Disk & Tape Technology Update & Directions

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IBM Storage Solutions
Data Storage Hierarchy

- RAM & Cache
- Flash memory
- Magnetic disk
- Optical disk
- Magnetic tape

Cost vs. Performance

- Megabytes to Terabytes
- Nanosecond to Seconds
- Minutes

IBM Storage Solutions
Worldwide $ Sales Revenue Marketshare % 1998

Disk Drives
Source - DiskTrend 6/99

- IBM 27.1%
- Seagate 19.8%
- Quantum 12.4%
- W Digital 9.4%
- Quantum 3.0%
- Futitsu 6.0%
- Yamaha 7.0%
- Read-Rite 8.0%
- TDK-SAE 15.0%
- Others 16.0%
- Others 16.0%

Magnetic Heads
Source - Peripheral Research 11/9

- IBM 25.0%
- Seagate 20.0%
- Others 31.3%
- IBM 25.0%
- Seagate 20.0%
- Others 31.3%

IBM Storage Solutions

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Storage Industry Growth

1998 ($45B)  
- HDD 52%  
- Tech. Components 6%  
- Software 5%  
- DASD Subsystems 29%  
- Tape 8%

2001 ($63B)  
- HDD 49%  
- Tech. Components 7%  
- Software 4%  
- DASD Subsystems 33%  
- Tape 7%

Source: IDC and TrendFocus

Segment CGR  
- HDD 10%  
- Tech. Components 19%  
- S/W 10%  
- DASD Subsystems 18%  
- Tape 7%

IBM SSD has invested >$3 billion in 2 years in increased manufacturing facilities, and in new product development.
Magnetic Disk Characteristics

- Permanent, non-volatile storage
- On line
- Fast, direct access (milliseconds)
- Fast data transfer (Megabytes per second)
- Multiple concurrent users
- Multiple concurrent applications
- No data degradation
- Highly reliable
Micro Technologies Drive Capacities

1 metre (m) = 1,000 millimeters (mm)

1 millimeter = 0.001 m (1 thousandth /metre)
= 1,000 micrometres (um)

1 micrometer = 0.000,001 m (1 millionth /metre)
= 1,000 nanometers (nm)

1 nanometer = 0.000,000,001 m (1 billionth /metre)

A human hair = 0.05 millimetres (approx)
A Recording Track

Areal Density = Linear Density x Track Density

bits/in²  bits/in  tracks/in
Magnetic Read/Write Head

Principles of Inductive Recording

- Magnetic core
- Gap with magnetic fringe field
- Magnetized track

Media movement

Write current

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Magneto Resistive Heads
Write Wide / Read Narrow Recording

Inductive Read/Write Element

Inductive Write & GMR Read/Write Element

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The Shrinking Bit Cell

Smaller bits deliver lower signal strength

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Signal Level Improvement

Signal level is independent of velocity and # turns

Giant Magneto-Resistive Head
(10 to 50 times better)

Magneto-Resistive Head
(2 to 3 times better)

Inductive Head

Signal level is function of velocity and # turns

Velocity, m/sec

Relative Head Signal Level

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MR & GMR / Spin Valve Head Characteristics

- GMR effect exhibited by certain very thin materials.
- Magnetic property of bits controlled by spin of electrons.
- Spin can be controlled by adding alternating thin layers of magnetic / non-magnetic materials.
- N Pole in one layer points in opposite direction to Pole of alternate layer.
- When in magnetic field one layer flips so all N Poles point in same direction - generating Giant signal.

