Advanced Storage Technology- Trends in Magnetic Hard Disk Drives

Ed Grochowski
Program Manager of Storage Devices
IBM Almaden Research Center
San Jose, CA 95120-6099

Eighth NASA Goddard Space Flight Center Conference
Mass Storage Systems and Technologies
17th IEEE Symposium Mass Storage Systems
University of Maryland, College Park, Maryland
March 27-30, 2000

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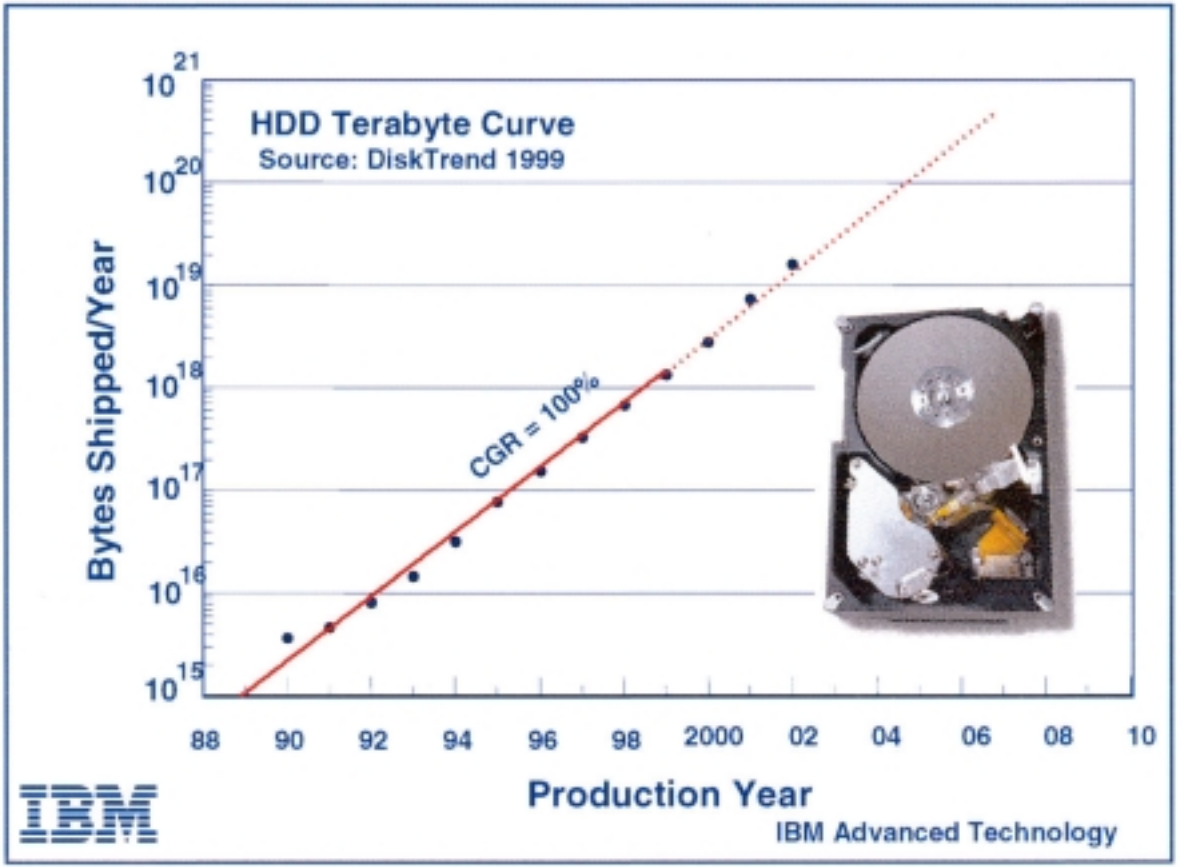
HDD Terabyte Curve
Source: DiskTrend 1999
Bytes Shipped/Year
10^{21}
10^{20}
10^{19}
10^{18}
10^{17}
10^{16}
10^{15}
CGR = 100%
88
90
92
94
96
98
2000
02
04
06
08
10
Production Year
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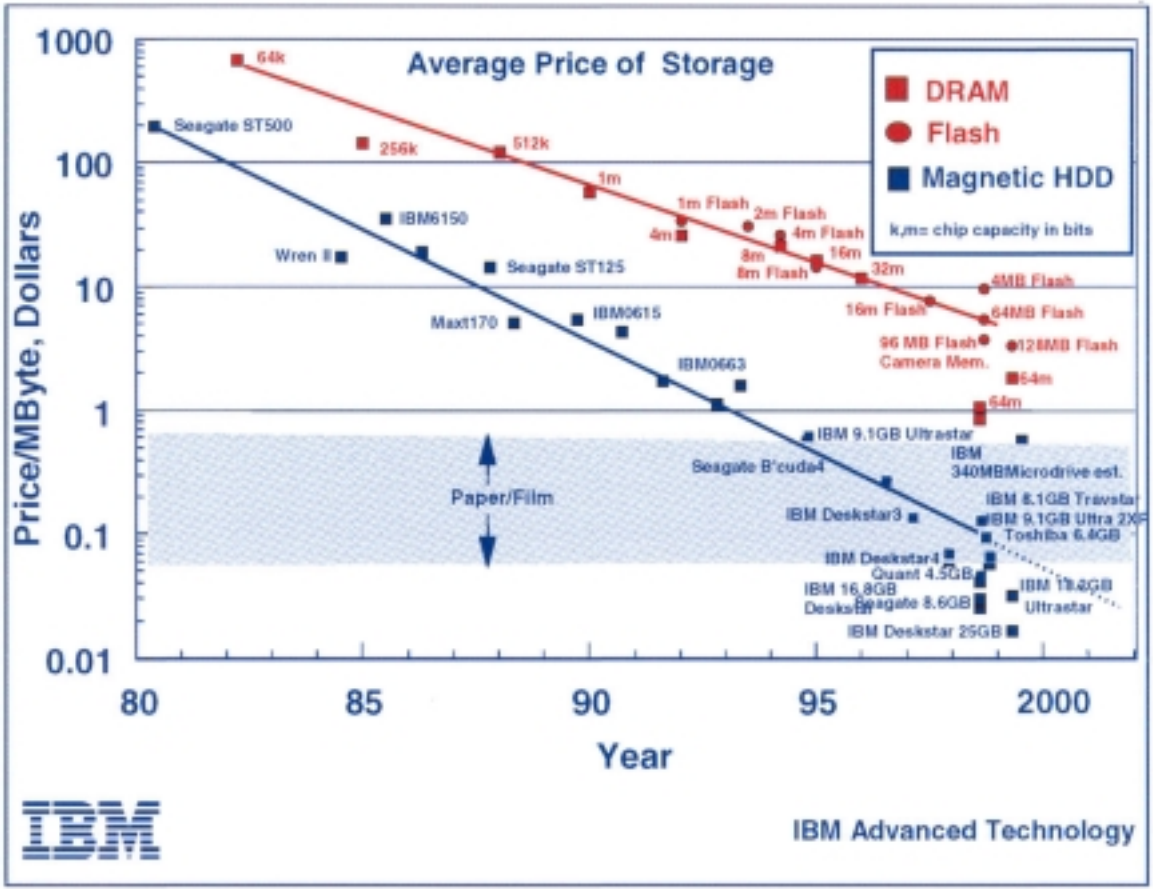
