

## High Performance Storage - Dream Versus Reality

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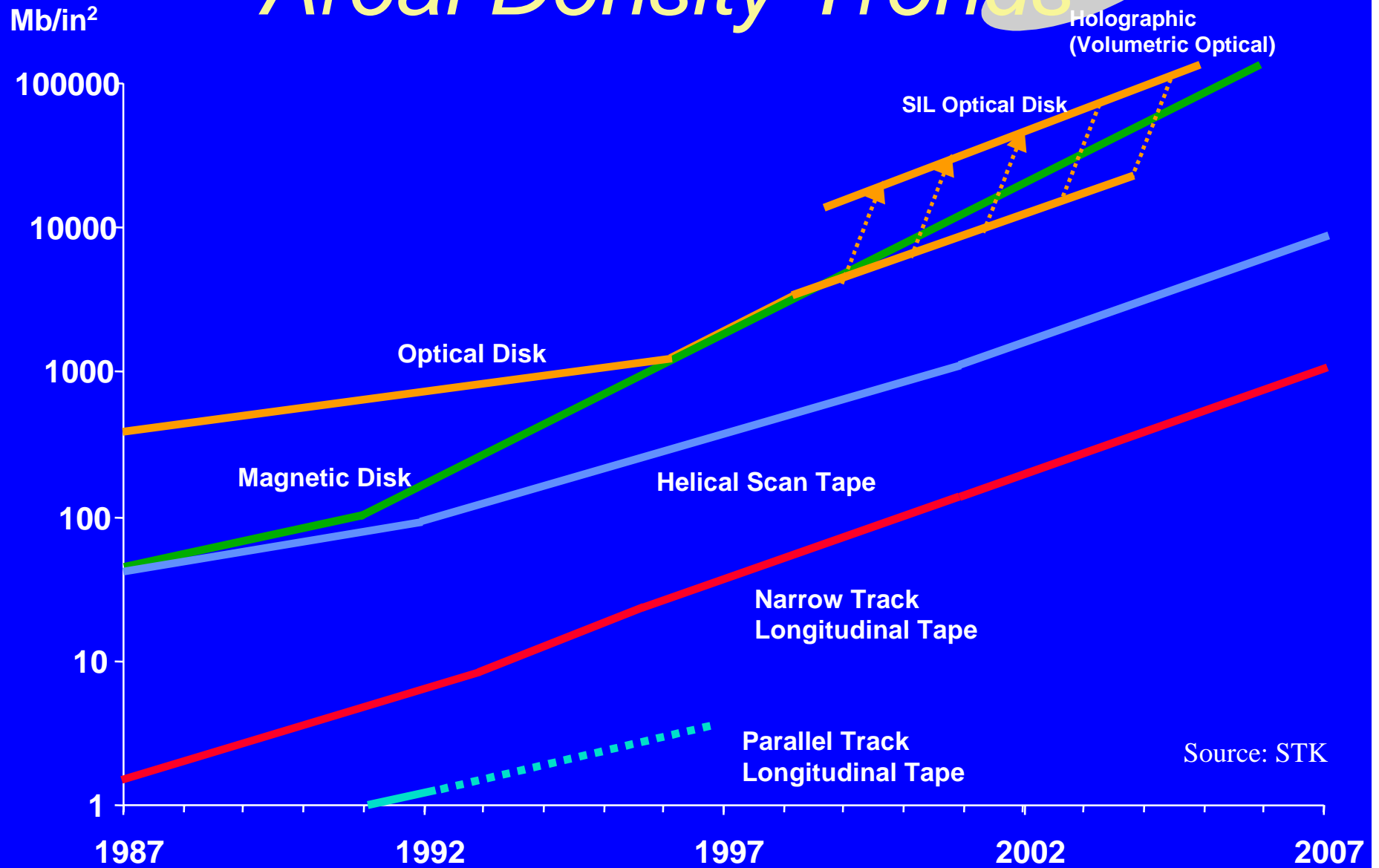
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# *Storage Trends*

- Magnetic disk is the areal density leader with 60%/year growth
- “Optically assisted” approaches are in development to continue magnetic disk’s growth past “2003 technology limit”
- Optical disk using “near-field” technology (e.g.SIL) could regain areal density lead
- Distinction between magnetic and optical recording will become “blurred”
- Major technical challenges remain for holography
- Tape’s “third dimension” gives it a volumetric storage efficiency advantage (30-50%/year growth)
  - 2 - 10x over disk drives
  - 3x over optical media

