Jim Porter

President, DISK/TREND

Disk Drives' Evolution

INTRODUCTION:

We are going to shift from a kind of technological perspective and helicopter up to look at a kind of market perspective if you will, and who better to do that than Jim Porter, our next speaker. Jim by the way is not an IBM alumnus, which is kind of great. We had an IBM alumni party, I think, to a degree here today, but Jim started in this industry 30 years ago with Memorex. He is today president of DISK/TREND. DISK/TREND report is an annual market study of the worldwide disk drive, disk drive array and removable data storage industries. In addition to his work in publishing DISK/TREND report he is a consultant to data storage manufacturers and a co-sponsor at various data storage conferences. He's also a member of the board of directors of IDEMA, the International Disk Drive Equipment and Materials Association, and Jim I want to welcome you and we're looking forward to your remarks.

Jim Porter:

As just mentioned, I never worked for IBM, but I worked for the company that bought the first disk drive. (SLIDE 1) This is the first disk drive in the world being loaded on the delivery truck. 305A RAMAC was the first disk drive delivered to a customer and I believe that there were about a dozen of that model built. This is only part of the first RAMAC being loaded for delivery. As you saw from pictures in earlier presentations, it took up more space than this. This delivery went to Crown Zellerbach Corporation in San

Francisco, and a year later I went to work for that company in the home office. After having worked in San Jose for a year in the 1950's, a really quiet little town and a terrible place for a young man to start his business career, I went 50 miles north and worked in the home office of the company that coincidentally bought the world's first disk drive. Crown Zellerbach moved into the first new glass curtain wall high rise built in San Francisco after the second World War. Whenever we had a business guest they always wanted to see the place, so I'd take them up to the top floor and show them a vice-president's office, and then down three levels below the street to the computer room, and the RAMAC was there doing it's thing, loading heads, always putting on a good show. How many in the room today have seen a RAMAC in operation? I mean the original RAMAC – and I see that several of you actually remember what it looked like in action. It put on a show, and because of those glass sides it was very interesting to watch what was going on.

(SLIDE 2) Now this happened in 1956. This is Rey Johnson here, who died earlier this year, with an engineering prototype of the RAMAC and a few of his key people, as shown in the IBM San Jose internal newspaper at the time. My understanding, although I cannot document it, is that the very first disk drive is now in the Smithsonian, as an industrial historic relic. The trouble is the Smithsonian buys these things, puts them in a warehouse and brings them out 100 years later.

I would just like to comment that as you have seen there was tremendous progress made from 1956, when the RAMAC was shipped, through the series of projects Al Hoagland mentioned to you. One of the biggest advances in this Industry from 1956 to about 1963 occurred when IBM brought out the first 14 inch disk drive, the 1311. The 1311 was quickly superseded by the 2311, with increases in capacity made possible by the 6 high disk pack. Then the 11 high disk pack came out in the middle of the decade, 1965 or 1966, depending on which story you want to believe, with the 2314 drive, and a

capacity of 29 megabytes, which was marvelous. The 2314 became the first big disk drive of the mainframe era, until, of course, the 3330, the “Merlin”, a few years later in 1971.

The biggest advance of all in the technology probably was the 3340 drive with its 3348 “Data Module”. We have with us today Ken Haughten, who managed this IBM project, which like all IBM projects had to have a codename. My understanding is that the project as originally conceived involved a drive that would have 30 megabytes fixed and 30 removable. Of course Ken named it after the Winchester rifle in his closet and thus contributed a new meaning to a word in the English language.

IBM’s 3340 Winchester , introduced in 1973, incorporated the closed environment, the low mass head, and the lubricated disk --all technology improvements which have continued into the existing products. Of course, from that technology IBM’s disk drive product line evolved through the 3350 in 1975 and then the 3370 in 1979, the first production drive with thin film heads, followed by a succession of 3380 and 3390 models during the 1980’s. But this period was the last of the BIG disk drives, not only for IBM, but for all of the manufacturers producing large diameter drives for mainframe and minicomputer applications.

(SLIDE 3) In the meantime, the computer industry was changing and numerous new disk drive manufacturers appeared on the scene, most of them willing to provide the new types of disk drives needed. The first 8 inch drives appeared in 1979, with IBM the first to ship, but the 8 inch drive models were just the first step in shrinking drives down to today’s standard sizes. I first started tracking the details on disk drive industry shipments in 1976, and the first year I counted a total of 175,200 drives. At the end of the 1970’s we were still in the era of the mainframe and the minicomputer and of the types of disk drives designed for those markets. The drive capacities were large by the standards of the era, most of

the drives were also large, and so were the prices, but the drive shipment quantities were very small, by today's standards.