Average Price of Storage
DRAM
Flash
Magnetic HDD
k,m= chip capacity in bits
Price/MByte, Dollars
Year
1000
100
10
1
0.1
0.01
80
85
90
95
2000
64k
256k
512k
1m
1m Flash
2m Flash
4m Flash
4m
8m
8m Flash
16m
32m
16m Flash
4MB Flash
64MB Flash
96 MB Flash
Camera Mem.
128MB Flash
64m
64m
Seagate ST500
IBM6150
Wren II
Seagate ST125
Maxt170
IBM0615
IBM0663
IBM 9.1GB Ultrastar
Seagate B'cuda4
IBM 340MBMicrodrive est.
IBM 8.1GB Travsta
IBM 9.1GB Ultra 2X
Toshiba 6.4GB
IBM Deskstar3
IBM Deskstar4
Quant 4.5GB
IBM 16.8GB
Seagate 8.6GB
IBM 18.2GB
Ultrastar
IBM Deskstar 25GB
Paper/Film
IBM
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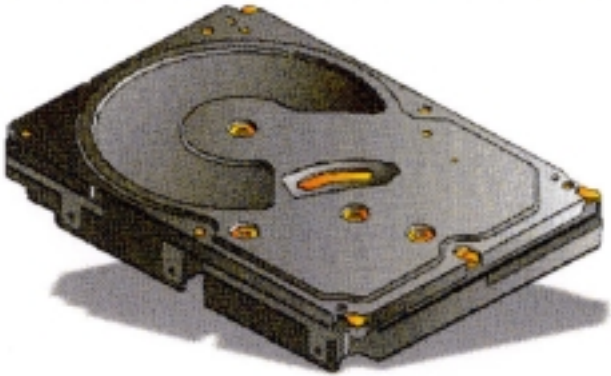
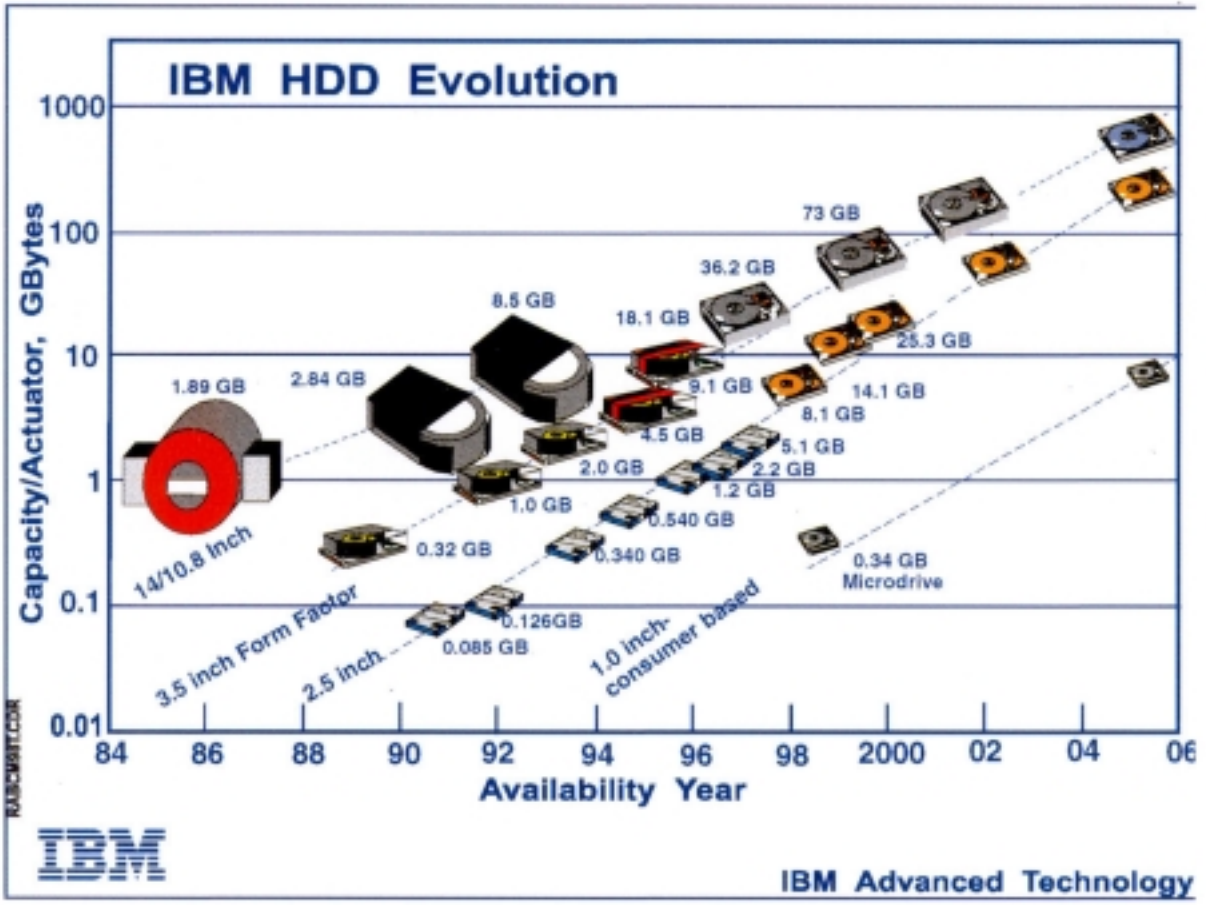
Assembling a Disk Drive