Source:STK

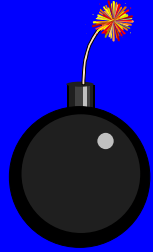
# Areal Density Trends



Source: STK

# Storage Importance

- Risk Avoidance
- Legal Requirements
- Legacy Considerations
- Future Planning and Profitability



# Financial Impact of Downtime

Type of Business	Average Hourly Impact
Retail Brokerage	\$6.45 Million
Credit Card Authorization	\$2.6 Million
Home Shopping Channels	\$113,750
Catalog Sales Centers	\$90,000
Airline Reservation Centers	\$89,500
Cellular Service Activation	\$41,000
Package Shipping Service	\$28,250
Online Network Connect Fees	\$25,250
ATM Service Fees	\$14,500

Source: Contingency Planning Research, September 1996

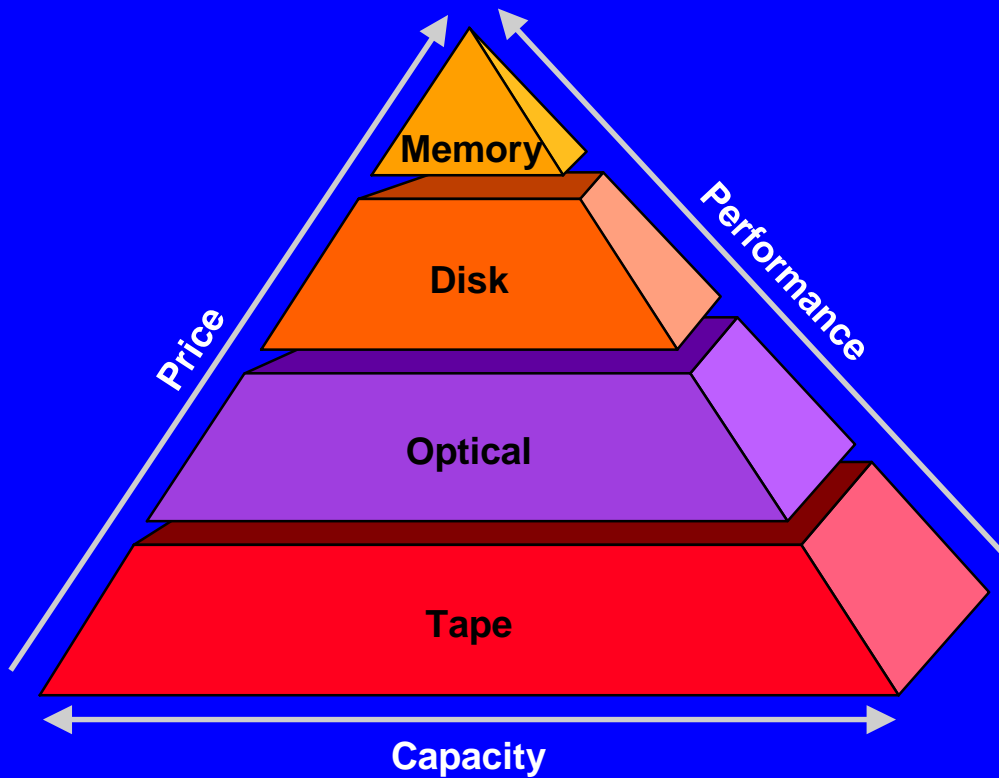
# Technology Importance

- **Strategic Planning**
- **Maintainability**
- **Reliability**
- **Migratability**