Then, at the beginning of the 1980's, something very interesting happened -- not the minicomputer, which was going away, but the personal computer, as we call it today. In those days we were arguing about whether to call it a desktop, or a personal computer, or something else. But it needed something more than a floppy drive for disk storage. Al Shugart, who will speak to you at lunch time, and Finis Conner started a company in 1979 to make a 5.25 inch hard drive, and the first of those drives shipped in 1980. The first 3.5 inch disk drive shipments started a few years later in 1983 by Rodime, a company founded in Scotland by Burroughs disk drive veterans, and the first 2.5 inch drive appeared later in the decade when a few veterans from multiple disk drive companies started PrairieTek in Colorado, with first shipments in 1988. Some of the same individuals later founded Integral Peripherals and made the first shipments of 1.8 inch drives in 1991.

The key change that occurred at the beginning of the 1980's to stimulate this swing to smaller diameter disk drives was the desktop PC, which resulted in the shipments of over 100 million 3.5 inch drives we now enjoy, followed by the notebook computer, which has caused 2.5 inch drive shipments to reach almost 20 million per year. It's clear that the disk drive industry didn't invent these markets, but it certainly has demonstrated a talent for responding to a market opportunity. Changes in the usage pattern for disk drive products are what made all of this possible. And we are clearly not at the end of the industry's evolutionary path. You saw a sample in the front of the room already this morning of the IBM microdrive, and I fully expect that you'll see a continuation of the same kind of evolution that we've been reviewing.

(SLIDE 4) Now, lest we forget that there were other things happening in this industry besides hard disk drives, I'd like to point out to you that the 1970's saw the appearance of the first floppy drives. The first 8 inch flexible disk drive was introduced with IBM's 3330

disk drive, the Merlin. At the time, the floppy had only one application, to load microcode in the controller for the Merlin. IBM's Minnow project resulted in that original floppy drive, which was somewhat different from the 8 inch floppy drive which later became the world standard. In 1973 IBM brought out the 3740 key-to-diskette system, essentially a tab card replacement, to enable a user to keystroke directly onto a magnetic recordable medium. The 3740 used a different style of 8 floppy diskette, which spun in a different direction, and the encoding scheme was completely different, but what it did was establish the recording format that has been used since. Actually, the 8 inch floppy drive is still in production by one company, Y-E-Data in Japan, resulting in a 25 year production life cycle for one type of disk drive – a rare phenomenon in this industry. Of course, Y-E Data's customer is IBM, which still needs 8 inch floppy drives to handle maintenance contracts on some hardware which has been around a long time.

Starting in the 1970's, the 8 inch increased in production up through the middle 80's, then gradually declined. The 5.25 inch floppy got stared in 1976. It has an interesting background. One of the people who I don't think is here today, who was a key factor in establishing the 5.25 inch floppy standard, was Jim Adkisson, who was with Shugart Associates, at that time the world leader in floppy drive shipments. Jimmy had been working with people at Wang Laboratories, who wanted to do this revolutionary thing of taking a computer that had been the size of a desk and making it small enough to put on top of the desk. The 8 inch floppy was a bit too large. In a dark bar in Boston one night the decision was made that the new floppy disk would be the size of a cocktail napkin on the table.

That cocktail napkin, which happened to 5.25 inches square, was brought back to Sunnyvale by Jimmy, and the engineering staff was told to make a floppy drive to use a diskette that size. No one was confident that the market was significant, so they were told to make no changes in any of the technology: Keep it at 48 TPI, don't buy any special

stepping motors or other parts, but make the drive as small as you can while using the same recording technology used in 8 inch floppies. The resulting drive was 3.25 inches high, 5.75 inches wide, and 8 inches deep, and those became sacred dimensions in the industry. Everything that's become a major disk drive format since that day has been the result of cutting one of those dimensions in half. Today we still use the word "half-high", which was originally the industry's slang expression for the follow-on drives which came after the SA400 5.25 inch disk drive introduced in 1976. The language somehow caught on.

(SLIDE 5) Although the purpose of this meeting is to recognize the history of magnetic recording, optical disk drives cannot be overlooked, because many utilize magneto optic recording, a form of magnetic recording made possible by raising the temperature of certain magnetic materials to the Curie point through the use of a laser. The MO drives in use today are predominately in the 3.5 inch and 5.25 inch sizes. The 5.25 inch drives are used mostly in high end optical disk libraries for enterprise system applications, and the 3.5 inch drives are used mostly with personal computers, predominantly in the Japanese market. As you can see, the shipments of both sizes of MO drives are modest when compared with magnetic hard disk drives, but some of the current advanced drive development projects combining MO with other technologies are regarded, of course, as one of the potential future paths for the industry's recording technology.