IBM HDD Evolution
Capacity/Actuator, GBytes
1000
100
10
1
0.1
0.01
84
86
88
90
92
94
96
98
2000
02
04
06
Availability Year
1.89 GB
2.84 GB
8.5 GB
18.1 GB
36.2 GB
73 GB
9.1 GB
25.3 GB
14.1 GB
8.1 GB
4.5 GB
5.1 GB
2.0 GB
2.2 GB
1.2 GB
1.0 GB
0.540 GB
0.32 GB
0.340 GB
0.34 GB
Microdrive
0.126GB
0.085 GB
14/10.8 Inch
3.5 inch Form Factor
2.5 inch
1.0 inch-
consumer based
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HDD Design Projections

	1999	2000	2002	2004	2006
Server 3.5 Inch HDD 41.3 mm high 	36GB 10000 RPM 5.4ms Tseek	73 GB 10000 RPM 4.9ms Tseek	73GB 15000 RPM 4.5ms Tseek		
Entry-Server 3.5 Inch HDD 25.4 mm high 	37 GB 7200 RPM 8.5 ms Tseek	50 GB 7200 RPM 8.5 ms Tseek	72 GB 10000 RPM 7.0 ms Tseek	150 GB 15000 RPM 4.0 ms Tseek	300 GB 15000 RPM 3.0 ms Tseek
Mobile 2.5 Inch HDD 9.5/12.5/17 mm high 	25 GB 5400 RPM 12 ms Tseek	35 GB 5400 RPM 10 ms Tseek	50 GB 5400 RPM 9.0 ms Tseek	100 GB 7200 RPM 7.0ms Tseek	150 GB 10000 RPM 5.0ms Tseek
Consumer 1.0 Inch HDD 5.0 mm high 	0.34 GB 4500 RPM 15 ms Tseek	0.6 GB 4500 RPM 15 ms Tseek	1.3 GB 4500 RPM 15 ms Tseek	3.2 GB 5400 RPM 12 ms Tseek	6.0 GB 5400 RPM 10 ms Tseek

IBM Microdrive-A New Disk Drive Technology

- 340 MB CF Type II format, removable HDD, 43 x 36 x 5 mm
- GMR Heads, 1 inch diameter glass disk, ramp load/unload
- Weight 17 g
- Handheld market: digital cameras, cellular phones, palmtop computers
- High capacity alternative to flash cards
- 15 ms average seek time, 49 mbits/sec. media transfer rate

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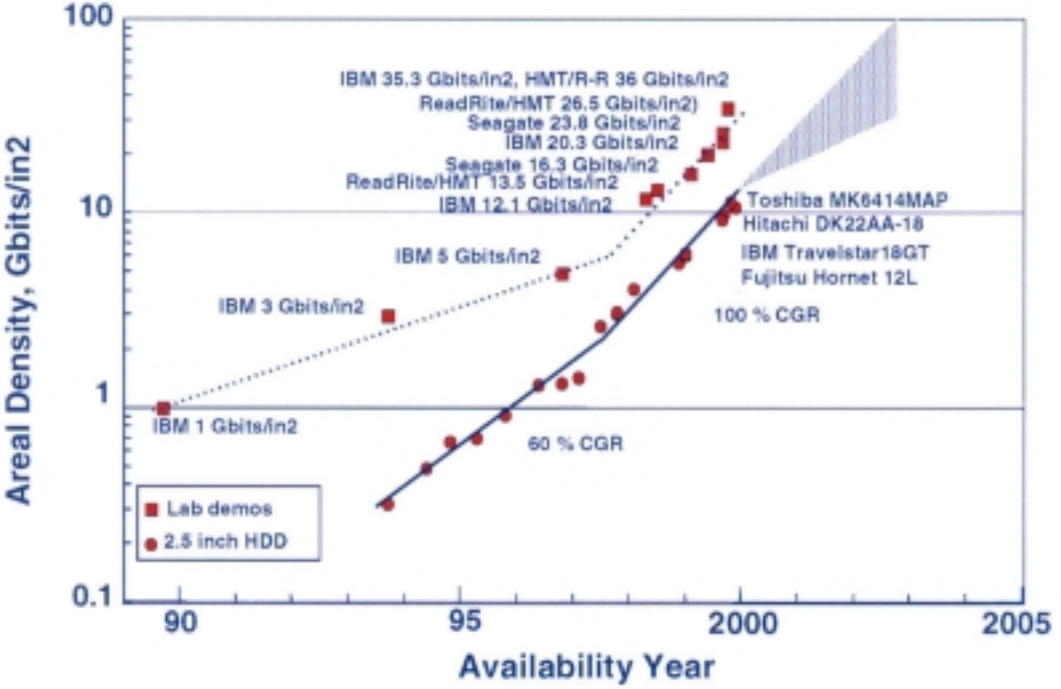
Areal Density Progress



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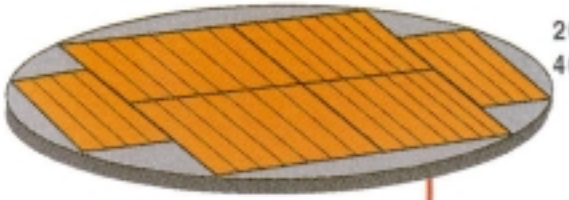
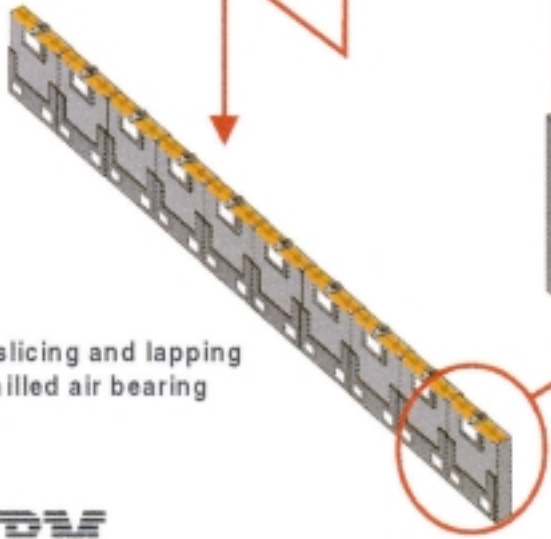
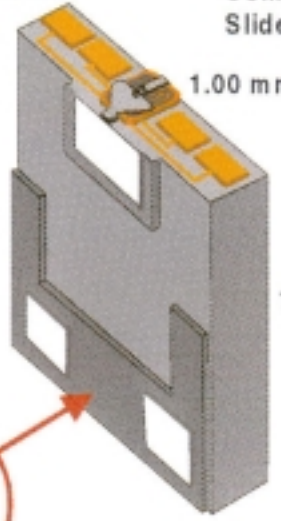
Magnetic Head/Slider/Air Bearing Design



