
How to Select Storage Media for the 21st Century

Linda Kempster
Storage Media Specialist
IIT Research Institute
Lanham, Maryland 20706
301-918-1037
E-mail: lkempster@iitri.com

THIC Meeting at the Del Mar Hilton, Del Mar CA 92014
January 20, 1998



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

Storage Technologies

- **Why storage technology is important**
 - Strategic planning
 - Technology investment today
- **Storage media**
 - History
 - Present
 - Future

Why Technology Is Important

- **Strategic planning**
 - Standards
 - Vendor partnerships
- **Technology investment today**
 - Drive strategies
 - Media futures
 - Jukebox possibilities

Media Mania!



1998 EMASS AML/2 Capacity

Media Type	Capacity (Gbytes)	AML/2 Maximum Units	AML/2 Maximum Capacity (Tbytes)
8mm	25	58,880	1,472.0
VHS	21	20,480	430.1
DLT	35	32,720	1,145.2
3490E	0.8	46,080	36.9
Magstar	10	46,080	460.8
NCTP	20	46,080	921.6
DTF-S	12	20,480	245.8
DTF-L	42	10,752	451.6
DD-2S	50	16,896	844.8
DD-2M	150	10,752	1,613
5.25" Disks	2.6	46,080	119.8
Apex	4.6	46,080	212

VHS Cassettes

VHS Cassettes			
1986	1990	1995	1998
5.2 Gbytes	15 Gbytes	21/50 Gbytes	100+ Gbytes
Autoloaders			
V-48 (48) 249 Gbytes	720 Gbytes	1 Tbytes	4.8 Tbytes
V-600 (600) 3.12 Tbytes	9 Tbytes	12.6 Tbytes	60 Tbytes
AML/2 (20,480)		430 Tbytes	2,048 Tbytes

DTF Cassettes

DTF Cassettes				
	1996	1997	1999	2001
Small	12 Gbytes	24 Gbytes	48 Gbytes	108 Gbytes
Autoloaders				
MTG-BIO (9)	108 Gbytes	216 Gbytes	432 Gbytes	864 Gbytes
DMS-B35 (70)	80 Gbytes	1.7 Tbytes	3.4 Tbytes	7.6 Tbytes
DMS-B400 (351)	N/A	8.4 Tbytes	16.8 Tbytes	37.9 Tbytes
DMS-B1000 (1,014)	N/A	24.3 Tbytes	48.7 Tbytes	109.5 Tbytes
AML/2 (20,480)	245.8 Tbytes	491.5 Tbytes	983 Tbytes	2,211.8 Tbytes

DTF Cassettes (Cont)

DTF Cassettes				
	1996	1997	1999	2001
Large	42 Gbytes	84 Gbytes	168 Gbytes	386 Gbytes
Autoloaders				
MTG-BIO (9)	378 Gbytes	756 Gbytes	1.5 Tbytes	3.0 Tbytes
DMS-B35 (35)	1.5 Tbytes	2.9 Tbytes	5.9 Tbytes	13.5 Tbytes
DMS-B400 (28)	N/A	2.4 Tbytes	4.7 Tbytes	10.8 Tbytes
DMS-B1000 (28)	N/A	2.4 Tbytes	4.7 Tbytes	10.8 Tbytes
AML/2 (10,752)	451.6 Tbytes	903.2 Tbytes	1,806.3 Tbytes	4,150.3 Tbytes

DD-2 Cassettes

DD-2 Cassettes				
	1994	1997	1998	2000
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 (256 S)	6.4 Tbytes	12.8 Tbytes	25.6 Tbytes	51.2 Tbytes
AML/2 (16,896 S)	422 Tbytes	8,445 Tbytes	1,690 Tbytes	3,380 Tbytes
(10,752 M)	806 Tbytes	1,613 Tbytes	3,226 Tbytes	6,451 Tbytes

QIC Cartridges

QIC Cartridges				
1990	1993	1996	1997	2000
1.3 Gbytes	2.1 Gbytes	13 Gbytes	25 Gbytes	100 Gbytes
Autoloaders				
	1996	1997	2000	
Tandberg or Imation (10)	130 Gbytes	250 Gbytes	1 Tbytes	
Tandberg or Imation (20)	260 Gbytes	500 Gbytes	2 Tbytes	
Tandberg or Imation (40)	520 Gbytes	1 Tbyte	4 Tbytes	

Travan Cartridges

Travan Cartridges				
1995	1996	1998	1999	2000
400 Mbytes	4 Gbytes	10 Gbytes	26 Gbytes	40 Gbytes
Autoloaders				
Coming from Exabyte and Conner				



8 mm Cassettes (Exabyte)

8 mm Cassettes				
1991	1994	1996	1998	2000
2.5 Gbytes	7 Gbytes	20 Gbytes	40 Gbytes	80 Gbytes
Autoloaders				
ADIC (11)	77 Gbytes	220 Gbytes	440 Gbytes	880 Gbytes
Exabyte (10)	70 Gbytes	200 Gbytes	400 Gbytes	800 Gbytes
Exabyte (40)	280 Gbytes	800 Gbytes	1.6 Tbytes	3.2 Tbytes
Exabyte (80)	560 Gbytes	1.6 Tbytes	3.2 Tbytes	6.4 Tbytes
AML/2 (58,880)	412 Tbytes	1,178 Tbytes	2,355 Tbytes	4,710 Tbytes