(SLIDE 6) A key point that needs to be made about the business side of the Industry is that it is not easy. The product life cycles are short, and for those who are able to keep up with the industry's pace on the development treadmill, it's a nice business. However, only a small minority of the companies which enter the disk drive manufacturing business manage to survive in this extremely competitive environment.

This is a list of the companies which previously made disk drives that don't do it anymore. It's a list of about 250 companies, approaching 260, and we've had to add a

few more every year. The point I would make is that the companies that have not made it are those which haven't been able to keep up with the changes in technology. This is frequently an engineering problem, but more frequently a management problem, in being able to manage the rate of change, to accomplish appropriate "time to market", to use today's widely understood phrase.

(SLIDE 7) Despite the fact that people talk about the existence of only a handful of disk drive manufacturers, if you recognize all kinds of disk drives, you've got to include the producers of magnetic hard disk drives, floppy drives, and optical disk drives. This is a list of companies that are still making disk drives today, approximately 80 manufacturers, but the lessons of history say that this list will become smaller as time goes on.

(SLIDE 8) If you look at the nature of the Industry -- as to who's making what – let's just look at the totals at the bottom of this table, those making rigid disk drives, floppy drives or optical drives. Back in the 1980's we were looking at a total of rigid disk drive manufacturers which got up to 77 companies. The number of participating companies has gone down very rapidly, and we now have 16 companies left. And 16 companies, basically Japanese, are currently making floppy drives. That total came down from a figure up in the 60's, also. In optical drives, back in 1984 the industry was just getting started, with only 9 manufacturers. It peaked at 60, and we are down to 52, as many manufacturers find it difficult to run a business and also keep up with this technology. People talk about only a few companies, but we have to remember the breadth of the industry, the diversity of the manufacturers, and the kinds of products made. They are not all just making 3.5 inch drives for your PC's.

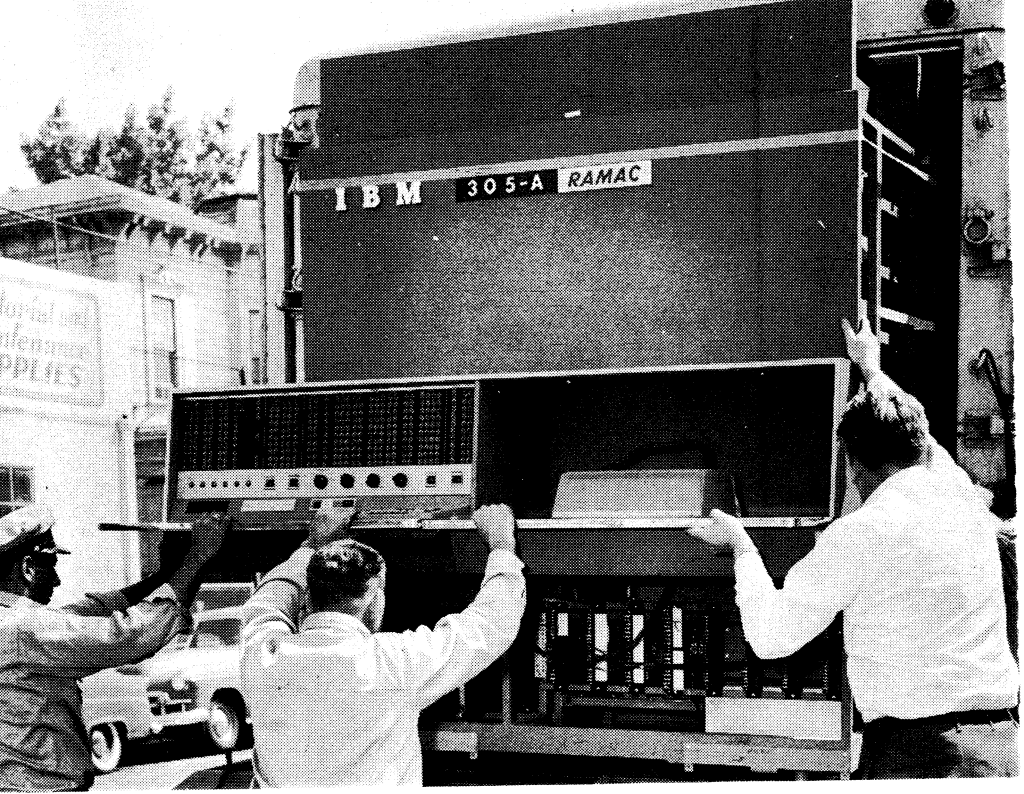
(SLIDE 9) In terms of the total business, if we look at the hard disk drives, which is where the big money is, you will see that last year we counted almost 32 billion dollars in sales revenue. If you look at the captive business in the U.S., IBM is the only company still making a captive drive. A captive drive is one which is sold with a computer system

that the drive manufacturer also happens to make. In non-U.S. drive sales, Fujitsu, Hitachi, NEC, Samsung Electronics, and Toshiba are still significant producers of captive disk drives. The big totals are in sales direct to the systems manufacturers, the OEM business. This is still $17.5 billion out of the total.