200 mm Ceramic Wafer
40,000 Read/Write Heads



Row slicing and lapping
RIE milled air bearing



0.30 mm

Completed Pico Slider

1.00 mm

1.25 mm

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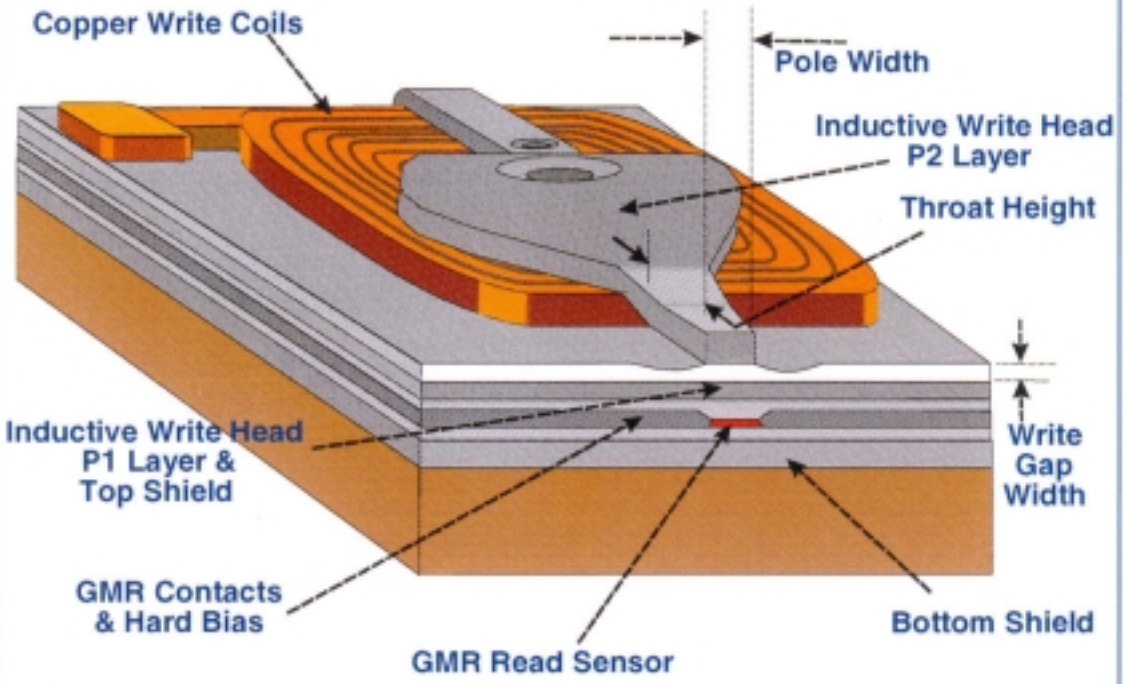
rheadprc.cd

Inductive Write/GMR Read Head Structure



GMR-READ.CDR

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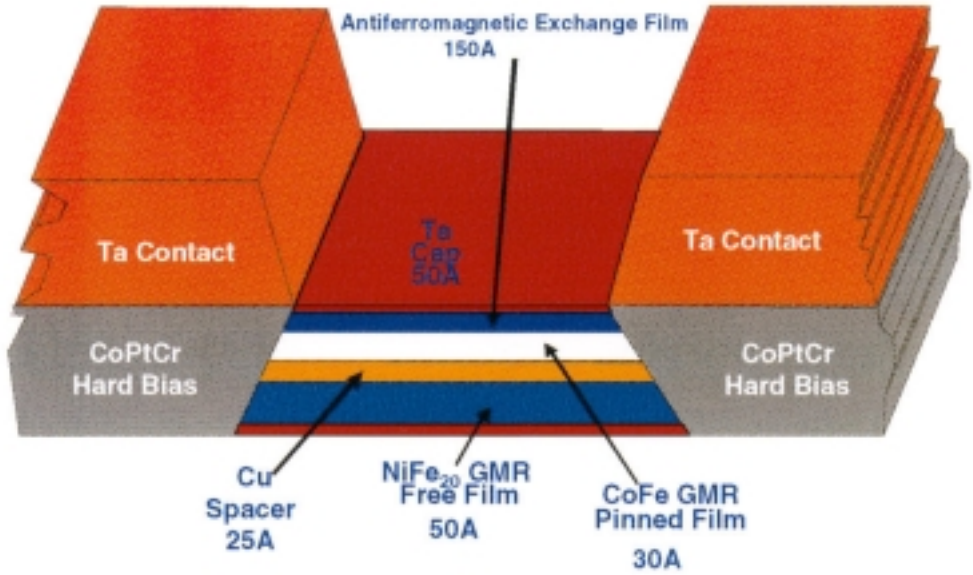
GMR Read Head Structure