8mm Cassettes (Sony)

8mm Cassettes			
	1996	1998	2000
Sony (4)	25 Gbytes	50 Gbytes	100 Gbytes
Autoloaders			
Sony (4)	100 Gbytes	200 Gbytes	400 Gbytes
Spectra Logic (40)	1 Tbytes	2 Tbytes	4 Tbytes
Qualstar (80)	2 Tbytes	4 Tbytes	8 Tbytes
ADIC (120)	3 Tbytes	6 Tbytes	12 Tbytes
Straightline (150)	3.75 Tbytes	7.5 Tbytes	15 Tbytes

4 mm Cassettes

4 mm Cassettes				
1991	1993	1994	1996	1998
1.3 Gbytes	2 Gbytes	4 Gbytes	12 Gbytes	24 Gbytes
Autoloaders				
	1994	1996	1998	
Sony (8)	32 Gbytes	96 Gbytes	192 Gbytes	
ADIC (12)	48 Gbytes	144 Gbytes	188 Gbytes	
ADIC (15)	60 Gbytes	180 Gbytes	360 Gbytes	
Exabyte (18)	72 Gbytes	216 Gbytes	432 Gbytes	
Carousel (54)	216 Gbytes	648 Gbytes	1.3 Tbytes	

DLT Cartridges

DLT Cartridges				
1991	1994	1995	1996	2000
2.6 Gbytes	10 Gbytes	20 Gbytes	35 Gbytes	100 Gbytes
Autoloaders				
ADIC (7)	70 Gbytes	140 Gbytes	245 Gbytes	700 Gbytes
BlackJack (21)	N/A	420 Gbytes	735 Gbytes	2.1 Tbytes
Q7 (28)	280 Gbytes	560 Gbytes	980 Gbytes	2.8 Tbytes
ADIC (48)	480 Gbytes	960 Gbytes	1,680 Gbytes	4.8 Tbytes
ATL (264)	2.6 Tbytes	5.3 Tbytes	9.2 Tbytes	26.4 Tbytes
D-360 (360)	3.6 Tbytes	7.2 Tbytes	12.6 Tbytes	36 Tbytes
STK 9710 (588)		11.8 Tbytes	20.6 Tbytes	58.8 Tbytes
D-900 (900)	9 Tbytes	18 Tbytes	31.5 Tbytes	90 Tbytes
AML/2 (32,720)	327 Tbytes	654 Tbytes	1,145 Tbytes	3,272 Tbytes

Half-Inch Cartridges

Half-Inch Cartridges				
1986	1994	1995	1995	1998
200 Mbytes	800 Mbytes 36 Track	50 Gbytes (STK)	10 Gbytes (IBM)	20 Gbytes (Philips)
Autoloaders				
Blackjack (21) STK Silo (6,000) IBM 3495 (18,920) AML/2 (46,080)	4.8 Tbytes 15.1 Tbytes 36.9 Tbytes	300 Tbytes	189.2 Tbytes 460.8 Tbytes	420 Gbytes 921.6 Tbytes

3.5-Inch Optical Disks

3.5-Inch Optical Disks				
1990	1993	1996	1998	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				
HP (16)	21 Gbytes	42 Gbytes	83 Gbytes	166 Gbytes
Plasmon (92)	120 Gbytes	239 Gbytes	478 Gbytes	957 Gbytes
MountainGate (626)	814 Gbytes	1.6 Tbytes	3.3 Tbytes	6.5 Tbytes
DISC (1,054)	1,370 Gbytes	2.7 Tbytes	5.5 Tbytes	11 Tbytes
AML/2 (46,080)	59,904 Gbytes	119.8 Tbytes	239.6 Tbytes	479.2 Tbytes

12-Inch Optical Disks

12-Inch Optical Disks				
1984	1995	1997-8	1998-9	2000
1 Gbyte	Various	Various	Various	60 Gbytes
Jukeboxes				
Philips LMS (6) No. Gbytes/Platter	72 Gbytes 12		180 Gbytes 30	0.36 Tbytes
Cygnnet (141) No. Gbytes/ATG Platter	1,438 Gbytes 10.2	2,256 Gbytes 16	3.9 Tbytes 28	8.5 Tbytes
FileNet (288) No. Gbytes/Platter	3,456 Gbytes 12		8.6 Tbytes 30	17.3 Tbytes

14-Inch Optical Disks

14-Inch Optical Disks				
1986	1994	1997	1999	2001
6.8 Gbytes	14.8 Gbytes	25 Gbytes	50 Gbytes	200 Gbytes
Jukeboxes				
Kodak (15)	222 Gbytes	375 Gbytes	750 Gbytes	3 Tbytes
Kodak (50)	740 Gbytes	1,250 Gbytes	2,500 Gbytes	10 Tbytes
Kodak (134)	2 Tbytes	3.4 Tbytes	6.7 Tbytes	26.8 Tbytes