![Diagram showing layers of GMR and MR heads with signal amplitude and sensing layer thickness graphs.](image-url)
Evolution of Magnetic Read/Write Sensors

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IBM MR Head World Leadership 1990-99

Disk capacity growth >60% CGR annually

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IBM Disk Capacity Growth 1990-99

95 mm (3.5"") format

IBM Storage Solutions

X 90 fold increase

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IBM's Revolutionary Microdrive

The world's smallest, lightest production drive

- Length - 42.8 mm (1.68"
- Width - 36.4 mm (1.43"
- Weight - 20 grams (0.7 ounces)
- 1 disk platter
- Capacity 340 MB
- Advanced GMR head
- Areal density > 3 billion bits/sq in.
# IBM HDD Design Projections

## IBM Storage Solutions

<table>
<thead>
<tr>
<th>HDD Type</th>
<th>1998</th>
<th>2000</th>
<th>2002</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Server</strong> 3.5 Inch HDD 41.3 mm high</td>
<td>18 GB 10000 RPM 6.5 ms Tseek</td>
<td>36 GB 10000 RPM 4.9 ms Tseek</td>
<td>72 GB 12000 RPM 4.5 ms Tseek</td>
<td>100 GB 15000 RPM 3.5 ms Tseek</td>
</tr>
<tr>
<td><strong>Entry-Server</strong> 3.5 Inch HDD 25.4 mm high</td>
<td>16 GB 7200 RPM 9.0 ms Tseek</td>
<td>34 GB 7200 RPM 8.5 ms Tseek</td>
<td>72 GB 10000 RPM 8.0 ms Tseek</td>
<td>150 GB 10000 RPM 7.5 ms Tseek</td>
</tr>
<tr>
<td><strong>Mobile</strong> 2.5 Inch HDD 9.5 mm 12.5 mm 17 mm high</td>
<td>8 GB 4900 RPM 12 ms Tseek</td>
<td>25 GB 5400 RPM 12 ms Tseek</td>
<td>50 GB 5400 RPM 10 ms Tseek</td>
<td>100 GB 7200 RPM 9.0 ms Tseek</td>
</tr>
<tr>
<td><strong>Consumer</strong> 1.0 Inch HDD 5.0 mm high</td>
<td>0.34 GB 4500 RPM 15 ms Tseek</td>
<td>0.6 GB 4500 RPM 15 ms Tseek</td>
<td>1.3 GB 4500 RPM 13 ms Tseek</td>
<td>3.0 GB 5400 RPM 13 ms Tseek</td>
</tr>
</tbody>
</table>
Average Price of Storage

IBM Storage Solutions
Advanced Storage Roadmap

- Enhanced Magnetic Disk Drive
  - New disk & head materials
  - Changes in linear to track densities
  - Ultra thin GMR sensors
- Holography
- Super-Paramagnetic Effect (v. small bits at high AD potentially less stable)

Year
- 1990
- 1995
- 2000
- 2005
- 2010
- 2015

Areal Density GBits/sq.in.
The Bottom Line

- Areal densities are growing at 60% annually
- Data Channel and Interface speeds are increasing
- Price per MB is reducing at >30% per year
- Ten year outlook:-

Larger capacities
Smaller size
Faster
Cheaper
Data Storage Hierarchy

- Cost:
  - RAM & Cache
  - Flash memory
  - Magnetic disk
  - Optical disk
  - Magnetic tape

- Performance:
  - Nanosecond
  - Seconds
  - Minutes

- Capacity:
  - Megabytes
  - Terabytes

IBM Storage Solutions
Magnetic Tape Characteristics

- Permanent, non-volatile storage
- High capacity removable media
- Fast data transfer (Megabytes per second)
- Solution for data Backup / Recovery
- Reliable
- Media has long shelf life for Data Archive
- Can be automated
- Low cost of ownership (assuming effective capacity utilisation)

IBM Storage Solutions
Magnetic Tape Marketplace

- Many competing, incompatible formats
- More emerging technologies on horizon
- Broad range of capacities, performance and prices

Which are the characteristics to choose?
What's Important?

- **Backups**
  - Large Capacity
    - simplify handling
    - reduced library size needed
    - reduce costs
  - Performance
    - complete within backup window

- **Restores**
  - Reliability
    - no permanent errors
    - lost data = $ lost
  - Performance
    - complete ASAP
    - application impact = $ business impact
Why Do You Need Tape?

- Server **Backups**?

- NO!!!