Spin Valve/GMR Sensor



GMR2000A.CDR

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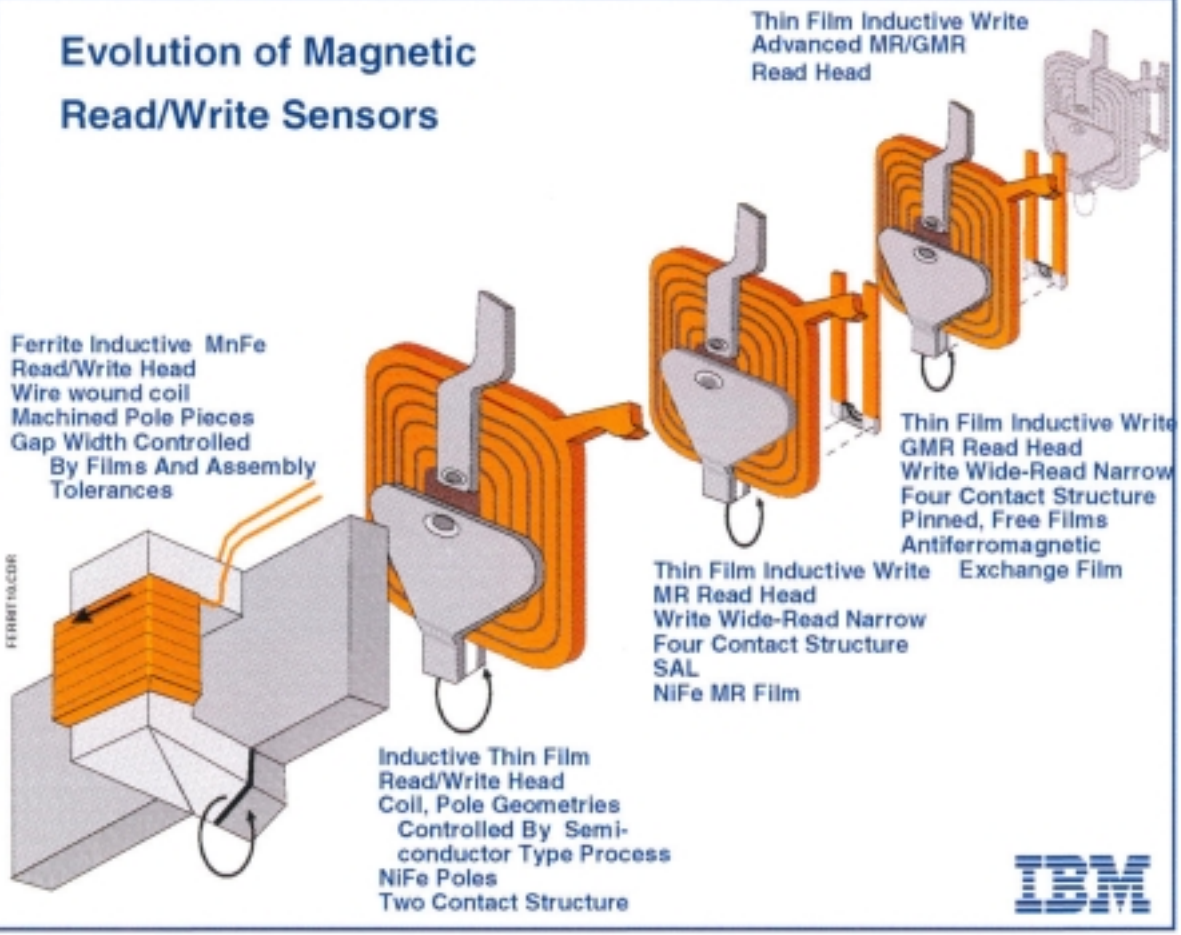
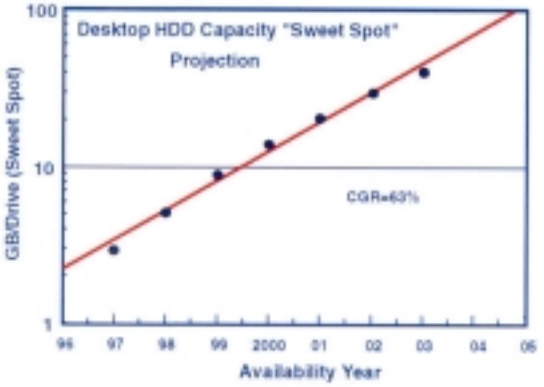
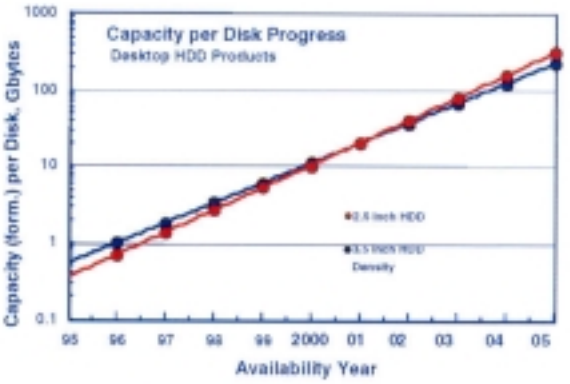
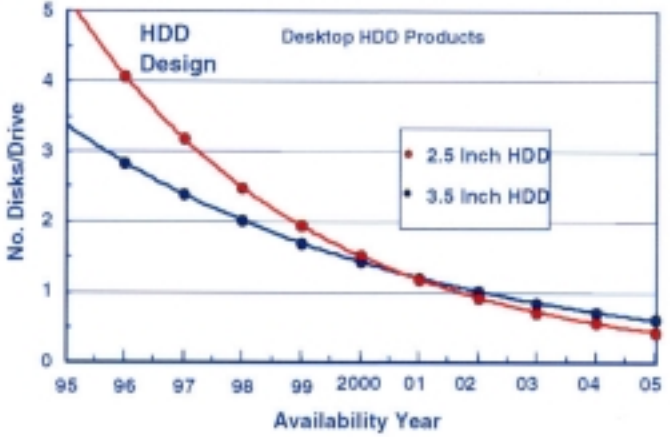
Evolution of Magnetic Read/Write Sensors




Desktop HDD Capacity "Sweet Spot"
Projection
CGR=63%
GB/Drive (Sweet Spot)
100
10
1
96 97 98 99 2000 01 02 03 04 05
Availability Year


Capacity per Disk Progress
Desktop HDD Products
Capacity (form.) per Disk, Gbytes
1000
100
10
1
0.1
95 96 97 98 99 2000 01 02 03 04 05
Availability Year


HDD
Design
Desktop HDD Products
2.5 Inch HDD
3.5 Inch HDD
No. Disks/Drive
5
4
3
2
1
0
95 96 97 98 99 2000 01 02 03 04 05
Availability Year

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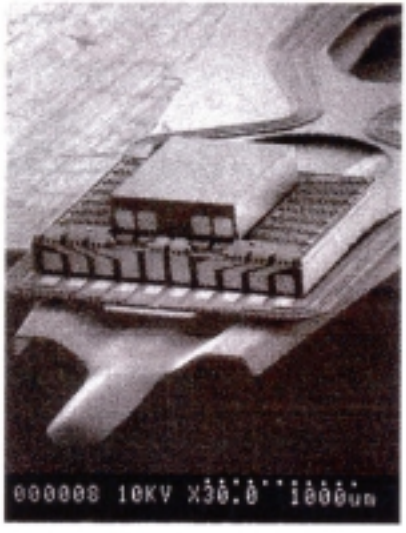
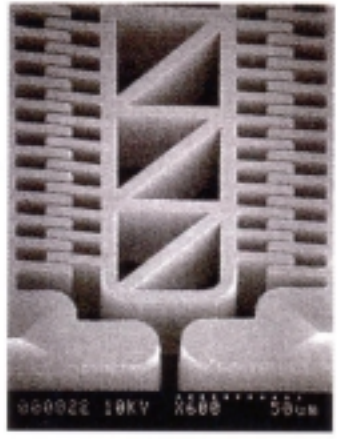
Microactuator for Precision Track Following

A secondary actuator between the suspension and slider can provide precise head positioning over the data track. Motion of the head results when voltage is applied to this actuator.





A MEMS (micromachined electromechanical systems) microactuator device fabricated using semiconductor processes with a four μm thickness over a 40 μm height.