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

- **How**

- Advanced version of magnetoresistive (MR) reading heads and thin film magnetic hard disks
- Head flies over disk at 2 millionths of an inch high—Visible light cannot pass through gap

Magnetic Hard Disk Storage (Cont)

- **Results**
 - 180,000 bits per inch stored along concentric tracks with packing density of 16,500 bits per radial inch
- **BER: E-12**
- **Ready: 2–4 years**

Waveguide Holograms

- **May 1995: Tamarack awarded \$22M from DoD Advanced Research Projects Agency (ARPA)**
- **Goal: Develop 125 Gbyte storage systems with no moving parts**
- **3-D environment supports writing all through the media, not just on the surface**
- **Wavelength-agile laser will provide data access, and the optical system will feature multimode beam steering**
- **100 times improvement in speed and storage over current WORM or erasable systems**
- **App: Video-on-demand or transaction processing**

“Sugar Cube” Technology

- **3-D two-photon photochromic storage funded by Rome Laboratory and developed by UCSD Irvine**
- **Requires no moving parts and supports near-instantaneous retrieval**
- **Capacity: 125 Gbyte (250 file cabinets of documents)**
- **Should be ready for commercialization by 1999**



Ion-Etching Technology

- **Los Alamos National Lab developed a nonerasable, high-density ROM storage device that could store 4.5 Gbytes on a 2-inch stainless steel pin. Norsam proposes 165 Gbytes on 4.72" disk**
- **Used ion-etching technology to carve lines 150 billionths of a meter wide**
- **Could store video, ASCII, image, or bit-mapped data**
- **Reading is done with COTS atomic force microscope**
- **Data should last up to 500 years**
- **Available in 4–6 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?*

Advanced Technology Award Winners (October 1997)

- **National Storage Industry Consortium**

- Joint Venture Partners: Calimetrics, Energy Conversion Devices (ECD), and Polaroid

- » Increase the DVD-R and PD optical media to 10 times capacity and 5 times the transfer rates while lowering the cost of the media. Calimetrics will provide multilevel technology, ECD will provide the phase-change media, and Polaroid will provide optics technology and low-cost media processing approach. These systems will be available for both desktop digital media systems and low-cost portable devices enabling a competitive position for the United States in a variety of storage markets.

Total estimated cost: \$21.1 Million

Duration 4 years



Advanced Technology Award Winners (October 1997) (Cont)

- **LOTS Technology, Inc.**

- **Joint Venture Partners: Avid Technology, EMC, Lucent Technologies, Polaroid**

- » **Demonstrate the use of a digital optical tape recorder and reusable optical tape in a dual-reel tape cartridge to meet the consumer needs of HDTV video recording and playback equipment. A successful system will provide high-rate recording, increased capacity per cartridge, reduced media costs, longer storage time, greater damage resistance, and faster data access.**

Total estimated cost: \$10.9 Million

Duration 2 years



Advanced Technology Award Winners (October 1997) (Cont)

- **Intevac, Inc.**

- Develop a commercially viable way of depositing the coatings of magnetic hard disks in a vacuum. The coating must be 30,000 times thinner than the width of a human hair. This technology could increase data-storage density to 10 Gbytes/in², reduce manufacturing costs, and provide a critical infrastructure improvement that supports the entire data-storage industry which is due to reach \$60 billion by 1999.

Total estimated cost: \$1.5 Million

Duration 2 years

- **Energy Conversion Devices, Inc.**

- Develop a process technology that both formats and coats the DVD disks as part of a continuous, low-cost manufacturing system. If this is successful, the throughput of a single production line will increase by tenfold and reduce the unit manufacturing costs of DVD-ROM by a factor of two to four.

Total estimated cost: \$5.9 Million

Duration 2 years



Advanced Technology Award Winners (October 1997) (Cont)

- **Quinta Corporation and SDL, Inc.**

- Demonstrate a high-capacity, multiple platter, magneto-optic storage device with flying optical heads to access each recording surface. Quinta will provide the low-cost, easily manufactured heads and SDL will develop advanced laser light sources. A 100-Gbyte drive would employ advanced red diode laser, but advanced blue diode lasers will increase the capacity to a potential of 350 Gbytes.

Total estimated cost: \$6.5 Million

Duration 3 years

- **Neural Systems Corporation**

- Demonstrate the use of trainable digital logic (TDL) pattern recognition technique and compare it to competing signal processors. The TDL will significantly increase data storage density and transfer rates while reducing costs. Ideally, a chip could be designed that could be programmed for use by every disk drive manufacturer.

Total estimated cost: \$1.2 Million

Duration 1.5 years



Conclusions

- **Uncle Sam mandated to stop issuing paper checks by 1999**
- **Students graduating after 4 years of using cash cards instead of cash or checks**
- **By end of 1996, we had 250,000 Tbytes on-line**
- **Corporate concerns: security fears may drive storage off-line**
- **Consumer concerns: where will "we" put what is caught in the Net?**

Now you have those answers!