- Tape is ONLY needed for data recovery

- Backup is just the first step of recovery

- Business benefit ONLY comes from successful recovery

Users need to focus more on Recovery than Backup

IBM Storage Solutions
Two Basic Design Technologies

Helical Scan
- spinning read/write head
- slow moving tape

Linear
- stationary read/write head
- fast moving tape

Implementations
- 4mm/8mm
- Mammoth
- AIT
- VXA

Implementations
- 1/2" Reel
- QIC
- 3480/3490/3590
- STK 9480(Eagle)
- DLT
- SLT
- NCTP
- LTO

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Helical Scan

Head Motion

Tape Motion

Head Ends Here

No edge guard band

Head Starts Here

Typical helical scan tape path

High Capacity
High media / head contact

Rotary Head Drum
3300+ RPM

WRITE
READ
WRITE

Head Motion

Tape Motion

IBM Storage Solutions
8mm "Mammoth" Overview

- Developed by Exabyte
- Latest in 8mm Evolution

Mammoth Specs
- 20 GB Native Cartridge Capacity
- 40 GB Compacted Cartridge Capacity (2:1)
- 3 MB/s Native Data Rate
- 6 MB/s Max Compacted Data Rate (2:1)
- Read Compatible with prior 8mm

Configurations
- Stand Alone
- Small 10-20 Cartridge Libraries (1 or 2 drives)

IBM Storage Solutions

Data for non-IBM products are estimates based on IBM's interpretation and have not been verified by the vendors.
Sony AIT Overview

- Developed by Sony

- Technology
  - 8mm Helical Scan Tape Drive
  - Uses standard 8mm 170 meter AME tape
  - Uses MIC (Memory In Cassette) for faster data access

- Specs
  - 25GB Native Cartridge Capacity
  - 2:1 Compression yields up to 50GB
  - 3MB/sec native data rate
  - Typical max sustained data rate with compression 4MB/s
  - Claim 56sec access time (typically 87sec with get and load)
  - Stand alone drive or 4 cartridge autoloader

- Considerations
  - Incompatible with other 8mm helical scan drives
  - MIC needs host software

IBM Storage Solutions

Data for non-IBM products are estimates based on IBM's interpretation and have not been verified by the vendors.
The VXA Tape Drive

- Manufactured by Ecrix
  - Start up company
  - Founded by 2 ex-STK executives

- Product Claims
  - Writes data in packets rather than tracks
  - Eliminates Backhitching
  - Helical Scan
  - AME Technology
  - 1st of 3 generations

- Tape Media Claims
  - Withstands
    - Boiling, Freezing, Hot Coffee
  - 20,000 media passes
  - 30 year shelf life

VXA-1 Drive

Roadmap Announced on March 1st, 1999

<table>
<thead>
<tr>
<th></th>
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<th>VXA-3</th>
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<td>33</td>
<td>66</td>
<td>135</td>
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<tr>
<td>Data Rate</td>
<td>3</td>
<td>4.5</td>
<td>9</td>
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<tr>
<td>Ship Date</td>
<td>1Q 99'</td>
<td>2Q 00'</td>
<td>2001</td>
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</table>

IBM Storage Solutions

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Data for non-IBM products are estimates based on IBM's interpretation and have not been verified by the vendors.
VXA Technology

VXA Data Packet
- Long strings of data are divided before writing to tape
- Packet contains:
  - Data
  - Synchronisation marker
  - Address information
  - Cyclical Redundancy Check (CRC) code
  - Error Correction Code (ECC)
- To read packets data is put in buffer and reassembled

Variable Speed Option
- Adjusts speed of tape to data transfer rate
- Claimed to eliminate tape repositioning & back hitch

Considerations
- Unproven technology from a small company

IBM Storage Solutions
Highlights
- Relatively large cartridge capacity
- Moderate Data Rates
- Large installed user base (esp. Exabyte)

Considerations
- Reliability Questions
  - Complex Data Path
  - High Media-Head-Roller Contact
  - No servo tracking
- Media shelf life approximately 4 years (except VXA)
- Slow back hitch impacts performance (except VXA)
- Relatively slow time to access data
Longitudinal / Serpentine Data Tracks