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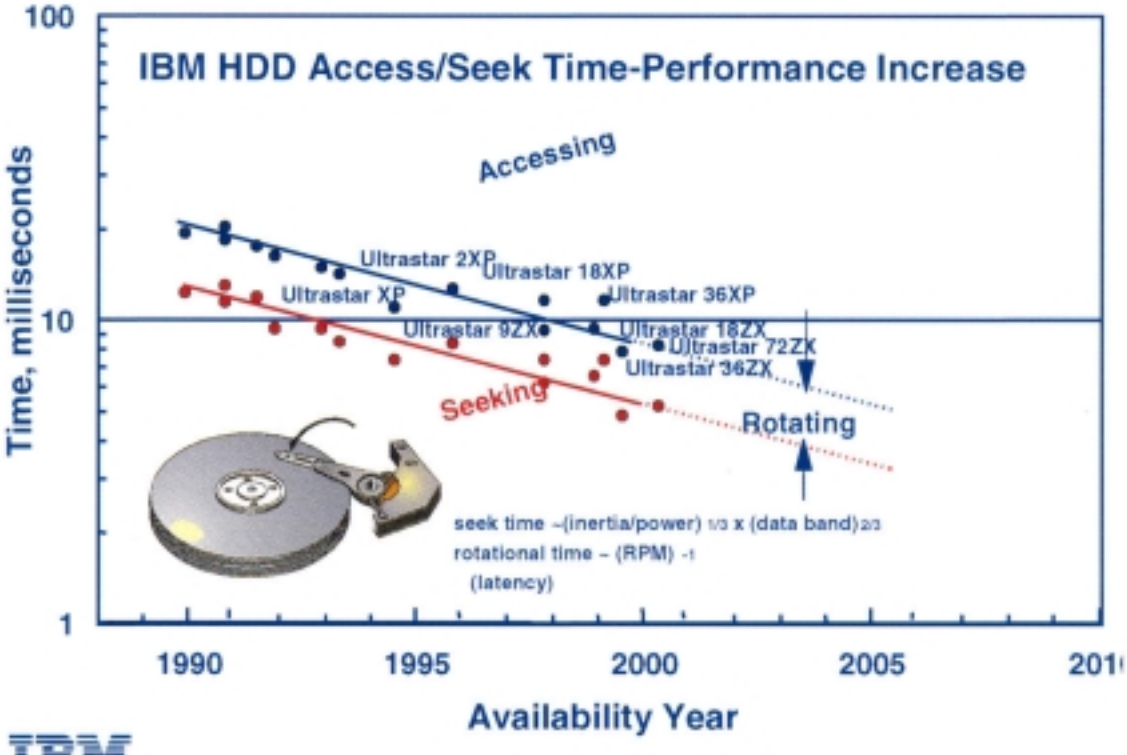

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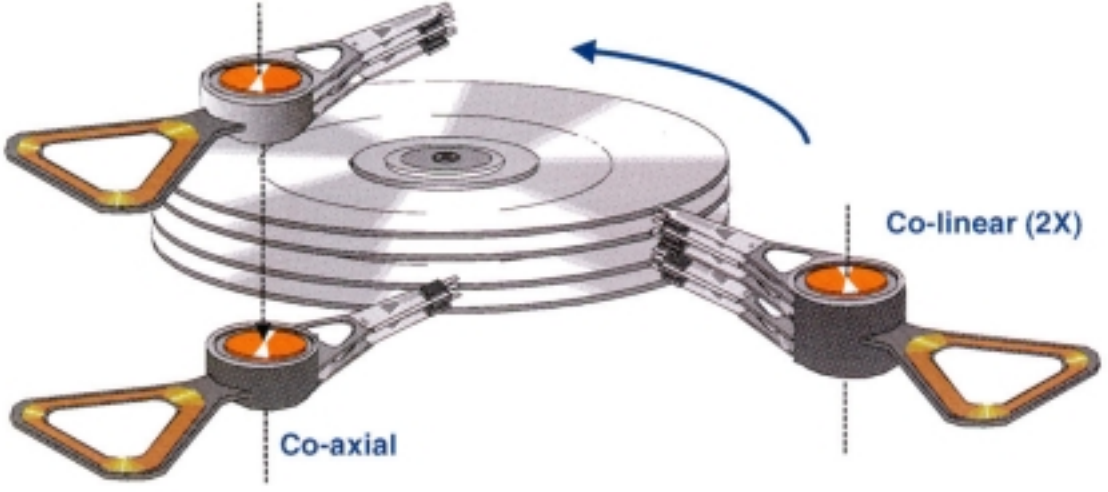
Dual Actuator Technology



Advantages

Significant reduction in seek and latency times, access time

Disadvantages

2X Actuator motors
2X Heads, suspensions, arms (co-linear)
2X Key electronic components
Space, power constraints
Cost increase