# Technology Investment

- Drive strategies
- Media futures
- Jukebox possibilities

# Storage Triangle

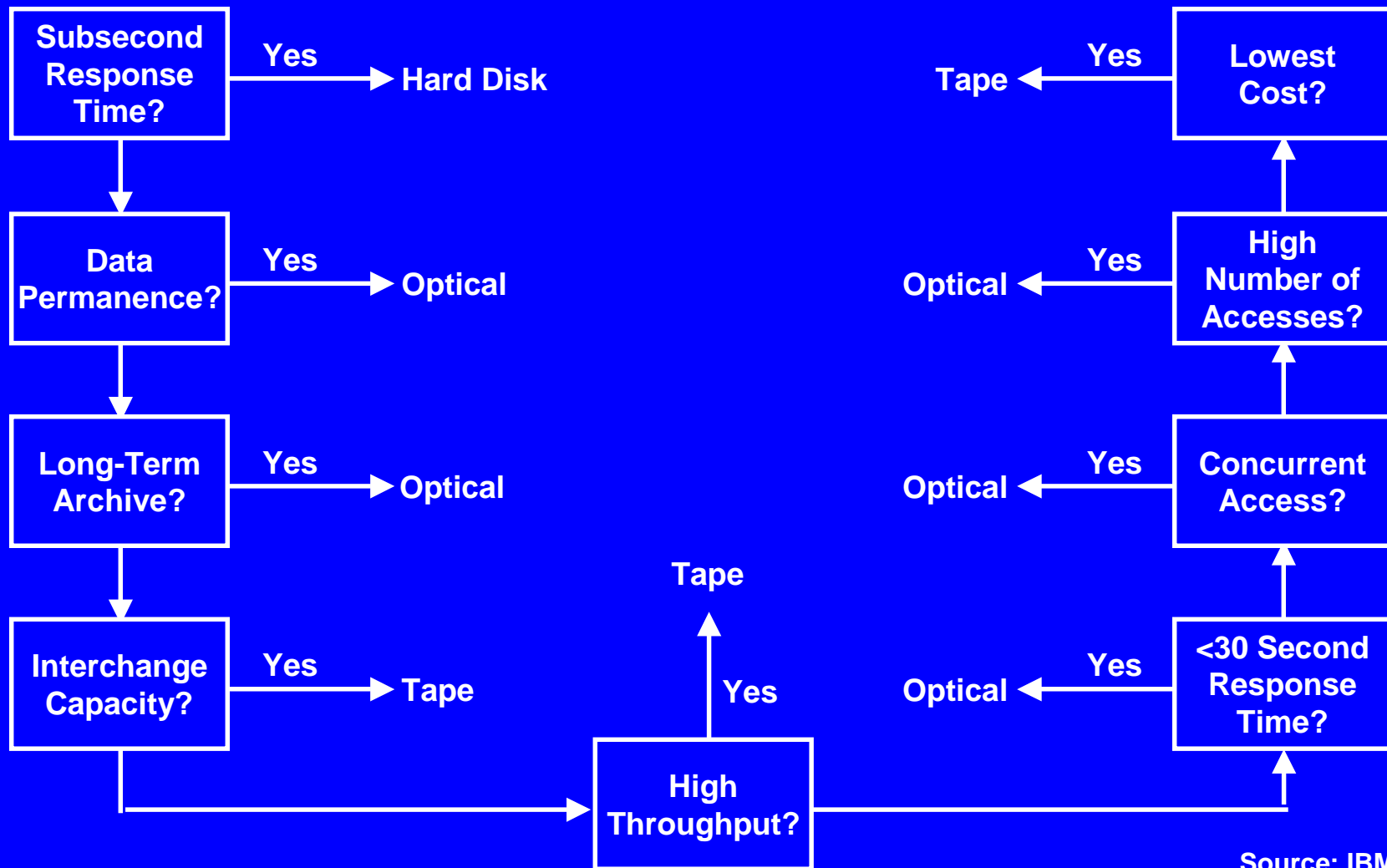


## Decision Criteria:

- Access time
- Frequency of use
- Concurrent access
- Archive requirements
- Permanent media
- Cost per megabyte
- Capacity

Source: IBM

# Decision Criterion: Summary



Source: IBM

# Petabyte Producers

Data Type	Sample Agency	Challenges
Research data	Rome Air Force Base	Owns 20 Pbytes off-line
Data repositories	Lawrence Livermore National Laboratories (LLNL)	Ingests 1 Tbyte/month
Imagery repositories	National Imagery Library (NIL)	Ingest 5 Tbytes/day by 1999
Earth sciences	EOS and Friends	Manage 7 Pbytes by 2010
Atmospheric data	National Center for Atmospheric Research (NCAR)	Manages 153 Tbytes
Oceanographic data	National Oceanographic Atmospheric Administration (NOAA)	Ingest 500 Tbytes/year by 2002