(SLIDE 10) To take stock in what is underlying all of this, and the rapid changes in the industry, we must recognize the rate of advancement in areal density. We started out in the early 1990's in the 259 megabits per square inch range. It's gone up at a varying annual rate, of 96%, then 30%, 82%, 43%, 47%, and last year a 130% increase. This adds up to an average of just over 60% per year in the 1990's. If you then take an even 60% per year and extend it through 2001 -- when we will be talking directly to Hal in the computer, I suspect. -- we should crack 20 gigabits per square inch on the areal density curve. The IBMers have talked about getting up to 10 or 11 gigabits per square inch by the end of the decade, but they are setting targets they can easily beat. If you assume that drive manufacturers will actually be able to achieve 60% per year, and I think they probably can, you're going to see drives with 20 gigabits per square inch in production by the end of 2001. What that amounts, since it will be done on 2.5 inch disks, is that you'll see 2.5 inch drives with over 10 gigabytes per platter at that time. On 3.5 inch desktop drives, which are running at about 85% of the utilization of areal density that 2.5 inch drives are, you'll be cracking 20 gigabytes per platter in 2001.

(SLIDE 11) The bottom line is that in the last 10 years, since we have had this data in our data base, the industry's improvements in value delivered have been incredible. Starting in 1988, the Industry shipped $20 billion worth of product with an overall capacity of 1,769 terabytes, and that worked out to an average price per megabyte of $11.54. In 1997, last year, the average price per megabyte was just under 10 cents. This year, in 1998, we expect the average price per megabyte will be under a nickel. And in 2001 we are projecting the over all average to be about 0.6 cents. Of course, for some of the

larger drives, it will actually be below that. I guess the bottom line is that you can say there is probably no other Industry in the world that has advanced the value of what it offers to society in the last 10 years at the same rate that the disk drive Industry has. And with that I'll wind it up, and thank you very much for your interest.


IBM 305-A RAMAC

IBM NEWS SAN JOSE

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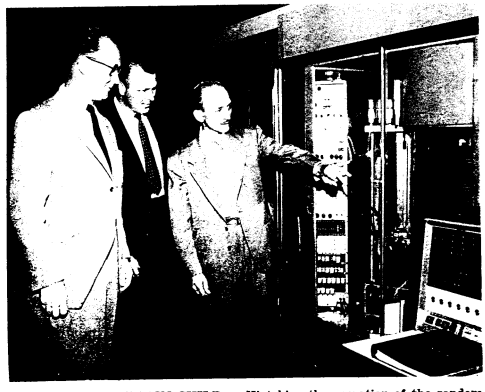
RAMAC Officially Announced

RAMAC Is First Major Achievement Of Mushrooming IBM San Jose Plant

Conceived and developed in the IBM San Jose Research and Development Laboratories, the huge electronic data processing machine equipped with the "juke box" memory file, known as RAMAC for Random Access Memory Accounting, was announced by press, radio and television September 14.

Hailed by President Thomas J. Watson, Jr., as "providing one of the most significant advancements toward business control and operation by electronics thus far," RAMAC is the result of four years of intensive research and development by upwards of 200 San Jose IBM engineers and technicians. In addition, scores of Product Planning, Test, Customer Engineering, CE School, Manufacturing and Sales personnel have collaborated to make the RAMAC electronic "brain" a reality.

RAMAC has spearheaded a tremendous growth for the IBM plant here in San Jose with several thousand persons expected to be employed at the new plant by 1960. Up-



IBM's SAN JOSE BRAIN CHILD — Watching the operation of the random "juke box" memory device of the San Jose-born RAMAC are Reynold B. Johnson, left, manager of the Research Laboratory, who with his associates originated the idea of the disk file; L. D. Stevens, manager of Development Engineering, and J. D. Fernbach, Engineering Laboratory manager, who were responsible for the development and engineering of the much-publicized