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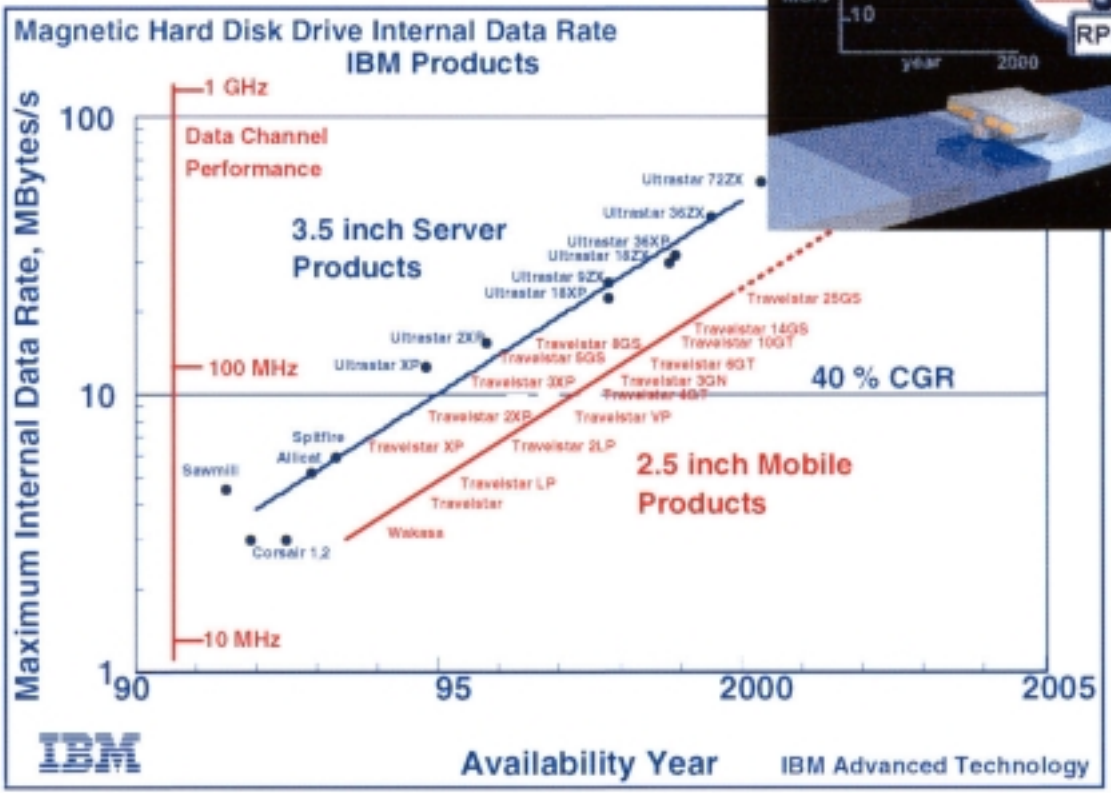
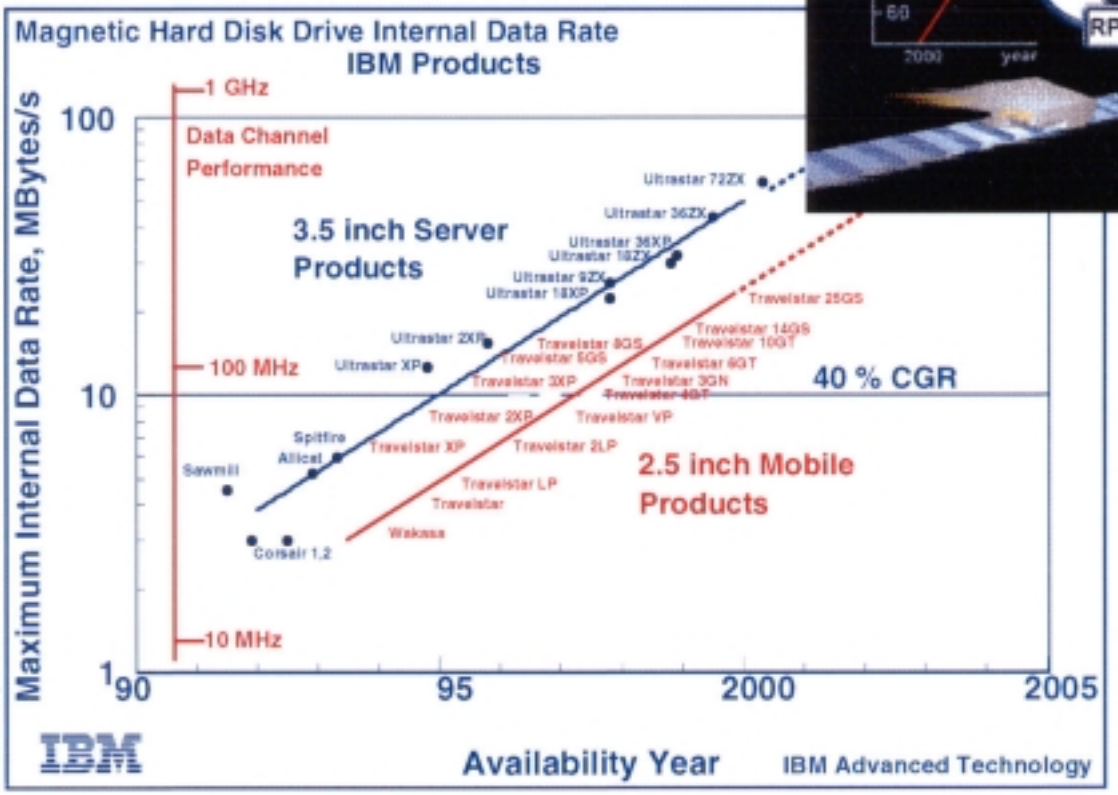
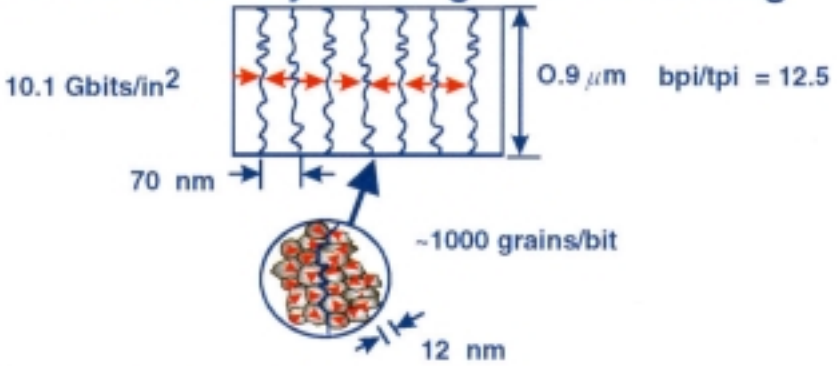
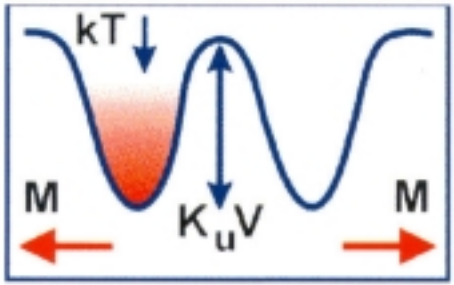

Magnetic Hard Disk Drive Internal Data Rate
IBM Products
Maximum Internal Data Rate, MBytes/s
100
10
1
1 GHz
Data Channel
Performance
100 MHz
10 MHz
3.5 inch Server
Products
2.5 inch Mobile
Products
40 % CGR
Ultrastar 72ZX
Ultrastar 36ZX
Ultrastar 36XP
Ultrastar 18ZX
Ultrastar 9ZX
Ultrastar 18XP
Ultrastar 2XP
Ultrastar XP
Travelstar 25GS
Travelstar 14GS
Travelstar 10GT
Travelstar 8GS
Travelstar 6GS
Travelstar 6GT
Travelstar 3GN
Travelstar 3XP
Travelstar 2XP
Travelstar VP
Travelstar 2LP
Travelstar XP
Spitfire
Allicet
Sawmill
Travelstar LP
Travelstar
Wakasa
Corsair 1,2
90
95
2000
2005
Availability Year
IBM Advanced Technology
IBM
Data Rate
MB/s
40
10
year
2000
7200
3600
RPM


Magnetic Hard Disk Drive Internal Data Rate
IBM Products
Maximum Internal Data Rate, MBytes/s
100
10
1
1 GHz
Data Channel
Performance
100 MHz
10 MHz
3.5 inch Server
Products
2.5 inch Mobile
Products
40 % CGR
Ultrastar 72ZX
Ultrastar 36ZX
Ultrastar 36XP
Ultrastar 18ZX
Ultrastar 9ZX
Ultrastar 18XP
Ultrastar 2XP
Ultrastar XP
Travelstar 32GS
Travelstar 14GS
Travelstar 10GT
Travelstar 6GS
Travelstar 6GT
Travelstar 3XP
Travelstar 3GN
Travelstar 40GT
Travelstar 2XP
Travelstar VP
Spitfire
Allicat
Travelstar XP
Travelstar 2LP
Sawmill
Travelstar LP
Travelstar
Wakasa
Corsair 1,2
90
95
2000
2005
Availability Year
IBM
IBM Advanced Technology
Data
Rate
>60
MB/s
60
2000
year
7200
3600
RPM

