

**THE DISK DRIVE
50 YEARS OF PROGRESS AND TECHNOLOGY INNOVATION
(THE ROAD TO 2 BILLION DRIVES)
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OVERVIEW / HISTORY

The hard magnetic digital disk drive as we know it today is used in all computer applications, in home appliances and PVR/DVR's; in automobiles, cameras, medical applications. It is now pervasive in all segments of our society.

The technology got its start in IBM's San Jose laboratories in 1952, with innovators, such as Rey Johnson, Dr. Al Hoagland, Al Shugart, Bobby Smith, and others.

The disk drive is unique in its history for overall cost reductions, while at the same time fostering rapid technology growth, and reaping amazing production ramps. Success in this industry has been associated with:

- Device Size reduction
- Ongoing and substantial cost reduction per MB
- Dramatic Technology Increases
- High Volume Production efficiencies.

As a result of the above accomplishments the industry has grown from a volume of several thousand disk drives per year, in the 1950's to over 260 Million drives per year in 2003.

The first digital hard disk drive was the 24 inch IBM 350-1 which was announced in 1955, and began shipping in 1956. This drive housed 50 24-inch disks, had an access time of 600 milliseconds, and a capacity of 5.0 Megabytes. Table 1 compares the specs on the 350 with the most recent Seagate Barracuda 7200.7 disk drive of 2003.

Table 1
Disk Drive Comparisons

	1956	2003
Manufacturer	IBM	Seagate
Model	350-1	7200.7
Capacity (MB)	4.4 MB	200 GB
Disk Size	24 In.	3.5 In.
No. Disks	50	3
RPM	1,200	7,200
Bit Density (BPI)	105	667,000
Track Density (TPI)	20	98,000
Areal Density (BPI)	2,100	63.36 Billion
Access Time (msec.)	600	8.5

During this same period of time and due to the technology, and production volumes, the cost of magnetic disk storage has decreased from \$2,057.00 per Megabyte in the 1960's to \$.005 today, and the price per MB will continue to decrease in the future (Table 2).

Table 2
Disk Drive Price Per MB History

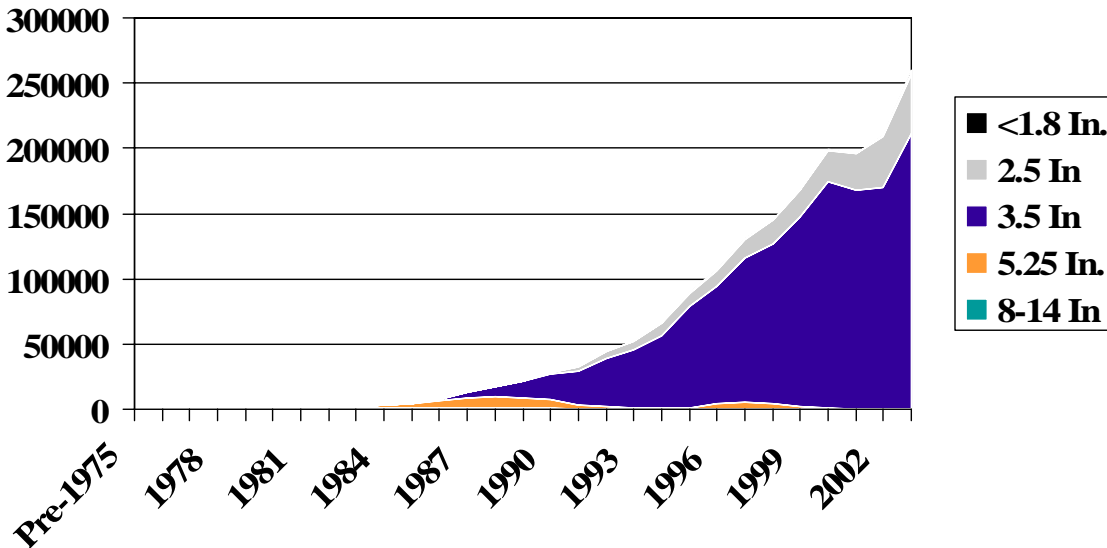
Year	Notes	Overall \$ per MB
1965	(2311 Disk Drive)	\$ 2,057.61
1971	(3330 Disk Drive)	\$ 300.00
1988		\$ 11.54
1990		\$ 6.86
1993		\$ 1.46

1995	\$.33
1998	\$.046
2000	\$.018
2003	\$.005

Source: Disk / Trend, Industry Data

The yearly volume demand of disk drives has, with the exception of 2001; increased each year since the late 1970's. Figure 1 shows the annual production of disk drives by form factor from 1975-2004. This data has been gathered yearly by Disk / Trend to 1999 and Peripheral Research and Coughlin Associates for 2000 on.

