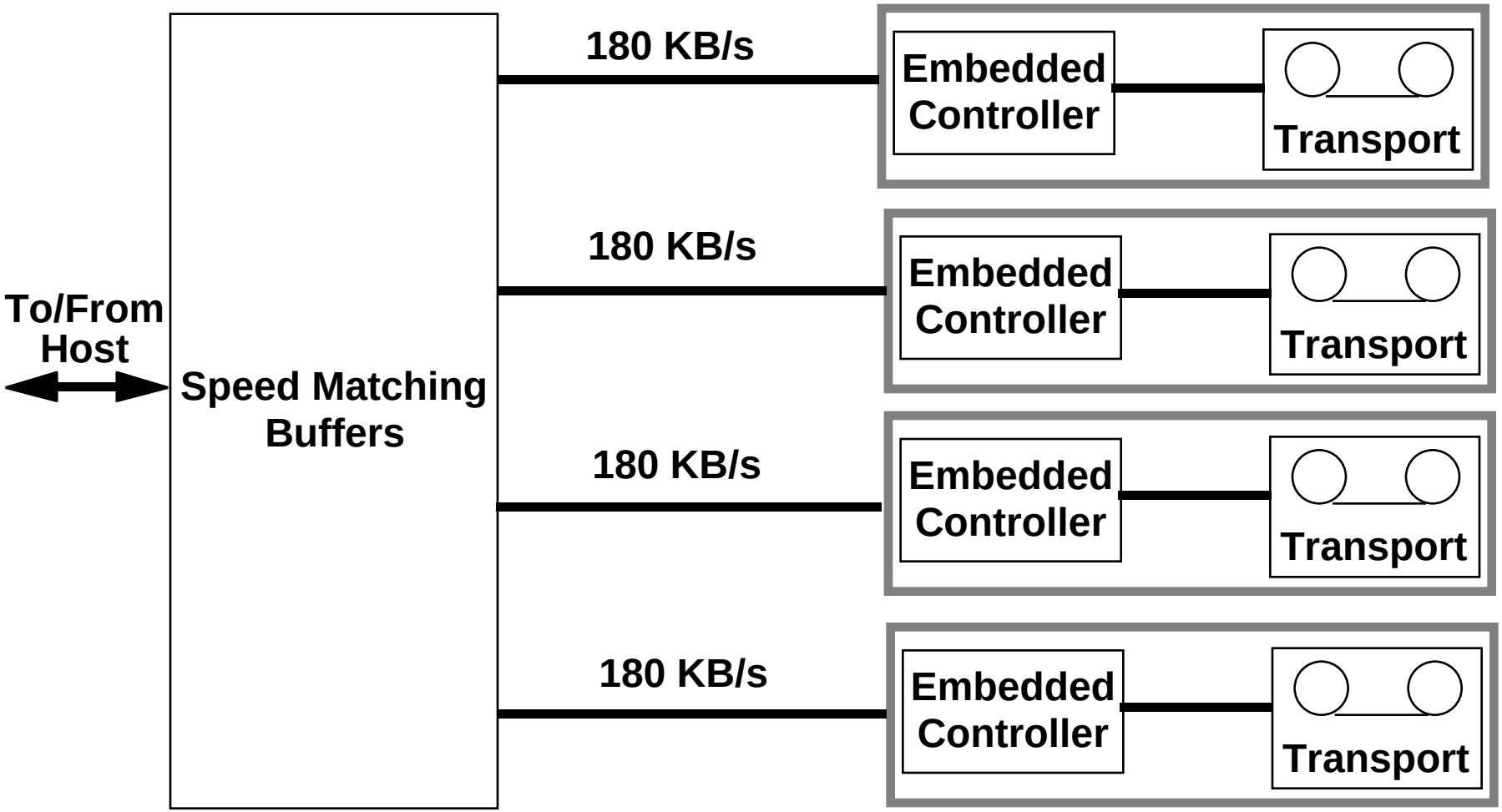



***Compression Done Here***

**System Approach:**



# Striped Tape

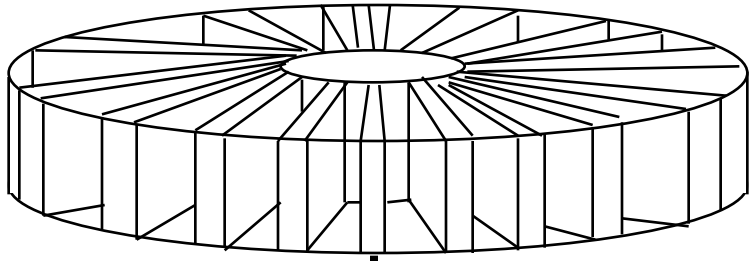



## Challenges:

- Difficult to logically synchronize tape drives
- Unpredictable write times

  R after W verify, Error Correction Schemes, N Group Writing, Etc.