IBM 3480
18 Tracks - 1 pass

IBM 3490E
18 Tracks / 2 pass = 36 Tracks

IBM Magstar 3590
1st
2nd
3rd

16 Tracks 8 passes = 128 Tracks (Model B)
16 Tracks 16 passes = 256 Tracks (Model E)

Servo Mechanisms for precision data tracking

Head indexing

Interleaved Tracks for reliable data recovery

Volume Control Region for fast search index

IBM Storage Solutions

Freehand drawing, not precisely to scale
3480/3490/3590 Tape Path

Minimized head contact

Air bearings prevent tape path contact with media surface

Ceramic guides to minimize edge wear

300m length
2m/s reg. speed
5m/s fast search

Simple tape path

IBM Storage Solutions

Minimized Head Wear
Minimized Media Wear
Fast Start - Stop Operations
IBM 3590E Magstar Technology

- Linear Serpentine Recording Technology
  - 20 GB native cartridge capacity
    - 60 GB with 3:1 data compression
  - 40 GB cartridge previewed
    - 120 GB compressed
  - 14 MB/sec data transfer rate
  - Ultra SCSI 40 MB/sec burst rate
    - 34 MB/sec sustained data rate (compressed data)

- Backward read compatibility with 3590B

- Configurations
  - Single or rack mounted drives
  - Large scale automation options including VTS

IBM Storage Solutions
Magstar Technology

Longitudinal Recording

Value = Performance, Data Integrity, Capacity, Drive R.A.S., Media Life

128 Data Tracks
or
256 Data Tracks

Track Following Servo

Value = Data Integrity, Drive R.A.S., Capacity

3 Servo Bands

IBM Storage Solutions
Magstar Head Technology
Read / Write Operations

- Two Sets of Read/Write Heads per Element
  - Writes (or reads) 16 tracks with Read after Write
  - Electronically Switches to Next Read/Write Heads at End of Tape
  - Physically Indexes to Next Index Position
  - Eight Index Positions to Write Entire Tape
Magstar Fast Search Capability

SERPENTINE INTERLEAVED TRACKSETS

Volume Control Region
- Device Block ID Map
- Media Statistics
- Format Identification

IBM Storage Solutions
Magstar Interleaved Longitudinal Recording

- Systematically distributes data horizontally and vertically when recording
- Reassembles data into original order when reading

Additional data bits are written to provide robust data integrity

IBM Storage Solutions
Media errors appear as many small, CORRECTABLE errors
3590 E Model Data Integrity

Tape Experiment:
1. Data written with a 256-track E Model
2. Read verify performed
3. Cut 1.25mm hole in the tape
4. The hole represents an area of approx. 100K bits of data across 33 data tracks
5. Read verify performed
6. Read data operation verifies all data is successfully recovered

Please don't try this at home!

IBM Storage Solutions
Cartridge Design - Magster MP

- Self-contained Tape Path
- Reel to Reel Configuration
- Both Reels on Common Plane
- Midpoint Load
  - "Instant" Loading
  - 25% Search
- Precision Tape Guiding
- Rigid Base Plate
- Reel to Reel Servo Control
Magstar Multi Purpose (3570 MP)

Fast Access Linear Tape Cartridge

- Twin Reels
- Cartridge Door
- Tape Pass to 2nd reel
- Two Servo Tracks
- Volume Control Region
- 128 Tracks in Total Written by 4/8 heads
- This Side Written First
- Head Contact

Optimised for:

Fast Data Access
- High Speed Search (5m/sec)
- Avg. 8 sec to First Byte (loaded cart.)
- Data Rate 7MB/sec (to 14 MB/sec compressed)

High Reliability

High Capacity Cartridge Tape
- 7GB Capacity/21GB with 3:1 Compression
- Long Shelf Life (10 year warranty)
- WORM

Configurations
- Single drive
- Small automation to 420 GB
- Large automation to 6.7 TBs