# A Petabyte Equals

**1,000 Tbytes**

**1,000,000 Gbytes**

**500,000,000,000 ASCII pages**

**31,600 mile-high stack of paper**

**5,000,000,000 pounds of paper**

**42,500,000 pulp trees**

**50,000,000 file cabinets**

**11,666 football fields of file cabinets**

**11,000 years to download at 28.8 kbps**

# Sony's PetaSite Library

Maximum # cassettes: 54,761

Media	1996	2001	2003
DTF-Small			
Unit	12 GB	56 GB	112 GB
Library	.66 PB	3.0 PB	6.1 PB
DTF-Large			
Unit	42 GB	200 GB	400 GB
Library	2.3 PB	11 PB	21.9 PB

# ***Projected Trend Tape Product Family (and the 5,600 -Unit Silo)***

	<u>GB Cap</u>	<u>Mbps</u>	<u>Available</u>	<u>Silo</u>
PT1	70	120	2000	392 TB
PT2	100	240	2001	560 TB
PT3	200	240	2002	1,120 TB
PT4	400	360	2003	2,240 TB

source: STK

# ADIC's EMASS AML/2 Library

Maximum Units	Media	Today		Future		Year
		Gbyte Capacity	Tbytes AML/2	Gbyte Capacity	Pbytes AML/2	
69,696	4mm	20	1,394	40	2.8	2001
46,656	8mm (Sony)	50	2,333	100	4.7	2001
46,656	8mm (Ebyte)	60	2,799	300	14	2002
23,040	VHS	21	484	50	1.6	2001
46,656	DLT	35	1,633	500	23.3	2005
51,840	3490E	0.8	41.5	1.6	.08	1999
51,840	Magstar	20	1,037	20	1.0	1999
51,840	NCTP	18	933.1	36	1.9	2000
16,128	DTF-L	42	677.4	400	6.5	2003
12,096	DD-2M	300	3,629	600	7.3	2002
41,184	5.25" Disks	5.2	214.2	10.4	0.4	2000

# VHS Cassettes

VHS Cassettes			
1986	1990	1995	2000 (?)
5.2 Gbytes	15 Gbytes	21/50 Gbytes	100+ Gbytes
Autoloaders			
V-48 (48) 249 Gbytes	720 Gbytes	1 Tbyte	4.8 Tbytes
V-600 (600) 3.12 Tbytes	9 Tbytes	12.6 Tbytes	60 Tbytes
AML/2 (20,480)		430 Tbytes	2.0 Pbytes

# DTF Cassettes

DTF Cassettes				
	1996		2001	2003
Small	12 Gbytes		56 Gbytes	112 Gbytes
Autoloaders				
DMS-B9 (9)	108 Gbytes		432 Gbytes	1.0 Tbytes
DMS-B35 (70)	80 Gbytes		3.9 Tbytes	7.8 Tbytes
DMS-8400 (54,761)	657 Tbytes		3.0 Pbytes	6.1 Pbytes

# DTF Cassettes (Cont.)

DTF Cassettes				
	1996		2001	2003
Large	42 Gbytes		200 Gbytes	400 Gbytes
Autoloaders				
DMS-B9 (9)	378 Gbytes		1.8 Tbytes	3.6 Tbytes
DMS-B35 (35)	1.5 Tbytes		7.0 Tbytes	14.0 Tbytes
AML/2 (16,128)	677.4 Tbytes		3.2 Pbytes	6.4 Pbytes
DMS-8400 (54,761)	2.3 Pbytes		11.0 Pbytes	21.9 Pbytes

# DD-2 Cassettes

DD-2 Cassettes				
	1994	1997	1999	2002
Small	25 Gbytes	50 Gbytes	100 Gbytes	200 Gbytes
Medium	75 Gbytes	150 Gbytes	300 Gbytes	600 Gbytes
Large	165 Gbytes	330 Gbytes	660 Gbytes	1.3 Tbytes
Autoloaders				
Ampex (7 L)	1.2 Tbytes	2.3 Tbytes	4.6 Tbytes	9.2 Tbytes
Ampex (116 S)	2.9 Tbytes	5.8 Tbytes	11.6 Tbytes	23.2 Tbytes
Ampex (256 S)	6.4 Tbytes	12.8 Tbytes	25.6 Tbytes	51.2 Tbytes
AML/2 (12,096 M)	907.2 Tbytes	1.8 Pbytes	3.6 Pbytes	7.2 Pbytes