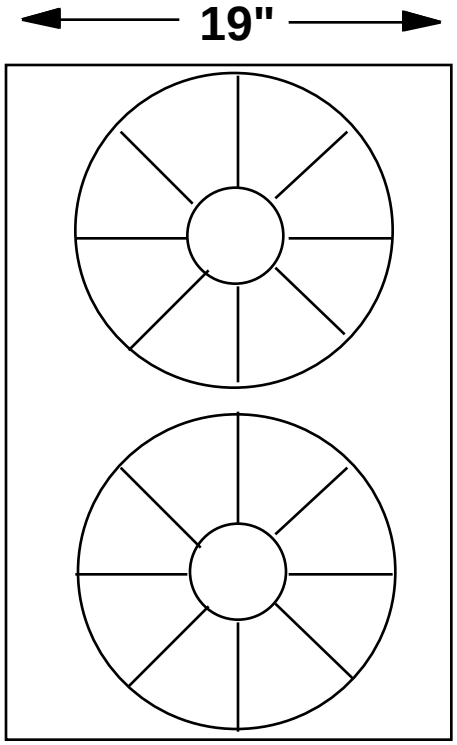
# Automated Media Handling



Tape Carousels

Gravity Feed

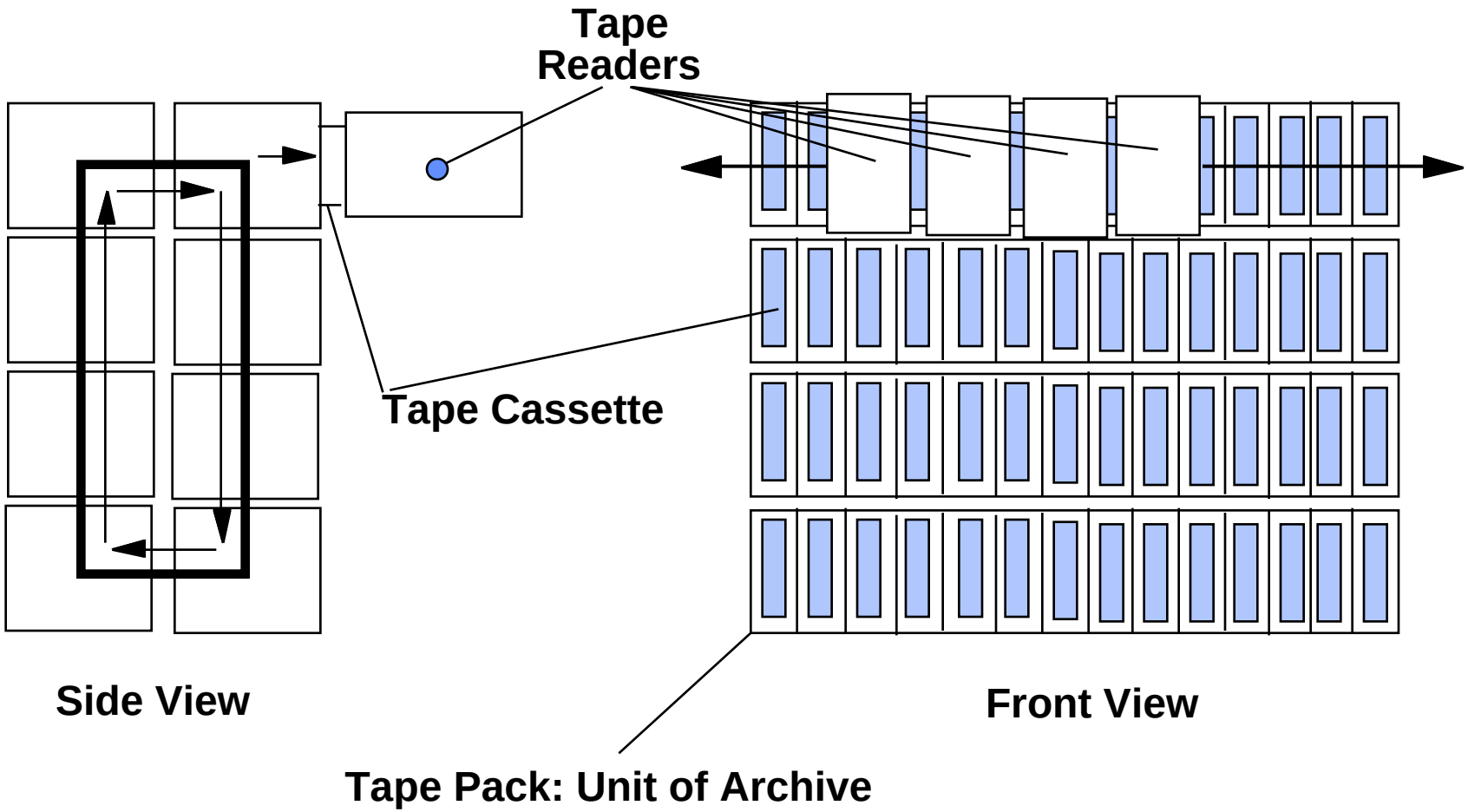
3.5" formfactor tape reader




Carousel

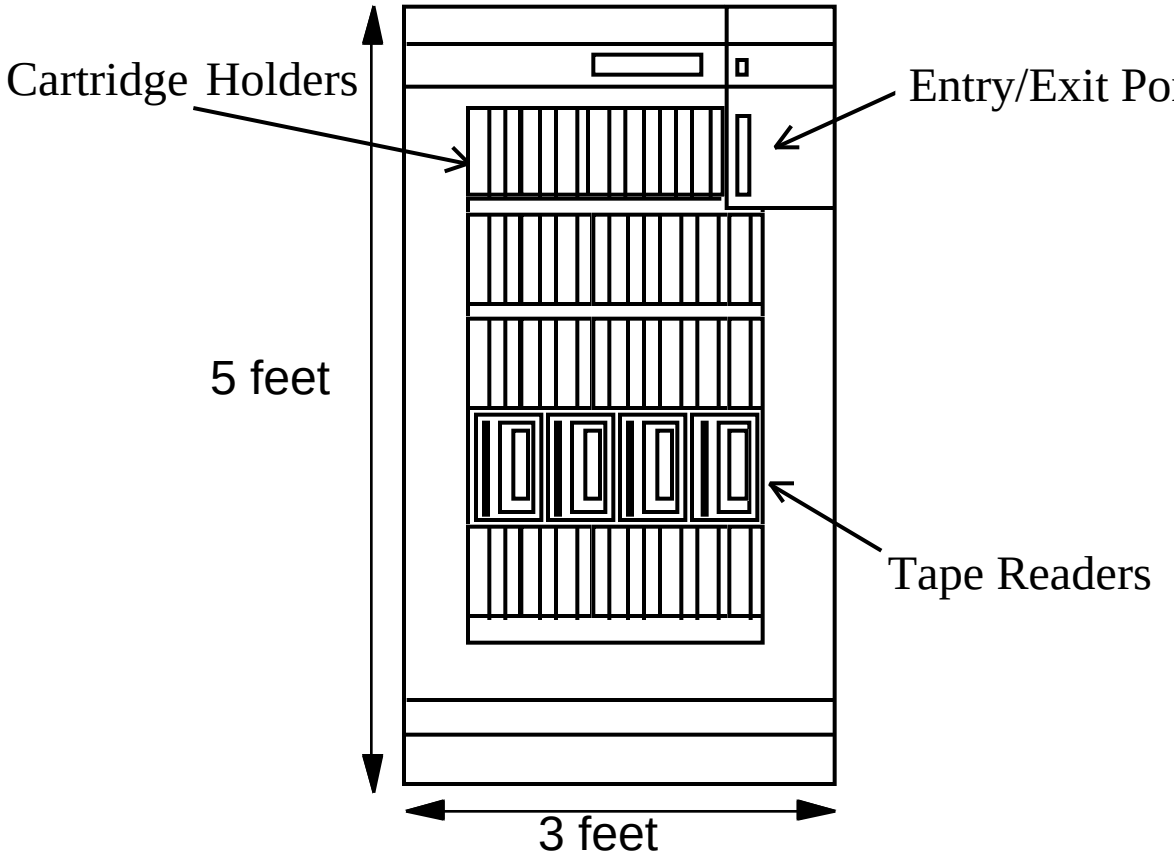
4mm Tape Reader

# Automated Media Handling



# MSS: Automated Tape Library

**EXB-120**




- **116 x 5 GB 8 mm tapes = 0.6 TBytes (1991)**
- **4 tape readers 1991, 8 half height readers now**
- **4 x .5 MByte/second = 2 MBytes/s**
- **$40,000 O.E.M. Price**
- **Predict 1995: 3 TBytes; 2000: 9 TBytes**

# Open Research Issues

- **Hardware/Software attack on very large storage systems**
  - **File system extensions to handle terabyte sized file systems**
  - **Storage controllers able to meet bandwidth and capacity demands**
- **Compression/decompression between secondary and tertiary storage**
  - **Hardware assist for on-the-fly compression**
  - **Application hints for data specific compression**
  - **More effective compression over large buffered data**
  - **DB indices over compressed data**
- **Striped tape: is large buffer enough?**
- **Applications: Where are the Terabytes going to come from?**
  - **Image Storage Systems**
  - **Personal Communications Network multimedia file server**