IBM Storage Solutions
DLT Overview

- Digital Linear Tape
  - First Developed by DEC
  - Bought by Quantum
  - OEM to many other vendors

- A Series of models
  - 2000 (10 GB)
  - 4000 (20 GB)
  - 7000 (35 GB) with 5 MB/sec native data rate
  - 8000 (40 GB) with 6 MB/sec native data rate
  - Super DLT proposed - 100 GB / 10 MB/sec

- Technology
  - Linear recording on 1/2" cartridges
  - Compression typically 2:1

- Configurations
  - Single drive & Mini library (10-15 cartridges / 1-2 drives)
  - Larger automation eg STK & ATL

IBM Storage Solutions

Data for non-IBM products are estimates based on IBM's interpretation and have not been verified by the vendors.
DLT Technology

- Metal Particle Media

- Head Technology
  - Ferrite heads in current versions
  - Magneto Resistive Clusters for Super DLT

- 208 tracks
  - Written 4 at a time (52 passes)
    - results in high media wear
  - Overlap at 8 degree angles
  - No servo tracking
  - No intertrack gaps or gap at edge of tape

- Complex head positioning mechanism.
  - Heads rotate and move up and down to write at a diagonal angle.
  - 6 tape contacts to capstans, used for alignment
  - Start/stop backhitch time of 1-2 second
    - Results in reduced sustained data rates.

IBM Storage Solutions
DLT Considerations

- **Highlights**
  - Large cartridge capacity
  - Large installed base
  - Backward read compatibility

- **Considerations**
  - Complex drive load and unload in automation system
  - Reliability Questions
    - High Contact with head & tape path with media (52 passes)
    - No servo tracking mechanism for precision tracking
    - Rotating heads
  - Moderate backup performance
  - Slow data access time

---

IBM Storage Solutions

Data for non-IBM products are estimates based on IBM's interpretation and have not been verified by the vendors.
The DATA ACCESS Race

25 MB Random Data Transfer Request
Robotic Exchange, Cartridge Load, Search & Reposition, File Transfer, Rewind, and Unload

And the winner is....Magstar MP!

37 Seconds!!

The Data Storage Race

Traditional Backup (save) Performance
Cheyenne Benchmark

GBytes Transferred

Magstar MP Mdl. B

Model C approx. 120GB in 4 hrs.

DLT7000 Mammoth Magstar MP

Rated Speed 5.0 MB/Sec 3.0 MB/Sec 2.2 MB/Sec
Sustained Rates 3.2 MB/Sec 3.7 MB/Sec 4.4 MB/Sec

Source: Cheyenne Software read/write benchmark performed on Windows NT; 11/96

Sustained data rates are dependent upon many factors including the host processor, attachment h/w, applications, and data compression, therefore, results may vary depending on the user environment.

IBM Storage Solutions
The Data Storage Race

Recall Performance

Average System Response Time: 160 Seconds
Avg. Transactions per hour: 2-drive automation

# Transactions/Hour:
Magstar MP rules!

> x 6

File Size 100MB

0 20 40 60 80 100 120 140

Magstar MP Mammoth DLT 7000

# Transactions/Hour:
Magstar MP rules!

> x 10

File Size 200MB

0 20 40 60 80 100

NOTE: This test consists of ad hoc queuing requests for random file locations on the tape. Calculations are estimated based on vendor specs, data rates with no compression. Performance is dependent upon the host processor, attachment h/w, and customer applications, therefore actual customer results may vary.