Figure 1. Disk Drive Production Per Year, 1975-2004



As we can see from Figure 2, sometime during the third quarter of 2004, the disk drive industry will reach a historical cumulative shipment level of 2 Billion disk drives, and will reach the 3.5 Billion mark within the next 3.5 years. The fastest growing segment in disk drive unit growth is for consumer electronic applications. Table 3 indicates 2003 shipments into the consumer electronics industry. CE disk drives will approach the numbers of disk drives used for conventional desktop computer applications by 2010.

Figure 2. Cumulative Shipments of HDDs (in 1000s)

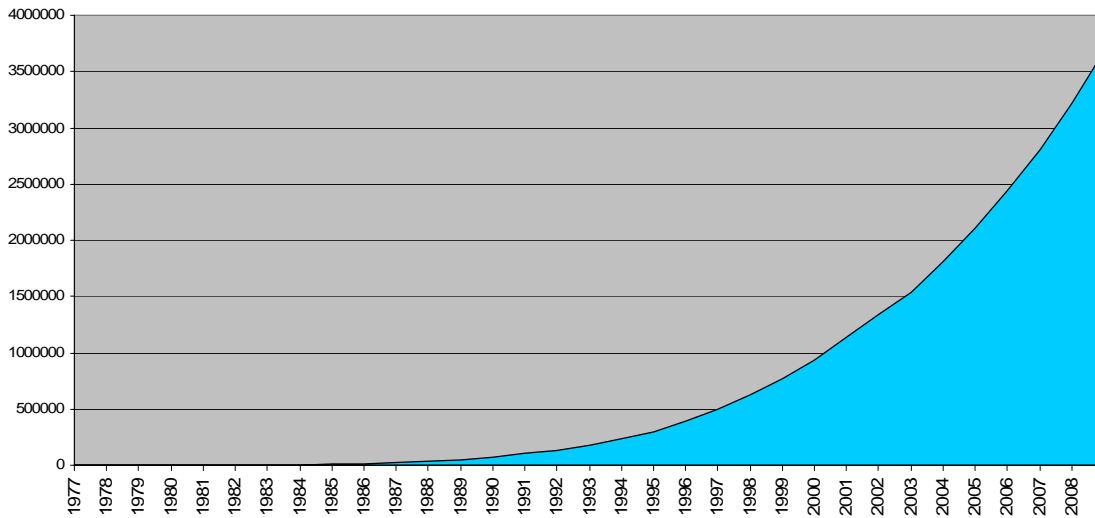


Table 3

Disk Drives Sold into the Consumer Electronics Industry

Applications	Units (thousands)
Games	5,300
PVR/DVRs	9,040
AV Players	3,980
Digital Still Cameras	615
Digital Video Cameras	140
Other CE	3,000
Total	22,075

Source: Coughlin Associates

To accomplish these volumes, technology feats, and production numbers; the disk drive industry grew in number of participant companies from initially IBM and a few other early companies, to approximately 136 competing companies in the mid 1980's. Due to intense competition and pricing wars, industry consolidation has decreased this number to the 9 companies that exist in 2004 (see Tables 4, 5 and 6).

Of the 9 companies in 2004 two of those are recent start-up companies focusing on the small disk drives for the Consumer Electronics markets (Cornice and GS MagicStor).

OTHER TECHNOLOGIES

Throughout the last 50 years there have been many other competing companies, with technologies that have threatened the future of disk storage. These include:

- Solid State Memory (many different types)
- Magnetic Bubble Memory
- Optical Tapes
- Optical Disks
- MRAM
- Probe Storage

However to date none of these technologies has been able to duplicate the momentum behind disk drive technology, and the dedicated, relentless striving for higher performance, and lower cost. Additionally as each year has gone by the production volumes have become higher, and production efficiencies have become better, leading to ever cheaper disk drives.

In the 1950's through the 1990's magnetic tape was widely used as a key storage component. Today tape continues to be used for back-up and archiving; with ATA-based RAID storage systems being increasingly used for primary back-up and tape as final archive storage.

Solid State memory is widely used in Solid State Disks and Flash memory. Due to the higher cost per megabyte of semiconductor memory it is not used for mass storage applications. For Digital Cameras and today's cell phones Flash memory is widely used and is cost effective versus most of the alternative storage options. Solid state disk drives are used in high performance enterprise systems, and military systems to speed up data processing; however they are usually used in conjunction with disk drives.