# QIC Cartridges

QIC Cartridges				
1990	1993	1996	1997	2000
1.3 Gbytes	2.1 Gbytes	13 Gbytes	25 Gbytes	100 Gbytes
Autoloaders				
Tandberg (8)	1996	1997	2000	
	104 Gbytes	200 Gbytes	800 Gbytes	

# Travan Cartridges

Travan Cartridges				
1995	1996	1998	1999	2000
400 Mbytes	4 Gbytes	10 Gbytes	15 Gbytes	30 Gbytes
Autoloaders				
	1998	1999	2000	
Spectra Logic (15)	150Gbytes	225 Gbytes	450 Gbytes	
Spectra Logic (30)	300 Gbytes	450 Gbytes	900 Gbytes	

# 4 mm Cassettes

4 mm Cassettes				
1991	1994	1996	1999	2001
1.3 Gbytes	4 Gbytes	12 Gbytes	20 Gbytes	40 Gbytes
Autoloaders				
	1996	1999	2001	
IBM (4)	48 Gbytes	80 Gbytes	360 Gbytes	
ADIC (12)	144 Gbytes	240 Gbytes	480 Gbytes	
ADIC (15)	180 Gbytes	300 Gbytes	600 Gbytes	
Spectra Logic (60)	720 Gbytes	1.2 Tbytes	2.4 Tbytes	
AML/2 (69,696)	836.4 Tbytes	1,394 Tbytes	2,788 Tbytes	

# 8 mm Cassettes (Exabyte)

8 mm Cassettes				
1994	1996	1999	2000	2001
7 Gbytes	20 Gbytes	60 Gbytes	200 Gbytes	300 Gbytes
Autoloaders				
IBM (20)	400 Gbytes	1,200 Gbytes	4 Tbytes	6 Tbytes
Exabyte (40)	800 Gbytes	2.4 Tbytes	8 Tbytes	12 Tbytes
Exabyte (120)	2.4 Tbytes	7.2 Tbytes	24 Tbytes	36 Tbytes
Exabyte (200)	4 Tbytes	12 Tbytes	40 Tbytes	60 Tbytes
AML/2 (46,656)	933 Tbytes	3.3 Pbytes	9.3 Pbytes	14 Pbytes

# 8mm Cassettes (Sony)

	1996	1999	2000
	25 Gbytes	50 Gbytes	100 Gbytes
<b>Autoloaders</b>			
<b>Spectra Logic (40)</b>	<b>1 Tbyte</b>	<b>2 Tbytes</b>	<b>4 Tbytes</b>
<b>Qualstar (84)</b>	<b>2.1 Tbytes</b>	<b>4.2 Tbytes</b>	<b>8.4 Tbytes</b>
<b>Qualstar (126)</b>	<b>3.15 Tbytes</b>	<b>6.3 Tbytes</b>	<b>12.6 Tbytes</b>
<b>Qualstar (360)</b>	<b>9 Tbytes</b>	<b>18 Tbytes</b>	<b>36 Tbytes</b>
<b>ADIC (1,182)</b>	<b>29.6 Tbytes</b>	<b>59.1 Tbytes</b>	<b>118.2 Tbytes</b>
<b>AML/2 (46,656)</b>	<b>1.2 Pbytes</b>	<b>2.3 Pbytes</b>	<b>4.7 Pbytes</b>

# Magstar MP (3570)

- **Capacity: 5 GB**
- **Maximum rate: 17.6 Mbps**
- **Rewind to center**
  - Time to first record: 8 sec
- **Dual-hub cassette**
- **Autoloaders from IBM and Plasmon**
  - 60, 120, 180, 240, or 324 cassettes:
  - 300, 600, 900, 1200 or 1,620 GB