IBM Storage Solutions
STK Eagle - 9840

- 3480/3490 cartridge shell size
  - Compatible with existing Silos
- 20 GB cartridge native capacity
- Fast-access
  - Two spool mid-point load design
  - 4 sec load & initialize
  - 8 sec avg 1st search to data
- 10 MB/sec drive
  - 20MB/s max sustained
- Tape Speed
  - 2 m/s R/W
  - up to 11 m/s search
- Emulates 3490E
- Enhanced LZ-1 compression
  - 4:1 ratio claimed
- Fully independent power supplies
- Channel interfaces
  (one adapter / drive)
  - 1 ESCON or 1 Ultra-SCSI
    - Fibre Channel (later)
- 288 tracks
  - 16 tracks per pass
- 10-20 drives / silo drive wall

IBM Storage Solutions

Data for non-IBM products are estimates based on IBM's interpretation and have not been verified by the vendors.
## Magstar 3590 compared to 9480

<table>
<thead>
<tr>
<th>Feature</th>
<th>3590 B Model</th>
<th>3590 E Model</th>
<th>9840</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cartridge Native Capacity</td>
<td>10GB</td>
<td>20GB</td>
<td>20GB</td>
</tr>
<tr>
<td></td>
<td>20GB preview</td>
<td>40GB preview</td>
<td></td>
</tr>
<tr>
<td>Cart. Capacity (3:1)</td>
<td>30GB</td>
<td>60GB</td>
<td>80GB</td>
</tr>
<tr>
<td></td>
<td>60GB preview</td>
<td>120GB preview</td>
<td>(4:1)</td>
</tr>
<tr>
<td>Native Data Rate</td>
<td>9MB/s</td>
<td>14MB/s</td>
<td>10MB/s</td>
</tr>
<tr>
<td>Max. Sustained</td>
<td>27MB/s (3:1)</td>
<td>34MB/s</td>
<td>20MB/s</td>
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<tr>
<td>Load/ready</td>
<td>19 seconds</td>
<td>4 seconds</td>
<td>4 seconds</td>
</tr>
<tr>
<td>Ultra SCSI Ports</td>
<td>2</td>
<td>2</td>
<td>1</td>
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<tr>
<td>Virtual Tape Support</td>
<td>Yes</td>
<td>Preview</td>
<td>No (Preview?)</td>
</tr>
<tr>
<td>Media Cost (est. U.S........ street)</td>
<td>$39</td>
<td>$39</td>
<td>$80</td>
</tr>
</tbody>
</table>
Magstar 3590 - 9480 Benchmark

Average Compressed Capacity (GBs)

Max Sustained Compressed Data Rate (MB/s)

Note: Performance measurements were taken in a controlled environment on an RS/6000 H50 with customer data, 256K block size, Ultra-SCSI. Actual customer tape performance results may vary.
STK 9840 Considerations

- Highlights
  - Capacity / Performance
  - 3480 Cartridge Slot Format
  - Number of Drives / Silo Frame Wall
  - Time to Data

- Considerations
  - Proprietary format
  - High media costs
  - Moderate sustained data rate
  - No Servo Track Mechanism?
  - 3490E Emulation
    - No native HSM support limits capacity
  - No ANSI, ECMA, ISO Standard
  - No interchange with other 3490 cartridge formats

IBM Storage Solutions

Data for non-IBM products are estimates based on IBM's interpretation and have not been verified by the vendors.
Benefits of Magstar Longitudinal Technology

- **Mechanical simplicity**
  - Few moving parts
  - Proven durability

- **Start-stop operation**
  - Complete backhitch cycle in fraction of second (450 m/sec)

- **Data integrity**
  - Improved ECC
  - Numerous concurrent data channels
  - Track following servo

- **Lower head wear**
  - Low forces between head and tape minimizes head wear

- **Superior performance**

**Designed to RESTORE your data**

IBM Storage Solutions
IBM & Tape Industry Growth

**RMSS Year-To-Year Growth**

<table>
<thead>
<tr>
<th>Year</th>
<th>Share %</th>
<th>Growth %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td></td>
<td>120%</td>
</tr>
<tr>
<td>1997</td>
<td></td>
<td>126%</td>
</tr>
<tr>
<td>1998</td>
<td></td>
<td>125%</td>
</tr>
</tbody>
</table>