COMPONENT TECHNOLOGIES

Disk drive technology growth has been very dependent on drive components, and sub-assemblies. These small parts require exact, efficient construction.

Disk Drive magnetic heads, magnetic media, motors, positioning systems and electronic circuits are the major areas of disk drive technology growth.

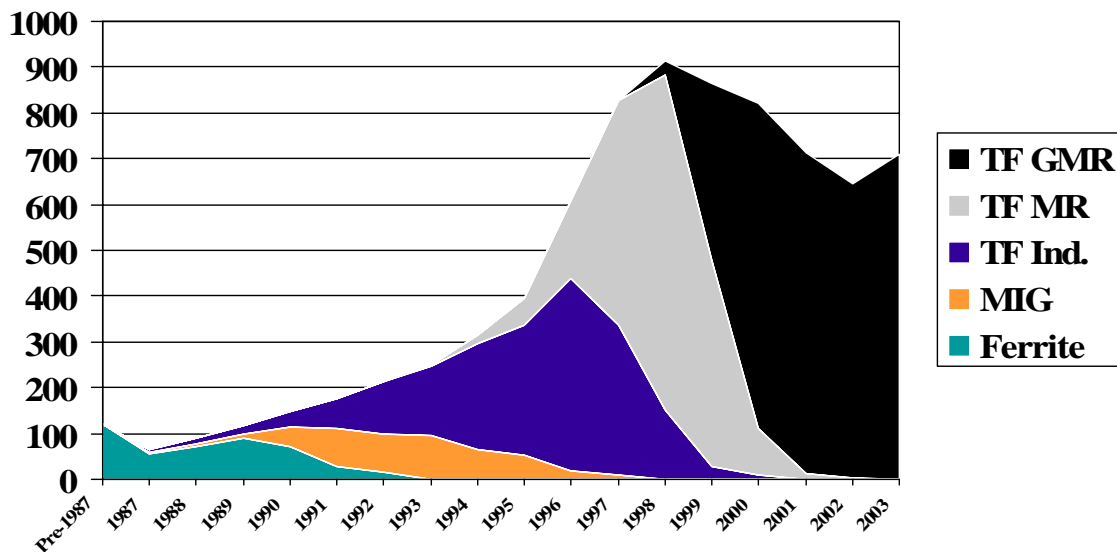
The first hard disk drive had a hand wound core of magnetic metal with an air bearing established by blowing air through a hole in the head. In the 1970's disk drives used hand wound ferrite core "Monkey Face" heads and 14-Inch 300 Oersted coercivity Ferric Oxide media. Today's GMR (Gigantic Magneto-Resistive) heads are produced using semiconductor processing methods, and precise machining operations.

The latest variety of magnetic recording media is 1 inch or less in diameter, and has a thin film media coercivity between 3500-4000 Oersted laid down on glass substrates. These advanced head and media components are mostly produced in Asia.

Disk spindle motors have progressed from ball bearings to fluid film bearings. These are also produced in Asia, by Asian companies. NMB, Nidec, Sankyo-Seiki, and a few others dominate these markets.

Figure 3 indicates the annual head production, and technologies. Figure 4 shows production and technology for magnetic media.

Figure 3. Magnetic Head Shipments vs. Technology (M/year)



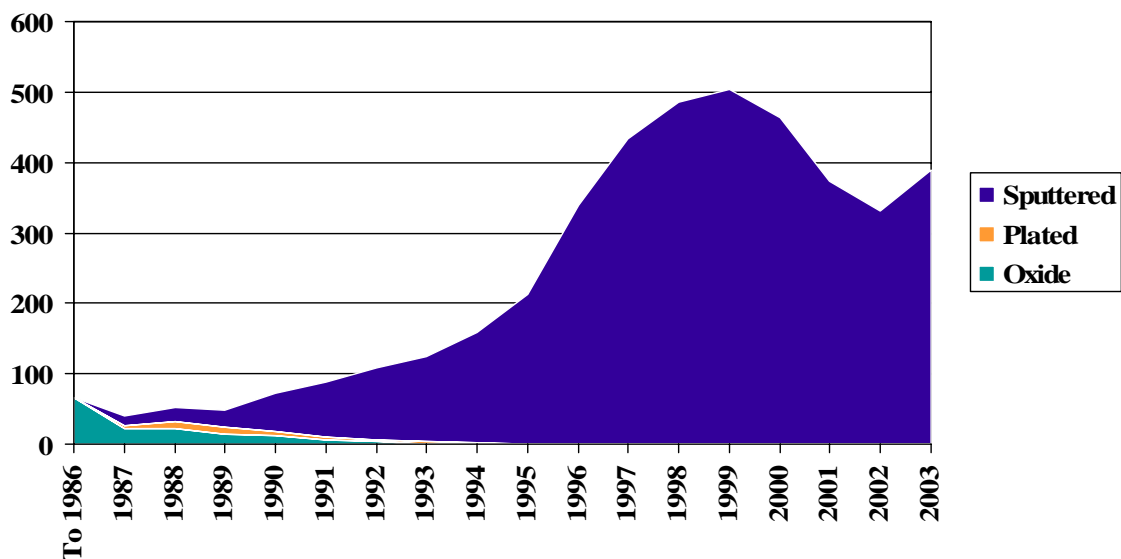
Note that while disk drives will reach 2 Billion cumulative units shipped in 2004, heads will reach close to 9 Billion cumulative units shipped and magnetic media will reach over 4.5 Billion cumulative units shipped.