RIGID DISK DRIVES
DISK DIAMETER SHIPMENT HISTORY

Unit shipments (000)	10-14"	6.5-9.5"	5.25"	3.5"	2.5"	1.8" or less	Worldwide total
1976	175.7	--	--	--	--	--	175.7
1977	235.2	--	--	--	--	--	235.2
1978	306.1	--	--	--	--	--	306.1
1979	370.8	15.5	--	--	--	--	386.3
1980	426.6	82.0	1.2	--	--	--	509.8
1981	463.3	185.9	51.5	--	--	--	700.7
1982	437.6	270.2	242.5	--	--	--	950.3
1983	435.0	309.8	1,214.9	5.0	--	--	1,964.7
1984	483.5	341.4	2,722.8	101.4	--	--	3,649.1
1985	465.6	322.8	3,637.9	428.7	--	--	4,855.0
1986	390.1	334.7	5,804.4	1,412.7	--	--	7,941.9
1987	359.6	341.3	8,162.3	4,328.7	--	--	13,191.9
1988	360.9	421.3	8,753.1	8,231.1	.1	--	17,766.5
1989	251.9	387.1	8,306.2	13,210.8	24.5	--	22,180.5
1990	217.7	334.1	6,714.7	19,765.6	847.0	--	27,879.1
1991	158.1	267.2	3,041.1	26,036.4	3,085.5	1.0	32,589.3
1992	98.3	155.0	2,202.5	36,313.7	5,115.9	21.7	43,907.1
1993	79.5	100.5	1,278.1	43,954.4	6,287.9	157.2	51,857.6
1994	46.1	75.4	791.6	60,343.2	8,507.2	235.3	69,998.8
1995	5.9	11.8	706.8	77,775.8	10,637.8	418.8	89,556.9
1996	--	10.0	4,648.9	88,356.5	11,769.9	232.3	105,017.6
1997	--	1.5	5,628.3	109,647.2	15,018.0	203.1	130,498.1
1998	--	--	4,073.9	123,047.1	17,729.9	115.9	144,966.8
1999	--	--	*2,175.0*	*145,188.8*	*20,817.0*	*173.0*	*168,353.8*
2000	--	--	*1,095.0*	*168,385.0*	*24,090.0*	*250.0*	*193,820.0*
2001	--	--	*400.0*	*193,330.0*	*27,740.0*	*475.0*	*221,945.0*
2002	--	--	--	*220,330.0*	*31,850.0*	*750.0*	*252,930.0*

Forecasts shown in italics above. 3.5" totals include 3" and 2.5" server platform drives. 2.5" totals include 3" mobile platform drives.

DISK/TREND REPORT

FLEXIBLE DISK DRIVES
DISK DIAMETER SHIPMENT HISTORY

Unit shipments (000)	8"	5.25"	3.5" or less	High capacity	Worldwide total
1976	198.4	1.0	--	--	199.4
1977	363.7	43.7	--	--	407.4
1978	604.6	127.9	--	--	732.5
1979	856.2	497.0	--	--	1,353.2
1980	1,152.1	866.8	--	--	2,018.9
1981	1,420.0	2,205.2	5.0	--	3,630.2
1982	1,630.2	3,597.9	25.5	--	5,253.6
1983	1,612.3	10,489.4	438.3	2.6	12,542.6
1984	1,422.7	15,615.7	1,972.0	45.1	19,055.5
1985	904.6	12,994.9	3,268.1	99.6	17,267.2
1986	574.1	16,287.1	6,198.8	113.5	23,173.5
1987	434.1	16,232.1	12,337.3	111.2	29,114.7
1988	363.5	16,573.8	18,115.4	126.4	35,179.1
1989	245.4	14,886.1	23,216.2	108.9	38,456.6
1990	141.6	14,946.2	29,445.9	81.3	44,615.0
1991	76.0	15,019.9	32,819.3	99.7	48,014.9
1992	51.6	17,290.7	41,790.0	134.1	59,266.4
1993	26.0	14,711.0	51,151.7	209.6	66,098.3
1994	26.0	9,814.0	65,674.0	203.5	75,717.5
1995	21.0	5,348.0	76,856.0	827.7	83,052.7
1996	4.0	1,192.7	87,809.4	3,938.5	92,944.6
1997	4.0	180.0	98,208.0	8,055.8	106,447.8
1998	4.0	40.0	113,377.0	12,758.0	126,179.0
1999	*3.0*	*21.0*	*120,208.0*	*18,760.0*	*138,992.0*
2000	--	*9.0*	*122,380.0*	*24,290.0*	*146,679.0*
2001	--	--	*122,720.0*	*29,810.0*	*152,530.0*
2002	--	--	*119,725.0*	*34,270.0*	*153,995.0*

Forecasts shown in italics above.