**Tape Industry growth in 1998 = 6%**
IBM growth x4 faster than the industry.

**Volume Market Share %**

**1/2" Drives**

<table>
<thead>
<tr>
<th>Year</th>
<th>IBM</th>
<th>StorageTek</th>
<th>Others</th>
<th>Share %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td></td>
<td></td>
<td></td>
<td>42%</td>
</tr>
<tr>
<td>1998</td>
<td>42%</td>
<td>38%</td>
<td>23%</td>
<td>38%</td>
</tr>
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**1/2" Libraries**

<table>
<thead>
<tr>
<th>Year</th>
<th>IBM</th>
<th>StorageTek</th>
<th>Others</th>
<th>Share %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td></td>
<td></td>
<td></td>
<td>21%</td>
</tr>
<tr>
<td>1998</td>
<td>56%</td>
<td>47%</td>
<td>12%</td>
<td>47%</td>
</tr>
</tbody>
</table>

Source: Dataquest & Freeman reports

IBM Storage Solutions
Linear Tape - Open

Technology Specifications

Magstar 3590 & MP Technologies at the Core

LTO licencees

IBM
HP
Seagate
Accutronics
Alps Electric
FCPA Intellistor
Fujitsu
Fujifilm
Hi/fn
Mountain Engineering
NEC
Philips Semiconductor

IBM Storage Solutions
LTO Formats

IBM Storage Solutions
Ultrium Characteristics

Ultra-high capacity- 200GB with compression (100GB native)

High data integrity and reliability

Single-reel cartridge maximizes capacity

Establishes a new benchmark for large volume backup requirements
## Ultrium Technology Roadmap

<table>
<thead>
<tr>
<th></th>
<th>Generation 1 1Q00</th>
<th>Generation 2</th>
<th>Generation 3</th>
<th>Generation 4</th>
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</thead>
<tbody>
<tr>
<td><strong>Capacity - Native</strong></td>
<td>100GB</td>
<td>200GB</td>
<td>400GB</td>
<td>800GB</td>
</tr>
<tr>
<td><strong>Capacity - Compressed</strong></td>
<td>200GB</td>
<td>400GB</td>
<td>800GB</td>
<td>1600GB</td>
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<tr>
<td><strong>Transfer Rate - Native</strong></td>
<td>10-15MB/s</td>
<td>20-40MB/s</td>
<td>40-80MB/s</td>
<td>80-160MB/s</td>
</tr>
<tr>
<td><strong>Transfer Rate - Compressed</strong></td>
<td>20-40MB/s</td>
<td>40-80MB/s</td>
<td>80-160MB/s</td>
<td>160-320MB/s</td>
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<tr>
<td><strong>Media</strong></td>
<td>Metal Particle</td>
<td>Metal Particle</td>
<td>Metal Particle</td>
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<tr>
<td><strong>Attachments</strong></td>
<td>SCSI-2 Ultra-SCSI</td>
<td>Fibre</td>
<td>SAN</td>
<td>SAN</td>
</tr>
</tbody>
</table>

* 2X Compression Assumed

---

**IBM Storage Solutions**
• Optimized for fast access to data (under 10 Seconds) (Utilizes Magstar MP design & Concepts)

• High data integrity and reliability

• Two-reel cartridge loads at tape midpoint (Minimizes access time)

• Online data inquiry, image retrieval, and data mining

• Excellent backup, restore and archive characteristics
# Magstar MP 3570/Accelis Roadmap

<table>
<thead>
<tr>
<th></th>
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<tr>
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<td>Native</td>
<td>5 GB</td>
<td>7.5 GB</td>
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<td>50 GB</td>
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<td>200 GB</td>
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<td>Compressed*</td>
<td>10 GB</td>
<td>15 GB</td>
<td>50 GB</td>
<td>100 GB</td>
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<td><strong>Access Time</strong></td>
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<td>&lt; 7 Seconds</td>
<td>&lt; 10 Seconds</td>
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<tr>
<td>Native</td>
<td>7 MB/s</td>
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<td>Metal Particle</td>
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<td>Thin Film</td>
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<td>SCSI-2</td>
<td>SAN</td>
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</tbody>
</table>