GEOGRAPHIC PRODUCTION STRATEGIES

As the disk drive industry strove for lower costs, US production costs were constantly increasing. As a consequence production for the hard disk drive industry kept moving to lower labor cost areas, at times at great cost. Initially the

components industry tried Mexico, Puerto Rico, and Barbados (AMC, Infomag, Microdata) however in most cases adequate infrastructure was not in place. In the mid to late 1970's the industry moved to Japan, and Korea to achieve greater stability, workforce dedication, and lower labor costs. During the 1980's, the industry began production plants in Singapore, as the Singapore government was giving tax subsidies, and capital subsidies for plant construction. Most of the disk drive companies relocated production to Singapore at one time or another and since then they have expanded to Thailand, Malaysia, China and other Asian localities. (See From Silicon Valley to Singapore, David McKendrick, Stanford University Press, published in 2000)

Figure 4. Magnetic Media Shipments vs. Technology (M/year)



The criteria that establishing these Asian manufacturing operations were a combination of government subsidies, educated labor force, lower labor rates, and country infrastructure that allowed sub-components to be produced by qualified local companies. Asian countries also developed an advanced education system such as Singapore had to produce qualified job candidates that could support corporate production goals.

Although most of the hard drive companies began with a high percentage of ex-patriots, the goal was to reduce them as soon as possible since ex-pat costs were high. Seagate Penang had approximately six ex-pats, for approximately 10,000 factory workers in their thin film head plant in the late 1980's

The industry expanded throughout Asia to Malaysia, Thailand, Indonesia (temporarily), the Philippines, Hong Kong, and China. Today companies are moving into China with factories for drives, and Components. Seagate, Hitachi, Fujitsu, TDK/SAE Maxtor, and others are building production plants in China.