Thermal Stability for Magnetic Recording





$$\tau = \tau_0 e^{\frac{K_uV}{kT}}$$

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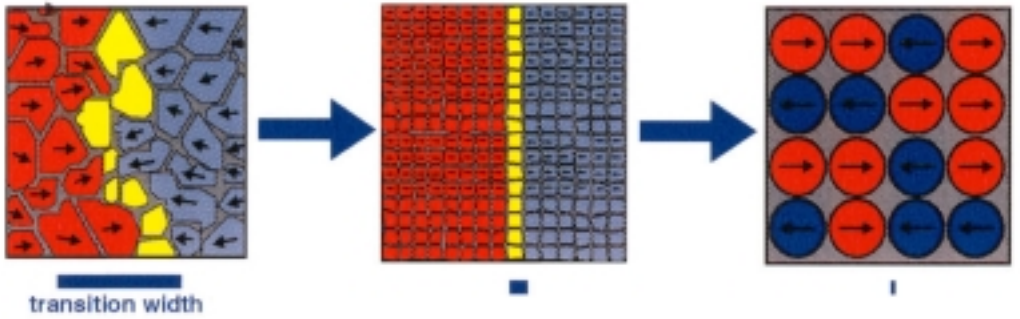
The Perfect Magnetic Medium



TODAY	NEAR FUTURE	FUTURE
• large random grains • broad noisy transitions • thermally stable	• small uniform grains • sharper transitions • less thermally stable	• patterned single bits-ultimate single grain/bit • sharper transitions • thermally stable

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Projected Year 200X Storage Array System

36 Gbyte Disk Drive
2.5 Inch
15K RPM
Dual Actuator
Access 3ms

72 Gbyte Disk Drive
3.25 Inch
10K RPM
Access 7 ms

Per Drawer
8 – 36 GB 2.5 Inch Drives
8 – 72 GB 3.25 Inch Drives
0.6 TB RAID 5

- >6TB – RAID 5
- 80 – 36 GB 2.5 Inch Drives
- 80 – 72 GB 3.25 Inch Drives
- 3+P Fault Tolerance Array
- 4 Arrays per Drawer
- Integrated Tape/DVD Libraries

RAMAC17.CDR

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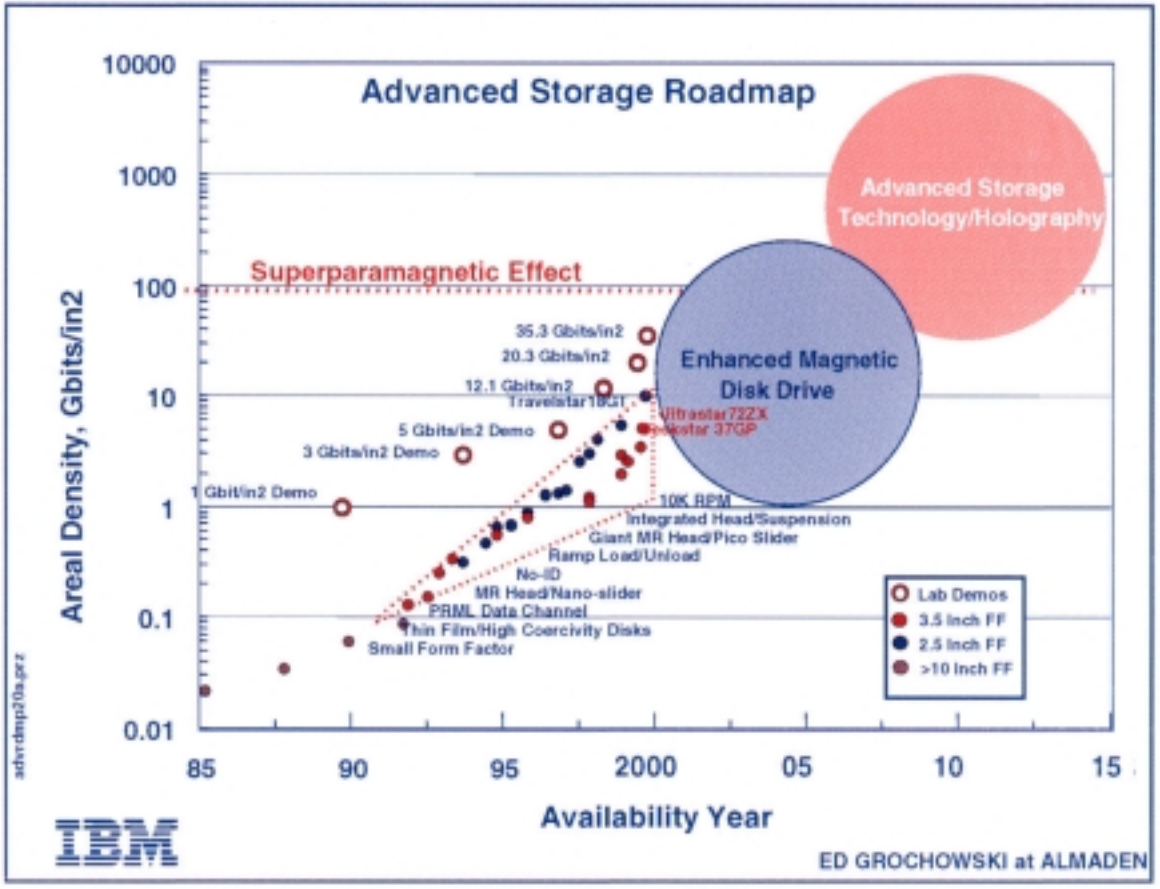
Advanced Storage Roadmap
Areal Density, Gbits/in2
Availability Year
10000
1000
100
10
1
0.1
0.01
85
90
95
2000
05
10
15
Superparamagnetic Effect
Advanced Storage Technology/Holography
Enhanced Magnetic Disk Drive
35.3 Gbits/in2
20.3 Gbits/in2
12.1 Gbits/in2
Travelstar18GT
Ultrastar72ZX
Deskstar 37GP
5 Gbits/in2 Demo
3 Gbits/in2 Demo
1 Gbit/in2 Demo
10K RPM
Integrated Head/Suspension
Giant MR Head/Pico Slider
Ramp Load/Unload
No-ID
MR Head/Nano-slider
PRML Data Channel
Thin Film/High Coercivity Disks
Small Form Factor
Lab Demos
3.5 Inch FF
2.5 Inch FF
>10 Inch FF
advrdmp20a.grz
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Conclusions/Summary

- 43 Years Of HDD Innovations Have Greatly Expanded Capacity and Performance, Reduced Price And Increased Applications
- Currrent HDD Products Have Achieved >10 Gbits/in^2
- Magnetic Heads Have Been Demonstrated At >35 Gbits/in^2 In Lab
- GMR Technology Should Sustain Areal Densities >60 Gbits/in^2
- Lower Head/Disk Spacings (<15 nm) Require Super Smooth Disks, Ramp Load/Unload, Glass Substrates
- Disk Drive Enhancements Are Required, MEMS, Dual Actuators
- Challenges of Superparamagnetism Will Be Addressed
- Magnetic Products Will Continue To Dominate Storage Industry Well Into The Next Millenium