* 2X Compression Assumed, 3X Frequently Achieved
Magstar 3590 Characteristics

- Optimized for Mainframe / High End server requirements
- Cartridge matched to broad set of automation solutions
- Highest data transfer rates
- Highest data integrity and reliability
- True start-stop operation and performance
- Broadest attachability
# Magstar 3590 Roadmap

<table>
<thead>
<tr>
<th>Capacity - Native</th>
<th>Magstar 3590 B1x 9</th>
<th>Magstar 3590 E1x</th>
<th>Magstar 3590 Generation 1 with LTO</th>
<th>Magstar 3590 Generation 2 with LTO</th>
<th>Magstar 3590 Generation 3 with LTO</th>
<th>Magstar 3590 Generation 4 with LTO</th>
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<tr>
<td>Capacity - Compressed*</td>
<td>10/20GB</td>
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<td>20/40GB</td>
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<td>Add FICON Add FC-AL in 1Q00</td>
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</tr>
</tbody>
</table>

* 2X Compression Assumed, 3X Frequently Achieved
**Option for WORM Media with Model B2x

**SAN**

IBM Storage Solutions
IBM Tape Drive Strategy

**3590**
- 128 Tracks
- 20 GB
- Media Reusability
- Native Ultra-SCSI Attach
- Field Upgrades
- FC-AL to SCSI Bridge
- 256 Tracks
- 20/40 GB (Backward Read)
- (Media Compatibility) 14 MB/Sec
- Faster Load/Thread
- Field Upgrades
- FICON

**3590-LTO**
- 100 GB Or More
- ~ 25-30 MB/Sec
- Migration Services Provided

- Products with "LTO" Technology

**3570**
- Ultra-SCSI/Fibre
- 10GB Capacity
- 3494 Library

**3490**
- Model F ESCON and OEMI Attachment
- 3494 Library and Standalone Support

**IBM Tape Drive Strategy**

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<thead>
<tr>
<th>Year</th>
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IBM Tape Formats

Magstar 3590

Magstar MP & ACCELIS

ULTRIUM

3490E
IBM Tape Positioning

<table>
<thead>
<tr>
<th>Magstar 3590</th>
<th>Magstar MP &amp; Accelis</th>
<th>Ultrim</th>
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<td>Non-IBM UNIX</td>
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<td>AS / 400</td>
<td>Non-IBM Proprietary</td>
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<td>PC LAN</td>
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</tbody>
</table>

IBM Storage Solutions
Summary

- Technology enables product attributes which translate to Business Value
- Customer investment in tape storage products should be evaluated with particular attention to underlying technology - not just looking at "speeds and feeds" claims
- IBM Tape Technology has demonstrated innovation, leadership, and set the standard in enterprises for over 46 years
- The IBM Magstar brand of tape products exemplifies tape technology leadership and innovation
- IBM Magstar Plus LTO technology enables products which address a broad array of customer requirements with rich and long product roadmaps
Head / Disk Interface

Suspension

Cables

Thinfilm inductive / MR element

Airflow

Lubrication Film
Carbon overcoat

Head
$\text{Al}_2\text{O}_3 - \text{TiC}$

Flying Height
$> 0.05 \mu\text{m}$

Magnetic Layer

Undercoat

Disk Substrate
$10 - 34 \text{ m/sec at 7200 rpm}$

IBM Storage Solutions
Thin Film Disk Technology

Laser textured landing zone

Lubricant (1nm)
C Overcoat (10 nm)
CoPtCr Magn. Layer (25 nm)
Cr Underlayer (25 nm)
NiP Underlayer (10 µm)
Aluminium or Glass Substrate
Higher bit densities and faster rotation requires improved data channel technology.
Partial Response Maximum Likelihood Channel

Closer, smaller bits increase chance of overlap errors

- Conventional channel detects peak of pulse
- PRML samples shape of pulse
- Two close transitions superimposed are detected with PRML
- Transition spacing can be closer
- Detector locates sequence most likely to explain all data
- Smoothes noise over sample set improves Signal to Noise Ratio performance

IBM Storage Solutions