DISK/TREND REPORT

OPTICAL DISK DRIVES
DISK DIAMETER SHIPMENT HISTORY

Unit shipments (000)	CD-ROM	DVD-ROM	Read/Write Drives 12"-14"	5.25"-8"	12 cm.	3.5" or less	Worldwide total
1984	--	--	2.0	--	--	--	2.0
1985	8.3	--	4.9	1.4	--	--	14.6
1986	19.0	--	8.4	4.3	--	--	31.7
1987	74.1	--	7.9	17.4	--	--	99.4
1988	232.8	--	10.6	42.6	--	--	286.0
1989	602.5	--	10.4	91.4	.1	--	704.4
1990	712.8	--	11.7	184.9	.4	.1	909.9
1991	1,435.1	--	9.8	195.9	1.5	17.1	1,659.4
1992	2,527.1	--	7.1	209.0	4.9	165.5	2,913.6
1993	11,074.8	--	7.1	187.2	16.0	253.9	11,539.0
1994	24,048.2	--	5.7	193.3	51.0	482.8	24,781.0
1995	41,692.0	--	6.4	184.8	514.0	518.5	42,915.7
1996	55,570.4	--	4.2	187.4	1,418.5	1,215.3	58,395.8
1997	74,580.9	1,199.0	2.4	143.6	3,413.7	1,411.0	80,750.6
1998	91,982.9	5,606.4	1.5	115.2	4,789.8	1,705.0	104,200.8
1999	*94,931.0*	*13,351.8*	*1.6*	*110.8*	*8,585.0*	*1,866.0*	*118,846.2*
2000	*82,809.2*	*30,089.0*	*1.7*	*154.5*	*12,037.0*	*1,821.0*	*126,912.4*
2001	*56,849.4*	*60,322.7*	*1.8*	*213.4*	*15,005.0*	*1,565.0*	*133,957.3*
2002	*30,265.0*	*92,832.4*	*2.0*	*367.8*	*29,805.4*	*1,319.0*	*154,591.6*

Forecasts shown in italics above.

5.25 inch drives include write-once and rewritable drives.

12 centimeter drives include CD-R, CD-RW, PD, DVD-R and DVD rewritable drives.

DISK/TREND REPORT

YESTERDAY'S DISK DRIVE MANUFACTURERS

ADI
Advanced Storage Technology
Aiwa
Alco Digital Devices
Alpha Data
Amcodyne
Amlyn
Ampex
Anelex
Apple Computer
Applied Information Memories
Applied Peripheral Systems
Areal Technology
Atasi Corporation
Atasi Technology
Athenaeum
Au Peripheral Products
Autonetics
Asia Commercial
Aura Associates
Avatar Peripherals
Aztech Systems
Ball Computer Products
BASF
Birdy Electronics
Brier Technology
Brand Technologies
Brother
Bryant Computer Products
Burroughs
Caelus Memories
CalComp
Caldisk
Calix Technology
Canon
Cardiff Peripherals
Century Data
Cerplex
Cipher Data Products
Cobra
Cogito Systems
Comport
Computer Memories
Conner Peripherals
Control Data
Copal
Creative Technology
Daeyoung Electronics
Daisy Holland
Dastek
Data 100
Data General
Data Master
Data Peripherals
Data Track Technology
Datapoint
Dataproducts
DDC Pertec
Decitek
Diablo Systems
Diamond Flower, Inc.
Digirede Informatica
Digital Equipment Corporation
Disctron
Disk Memory Technology
Disk Tech One
DMA Technologies
Drivetec
Dynastor
DZU
Edisa Informatica
Elcomatic
Elebra Informatica
Electronic Memories
Elitegroup Computer Systems
Ergo Electronics
EsPerT
Evotek
Exxon Office Systems
EZI GmbH
Flexdisc Tecnologia
Fuji Electric
Funai Electric
General Electric
General Systems International
Genisco Technology
Greenery Technology
Group Sense
Hanpin
Hawker Siddley
Hightrack Computer Technik
Hi-Tech Peripherals
Hokushin
Honeywell Bull
Honeywell Sperry
Hopax Industries
Ho Shin
Hyosung Computer
Ibis Systems
IMES
Innotronics
Innovex
Integral Peripherals
International Memories
Inventa
Iomec
IPC Peripherals
Irwin International
ISS
Itautec
Janome Sewing Machine
Jin Tech
Josephine County Technology
JTS
Juko Electronics
Kaimei Electronic
Kawasaki Steel
Kennedy Company
Konica
Kovo
Kubota
Kyocera
LaPine Technology
LaserByte
LFE
Literal
Lion Optics
Logabax
Longshine Electronics
Lung Hwa Electronics
Magnum Technology
Magtron
Magyar Optikai Muvek
Mantec Technology
Matsushita Elect. Components
Matsushita Graphics Com.
Maximum Storage
Media Vision
Memorex
Memory Systems
Metronex
MFE
MFM Technology
Microlab
Micro Peripherals
Microscience International
Micro Storage
Microcomputer Systems
Microdata
Micropolis
Miltope
Miniscribe
MiniStor Peripherals
Mitac
MOST
MountainGate Data Systems
Multidigit
Myrica
NCR
New World Computer
Newbury Data
Nippon Chemi-Con
Nippon Columbia
Nippon Electric Industry
Nippon Peripherals, Ltd.
Nippon Steel
Nippon Systemhouse
Nipponcoinco
Nixdorf Computer
Nomai
Norm Pacific Automation
Northern Telecom
Ocean Automation
Ohio Scientific
Okidata
Olivetti
Olympia International
Omek
Ontrax
Optics Storage
Optimem
Optotech
Orbis
Orca Technology
Oriental Precision
Otari Electric
Pentax Teknologies
Peripheral Data Systems
Peripherals General
Perkin Elmer
PerSci
Pertec Computer
Potter Instrument
PrairieTek
Priam
Prologica
Qualitron
Qume
Reference Technology
Remex
Robotron
Rotec Electronics
Rodime
ROM-CD
Rotating Memory Systems
Sagem
Sankyo Seiki
Seiko Epson
Seikosha
Sequel
Servo China
SFR (Safronic)
Sharp
Shinwa Co., Ltd.
Shinwa Digital Industry
Shugart Corporation
Shugart Associates
Siemens
SLI Industries
Sord Computer
Sperry
Storage Technology
Sunstrand Data Controls
Swan Instruments
Sycor
Sykes Datatronics
SyQuest Technology
T & E Engineering
Tabor
Tae Il Media
Takaya
Tandon
Tandy
Tecmate Electronic
Teco Electric
Tecstor
Telex
Texas Instruments
Texas Peripherals
3M
Tokico
Tokyo Electric
Tokyo Juki
Tosoh
Tulin
TXC
Umax
Unisys
Unitron
Vermont Research
Vertex
Vertimag Systems
Video Technology
Vitoria Tecnologia
Wangco
Weltec Digital
Western Dynex
Wintec Tecnologia
Wong's Technology
World Storage Technology
Xebec Co., Ltd.
Xebec Corporation
Zentek Storage