# DLT Cartridges

DLT Cartridges				
1991	1994	1995	1996	1999
2.6 Gbytes	10 Gbytes	20 Gbytes	35 Gbytes	80 Gbytes
Autoloaders				
ADIC (7)	70 Gbytes	140 Gbytes	245 Gbytes	560 Gbytes
HP (8)	80 Gbytes	160 Gbytes	280 Gbytes	640 Gbytes
BlackJack (21)	N/A	420 Gbytes	735 Gbytes	1.68 Tbytes
Breeze Hill (28)	280 Gbytes	560 Gbytes	980 Gbytes	2.24 Tbytes
ADIC (48)	480 Gbytes	960 Gbytes	1,680 Gbytes	3.84 Tbytes
D-360 (360)	3.6 Tbytes	7.2 Tbytes	12.6 Tbytes	28.8 Tbytes
STK 9710 (588)	5.9 Tbytes	11.8 Tbytes	20.6 Tbytes	47 Tbytes
ADIC (788)	7.9 Tbytes	15.8 Tbytes	27.6 Tbytes	63.0 Tbytes
AML/2 (46,656)	466.6 Tbytes	933.2 Tbytes	1.63 Pbytes	3.73 Pbytes

# Half-Inch Cartridges

Half-Inch Cartridges					
1986	1994	1995	1999	1998	2000
200 Mbytes	800 Mbytes 36 Track	50 Gbytes (STK)	20 GB-IBM 20 GB-STK	18 Gbytes (Plasmon)	36 Gbytes (Plasmon)
Autoloaders					
Blackjack (21) Plasmon (84) ADIC (788) STK Silo (5,600) IBM 3494 (18,720) AML/2 (51,840)	4.5 Tbytes  15 Tbytes 36.9 Tbytes	280 Tbytes	112 Tbytes  374.4 Tbytes 1037 Tbytes	378 Gbytes 1.5 Tbytes 14.2 Tbytes  933 Tbytes	756 Gbytes 3 Tbytes 28.4 Tbytes  1,866 Tbytes

# New Kids on the Tape Block

- **Enertec DD-5 (from Panasonic)**
- **Ecrix VXA**
- **Fujitsu M8100**
- **OnStream ADR**
- **STK 9840**
- **LOTS Optical Tape**

# Enertec DD-5 Tape Drive

- **Capacity of S, M and L:**
  - 40, 80 and 160 GB
- **BER 10E-15**
- **Maximum rate: 240 Mbps**
- **Library capacity: 6,720 GB**
- **Future media: 11  $\mu\text{m}$** 
  - Increases capacity by 30%
- **3 media sources**

# Ecrix VXA-1 Tape Drive

- Capacity: 12 or 33 GB
- BER  $10E-17$
- Maximum rate: 24 Mbps
- Record rate matches host data rate
- 8mm AME cassette

# Fujitsu M8100 Tape Drive

- **Capacity: 10GB**
- **Maximum rate: 108 Mbps**
- **IBM 3590 compatible**
- **7-cartridge stacker provides 70 GB**
- **Available 3Q99**

# OnStream ADR Tape Drive

- **Capacity: 15 or 25 GB**
- **BER 10E-19**
  - 8-channel head
- **Variable rate from 4 Mbps to 16 Mbps**
- **0.25-inch (QIC) wide media from Verbatim**

# STK 9840 Tape Drive

- **Capacity: 20 GB**
- **BER E-18**
- **Maximum rate: 80 Mbps**
- **Unique 2 hub cassette**
  - supports mid-tape load
- **Fits into > 10,000 libraries**
- **MP media from Imation**

# LOTS Optical Tape

- **Product: 25T**
  - Capacity: 1.5 TB
  - Max. rate: 200 Mbps (25 MBps)
  - Projected market date: 2Q00
- **Product: 40T**
  - Capacity: 2 TB
  - Max. rate: 360 Mbps (45 MBps)
  - Projected market date: 3Q01

# 3.5-Inch Optical Disks

3.5-Inch Optical Disks				
1990	1993	1996	1999	2000
128 Mbytes	256 Mbytes	640 Mbytes	1.3 Gbytes	2.6 Gbytes
Jukeboxes				
Maxoptix (35)		22.4 Gbytes	45.5 Gbytes	91 Gbytes