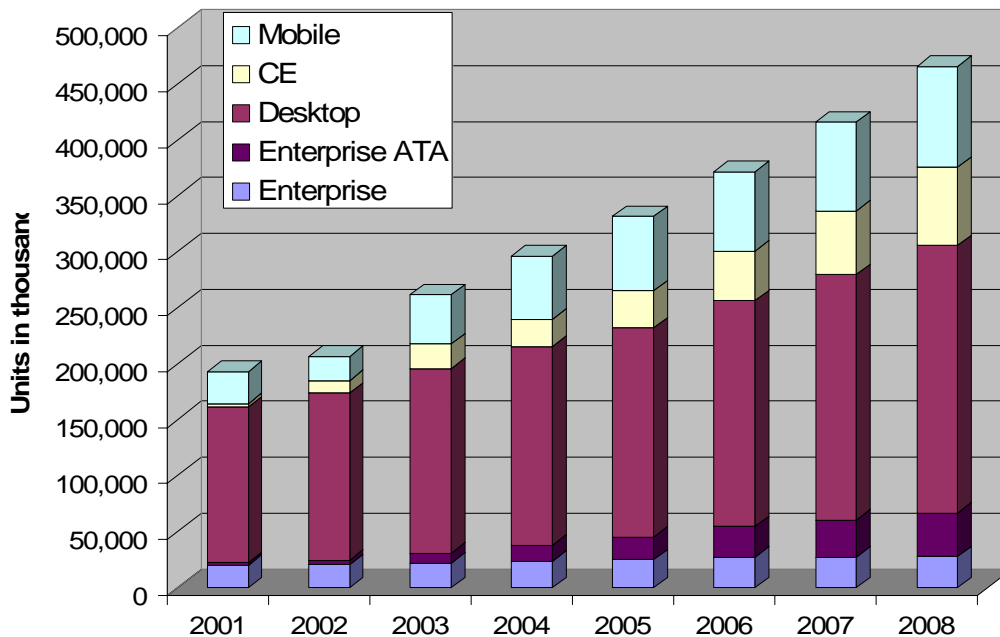
THE FUTURE

The disk drive industry will continue to be driven by manufacturing efficiency and rapid technology development. This will continue to result in cost competitive storage. The overall future for digital data storage remains excellent, driven by consumer and industrial applications. Today Motorola, Nokia, Samsung, and others are looking for storage for cell phones; Motorola's G-3 phones will be multi-functional and have storage and video capabilities, needing the significant amounts of storage that only hard disk drives can provide. According to IDC, 2003 worldwide cell phone numbers were 536 million increasing to 745 million in 2007. Eventually all cell phones will have significant internal memory. Cell phones may also have removable memory so the user can switch his data base among phones.

Most future HDTV systems will have disk storage; Hitachi recently announced a 400 GB TV disk drive which will store 400 hours of standard TV, or Video.

Figure 5 indicates the forecast of disk drives expected to be shipped into various market niches over the next few years.

Figure 5. Projections for Disk Drives in Various Market Niches.



The conventional data storage industry should be financially healthy over the next few years, as more hard copy data is transferred to magnetic storage and as stabilizing drive prices, slowing technology development and increasing volumes lead to large revenues and decent margins.

TABLE 4.
DISK DRIVE INDUSTRY SUMMARY
1960's

Bryant Computer
Burroughs
Caelus Memories
Century Data Systems
Control Data
Fujitsu
Hitachi
IBM
ISS/Univac
Marshall
Memorex
NCR
NEC
Potter Instruments
Toshiba

**TABLE 5.
DISK DRIVE INDUSTRY SUMMARY
1980's**

Advanced Storage Tech.	Data Peripherals	Josephine County Technology
Alpha Data	Datapoint	Kalok
Alps Electric	Data Recording Equipment	Kennedy Company
Amcodyne	Data-Tech Memories	Kovo
Ampex	DDC Pertec	Kyocera
Applied Information Memories	Digital Equipment Corporation	LaPine Technology
Applied Peripheral Systems	Disctron	Lexitron
Areal Technology	Disk Memory Technology	Magnum Technology
Atasi Corporation	Disk Tech One	Magtron
Athenaeum	DMA Technologies	Matsushita Com. Ind.
Ball Computer Products	DZU (ISOT)	Maxtor
BASF	Epson	Megavault
Brand Technologies	Evotek	Memorex
Burroughs	Fuji Electric	Memory Systems
Cardiff Peripherals	Fujitsu	MFM Technology
Century Data Systems	Goldstar Telecommunication	Micro Peripherals
CII-Honeywell Bull	Hawker Siddley	Microscience International
Cipher Data Products	Hewlett-Packard	Micro Storage
Cogito Systems	Hightrack Computer Technik	Microcomputer Systems
Comport	Hitachi	Microdata
Computer Memories	Hokushin	Micropolis
Computer Peripheral Technik	Hyosung Computer	Miltope
Conner Peripherals	Ibis Systems	Miniscribe
Control Data	IBM	Mitsubishi Electric
Cybernex	International Memories	Mitsumi Electric
Dastek	Irwin International	NEC
Data General	ISS/Univac	New World Computer

Newbury Data
Nippon Electric Industry
Nippon Peripherals, Ltd.
Nippon Systemhouse
Nipponcoinco
Nixdorf Computer
Northern Telecom
Ohio Scientific
Okidata
Olivetti
Otari Electric
Peripheral Technology
Perkin Elmer
PerSci
Pertec Computer
Philips Data Systems
Plus Development
PrairieTek
Priam

Qume
Quantum
Ricoh
Rodime
ROM-CD
Rotating Memory Systems
Sagem
Samsung Electronics
Seagate Technology
Seiko Epson
Shinwa Digital Industry
Shugart Associates
Siemens
SLI Industries
Sony
Sord Computer
Sperry
Storage Technology
SyQuest Technology

Tandon
Teac
Tecstor
Texas Instruments
3M
Tokico
Tokyo Electric
Toshiba
Toyo Soda
Tulin
Unisys
Vermont Research
Vertex
Victor Company of Japan
Western Dynex
Xebec Corporation
YE Data

TABLE 6.
DISK DRIVE INDUSTRY SUMMARY
2004

Cornice
Fujitsu
GS Magicstor
Hitachi GST
Maxtor
Samsung
Seagate
Toshiba
Western Digital