DISK/TREND REPORT

TODAY'S DISK DRIVE MANUFACTURERS

Acer, Inc. (AOpen)
Acer Peripherals
Actima Technology
Afreey
Alps Electric
Asaca
Asustek Computer
ATG
Behavior Tech Computer
Belfort Memory International
Calluna Technology
Caleb
Castlewood Systems
Citizen
Conner Technology
Delta
Eastman Kodak
EPO Technology
Fujitsu
Hewlett-Packard
Hitachi
IBM
Iomega
Kenwood
JVC
Konica
Kyushu Matsushita Electric
Leoptics
LG Electronics (GoldStar)
Lite-On
Matsushita Com. Industrial
Matsushita Electric Industrial
Matsushita Kotobuki Electric
Maxoptix
Maxtor
Mitsubishi Electric
Mitsumi Electric
Mountain Optech
Nakamichi
NEC
Nikon
Olympus Optical
O.R. Technology
Pan-International
PCS, Inc.
Philips Components
Pinnacle Micro
Pioneer
Plextor (Shinano Kenshi)
Plextor LMS
Quantum
Ricoh
Raymond Engineering
Samsung Electronics
Sanyo
Seagate Technology
Sega Enterprises
Sierra Technologies
Sony
Sujata Data Products
Tatung
Teac
Toshiba
Ultima Electronics (Artec)
US Drives
Wearnes Technology
Western Digital
Yamaha
Y-E Data
Yung Fu

DISK/TREND REPORT

DISK DRIVE MANUFACTURERS GEOGRAPHICAL DISTRIBUTION

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
UNITED STATES															
Rigid	52	43	38	34	35	31	28	25	21	20	19	16	13	12	9
Flexible	20	12	12	11	10	10	7	4	4	2	2	2	2	3	2
Optical	3	6	8	9	10	11	9	10	10	11	11	10	7	6	4
EUROPE															
Rigid	9	10	11	8	8	5	4	3	3	3	2	3	3	3	2
Flexible	10	7	6	6	6	5	5	1	--	--	--	--	--	--	--
Optical	2	3	3	3	3	2	2	3	3	3	3	3	3	3	3
ASIA/SOUTH AMERICA															
Rigid	16	23	26	23	25	27	27	29	23	17	9	5	10	7	5
Flexible	31	33	45	40	40	37	37	31	22	19	17	17	17	14	14
Optical	4	7	10	16	21	23	25	25	23	29	43	47	46	44	45
COMBINED TOTALS															
Rigid	77	76	75	65	68	63	59	57	47	40	30	24	26	22	16
Flexible	61	52	63	57	56	52	49	36	26	21	19	19	19	17	16
Optical	9	16	21	28	34	36	36	38	36	43	57	60	56	53	52