# 5.25-Inch Optical Disks

5.25-Inch Optical Disks				
1990	1993	1996	1998	2000
650 Mbytes	1.3 Gbytes	2.6 Gbytes	5.2 Gbytes	10.4 Gbytes
Jukeboxes				
Plasmon (20)	26 Gbytes	52 Gbytes	104 Gbytes	208Gbytes
Plasmon (32)	41.6 Gbytes	83.2 Gbytes	166.4 Gbytes	332.8 Gbytes
Plasmon (500)	650 Gbytes	1.3 Tbytes	2.6 Tbytes	5.2 Tbytes
AML/2 (41,184)	53,54 Gbytes	107.1 Tbytes	214.2 Tbytes	428.3 Tbytes

# 12-Inch Optical Disks

12-Inch Optical Disks			
1984	1995	1999	2001
1 Gbyte	12 Gbytes	30 Gbytes	60 Gbytes
Jukeboxes			
Plasmon LMS (6)	72 Gbytes	180 Gbytes	360 Gbytes
Cygnnet (141)	1,692 Gbytes	4.2 Tbytes	8.5 Tbytes
FileNet (288)	3,456 Gbytes	8.6 Tbytes	17.3 Tbytes

# New Kids on Optical Block

- **TeraStor**
- **First product: 10 GB per side**
  - second generation: 20 GB per side (third: 40 GB/side)
- **Maximum rate: 40 Mbps**
- **Avg. seek: <18 ms**
- **New head partner: Yamaha**
- **Product scheduled out before COM**

# New Optical Kid Number 2

- **Maxoptix Optical Super Density (OSD)**
- **First product mid-2000**
- **Capacity: 40 GB**
  - 20 GB per side
- **Dual head 5.25” full height drive**
- **Max. data rate: 120 Mbps**
- **Avg. seek: 20 ms**

# Storage Conclusions

- Magnetic tape based data archive can meet exabyte capacity, petabyte/day rate goals
  - Offers cost advantage over other storage types
  - Media is “medium to long term” archive capable
  - Tape technology will support continual performance enhancements
- Questions remain for a comprehensive archive model
  - Transport-Library ratios
  - Recall activity
  - Usage patterns
  - Data retirement
  - Technology adoption

Source: STK

# Magnetic Hard Disk Storage

- **Perspective**

- 1956: IBM RAMAC 350 used fifty 24-inch disks to store 4,400,000 bytes (4.4 Mbytes) of data (88 kbytes per platter)
- March 1995: the Advanced Magnetic Recording Laboratory of IBM demonstrated 375 Mbytes in one square inch: 85 times the entire RAMAC capacity
- February 1999: Seagate demonstrated 2 Gbytes per square inch, 455 times the entire RAMAC 350. This technology uses giant magnetoresistive heads flying 15 nm above the surface.
- October 1999: IBM demonstrated 35.3 Gb per square inch, 8,023 times RAMAC. Potential: 300 Gbytes in mobile 2.4 inch drive or 500 Gbytes in a desktop 3.5 inch drive.

# Emerging Technologies

<b>Technology</b>	<b>Promises</b>	<b>Pitfalls</b>
<b>Holograms</b>	<b>Volumetric</b>	<b>Media instability</b>
<b>Electron etching</b>	<b>200 Gbytes/CD</b>	<b>Expensive readers</b>
<b>Multilayer optical</b>	<b>Molecular-level storage</b>	<b>Chemical interactions</b>
<b>Optical Winchester</b>	<b>Multidisk stacks</b>	<b>Multiple laser heads</b>

# Electron-Etching Technology

- Los Alamos National Lab developed a high-density ROM storage device. Norsam is developing 200 Gbytes on 4.72" disk (HD-ROM) and 4.5 Gbytes on 2" disk (HD-ROSETTA)
- Uses electron (ROM) or ion (ROSETTA) etching technology to carve lines 50 billionths of a meter wide
- Can store video, text, image, or bit-mapped data
- Reading is done with Near-field Scanning Optical Microscopy (NSOM) device
- Data should last up to 500 years
- HD-ROSETTA disk now available
- HD-ROM available in 2–3 years

# “Bugs Full of Bytes”

- Halobacterium from brackish lagoons around San Francisco Bay
- Laser beams focused on photosensitive protein could create a fast, matchbox-sized optical storage device that could store 480 Gbytes (960 file cabinets of document images)
- Demonstration of technology by 2000
- *Interesting use of toxic waste?*