# MSS: Applications of Technology
# Robo-Line Library

**Books/Bancroft x Pages/book x bytes/page = Bancroft**
**372,910 400 4000 = 0.54** TB

**Full text Bancroft Near Line = 0.5 TB;**

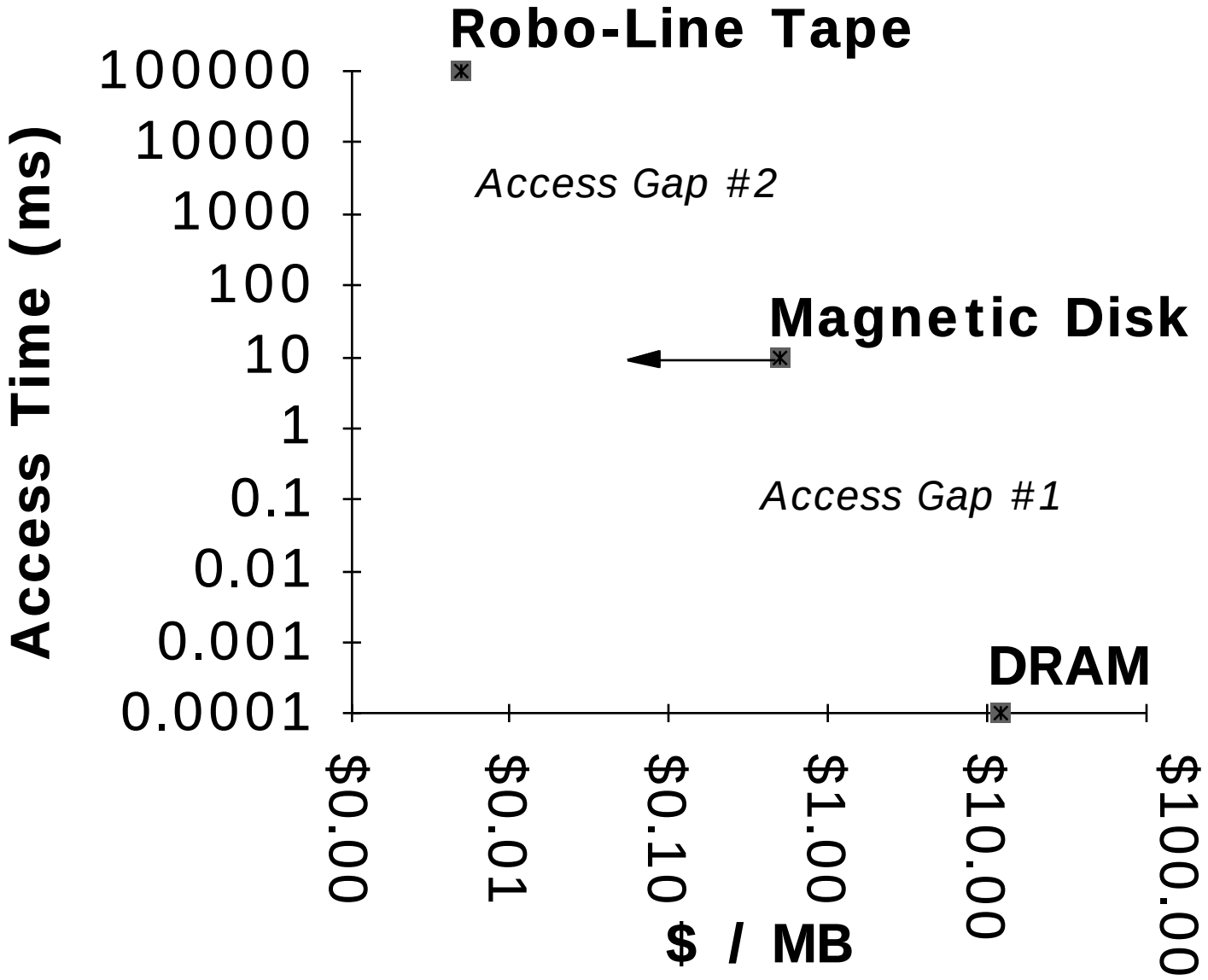
**Pages images ≈ 20 TB**

**Predict: "RLB" (Robo-Line Bancroft) = $250,000**

**Bancroft costs:**

| | |
|---|---|
| **Catalogue a book:** | **$20 / book** |
| **Reshelve a book:** | **$1/ book** |
| **% new books purchased per year never checked out:** | **20%** |

# MSS: Summary


Robo-Line Tape
Access Gap #2
Magnetic Disk
Access Gap #1
DRAM
Access Time (ms)
100000
10000
1000
100
10
1
0.1
0.01
0.001
0.0001
$0.00
$0.01
$0.10
$1.00
$10.00
$100.00
$ / MB