1998 DISK/TREND REPORT

RIGID DISK DRIVES
1997 ESTIMATED MARKET SHARES

Sales revenues in millions of U.S. Dollars	Captive	Distributor	OEM/Integrator	Total
U.S. Manufacturers				
IBM	4,434.6	298.0	2,858.8	7,591.4
Iomega	--	194.4	34.8	229.2
JTS	--	110.8	31.2	142.0
Quantum	--	1,483.5	3,437.6	4,921.1
Seagate Technology	--	2,809.0	4,475.9	7,284.9
SyQuest Technology	--	60.4	6.3	66.7
Western Digital	--	1,478.9	2,757.4	4,236.3
Other U.S.	--	71.3	23.4	94.7
U.S. Total	4,434.6	6,506.3	13,625.4	24,566.3
Non-U.S. Manufacturers				
Fujitsu	487.0	--	1,779.8	2,266.8
Hitachi	60.4	94.8	261.1	416.3
Maxtor	--	478.4	943.2	1,421.6
Micropolis	--	112.6	113.2	225.8
NEC	217.5	--	59.2	276.7
Samsung Electronics	73.1	509.7	148.2	731.0
Toshiba	1,042.1	124.5	646.6	1,813.2
Other Non-U.S.	--	16.7	1.9	18.6
Non-U.S. Total	1,880.1	1,336.7	3,953.2	7,170.0
WORLDWIDE TOTAL	6,314.7	7,843.0	17,578.6	31,736.3

DISK/TREND REPORT

HIGHEST DENSITY RIGID DISK DRIVES

Assuming areal density increases 60% per year, 1998-2001

Most advanced rigid disk drive in production	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Gigabits/square inch	.259	.354	.644	.923	1.358	3.123	5.000	7.995	12.792	20.467
	+96%	+37%	+82%	+43%	+47%	+130%	+60%	+60%	+60%	+60%
Drives with highest areal density										
2.5 inch disks										
% of highest density	56%	91%	100%	100%	100%	100%	100%	100%	100%	100%
Gigabits/square inch	.145	.321	.644	.923	1.358	3.123	5.000	7.995	12.792	20.467
Gigabytes/disk	.063	.172	.360	.540	.770	1.620	2.600	4.157	6.652	10.643
3.5 inch disks										
% of highest density	100%	100%	90%	90%	85%	86%	85%	85%	85%	85%
Gigabits/square inch	.259	.354	.579	.828	1.158	2.687	4.250	6.800	10.880	17.408
Gigabytes/disk	.251	.350	.664	1.011	1.444	3.360	5.313	8.495	13.592	21.746

Assumptions:

1. Highest areal density will increase 60% per year, 1998 through 2001.
2. Among all rigid disk drives, 2.5" drives will achieve highest areal density, 1998 through 2001.
3. Highest density 3.5" disk drives will have areal densities at 85% of the drives with highest areal densities, 1998 through 2001.
4. Highest density 3.5" drives will have typical gigabyte capacities per disk 1.25 times the gigabit/inch^2 areal density employed; 2.5" drives, .52 times.

1998 DISK/TREND REPORT

RIGID DISK DRIVES

DISK DRIVE CAPACITY AND PRICING HISTORY

Year	Worldwide disk drive sales revenues ($ million)	÷	Total disk capacity shipped (Terabytes)	=	Overall average price per megabyte ($)
1988	20,424.0		1,769.9		11.54
1989	22,660.3		2,435.9		9.30
1990	25,578.0		3,727.1		6.86
1991	24,632.0		4,710.8		5.23
1992	24,549.5		8,180.4		3.00
1993	21,729.8		14,855.5		1.46
1994	23,231.4		32,933.0		.705
1995	26,632.9		80,677.2		.330
1996	28,819.1		160,623.4		.179
1997	31,736.3		338,061.4		.094
1998	*34,229.3*		*772,275.4*		*.044*
1999	*37,094.2*		*1,534,068.4*		*.024*
2000	*38,621.2*		*3,279,513.8*		*.012*
2001	*38,672.4*		*6,141,889.4*		*.006*

Forecasts shown in italics above.

NOTES:
1 Byte = 8 bits
1 Kilobyte = 1,000 bytes
1 Megabyte = 1,000,000 bytes
1 Gigabyte = 1,000,000,000 bytes
1 Terabyte = 1,000,000,000,000 bytes
1 Petabyte = 1,000,000,000,000,000 bytes
1 Exabyte = 1,000,000,000,000,000,000 bytes
1 Zettabyte = 1,000,000,000,000,000,000,000 bytes
1 Yottabyte = 1,000,000,000,000,000,000,000,000 bytes