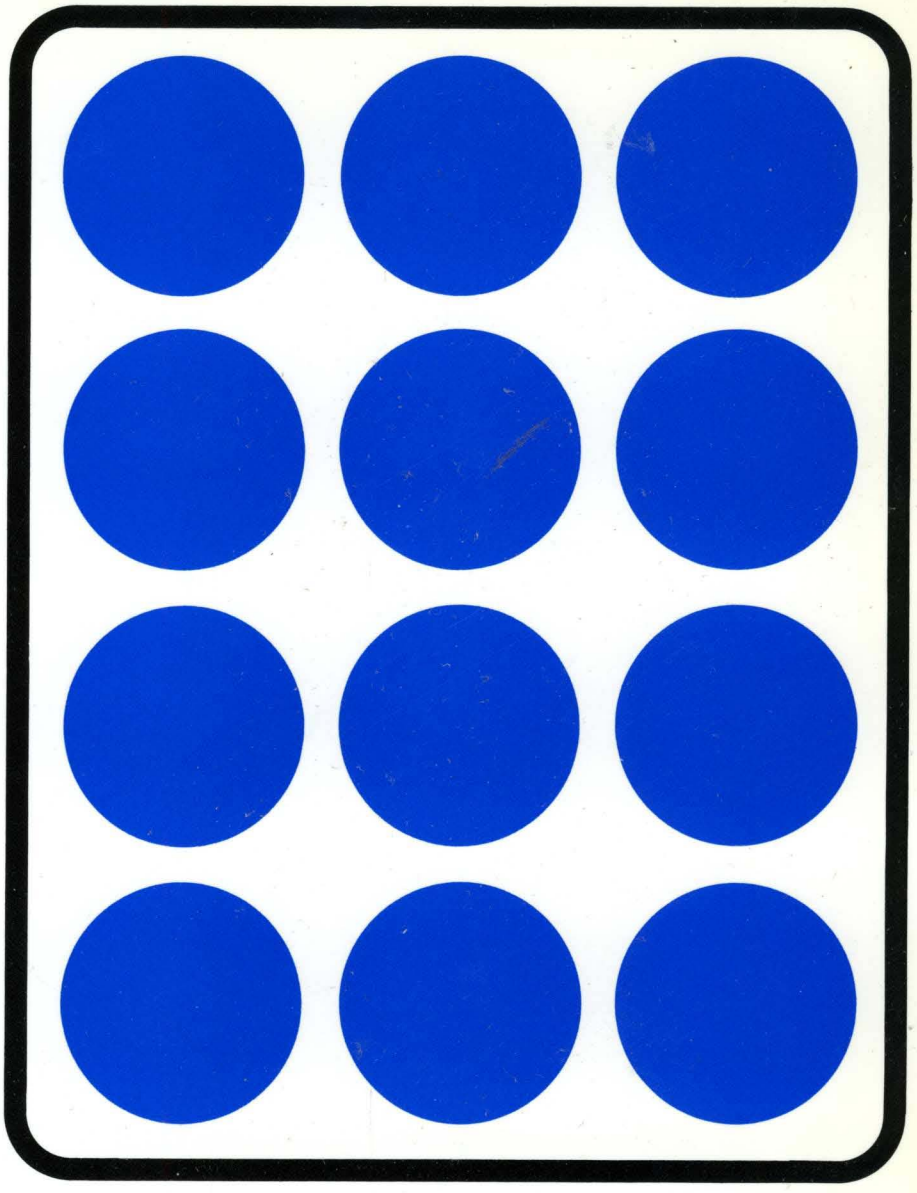
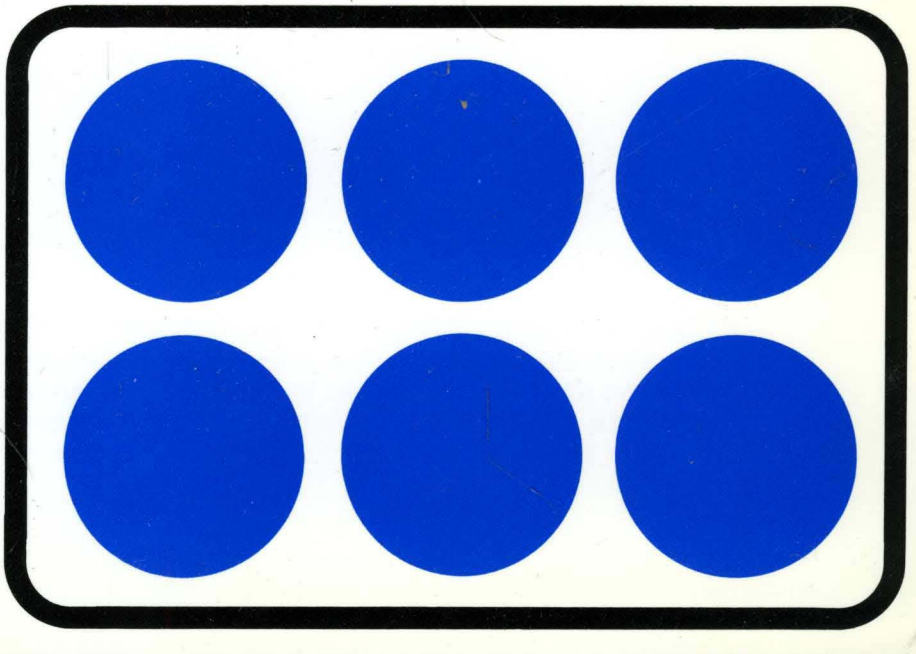


1998 DISK/TREND® REPORT



RIGID DISK DRIVES

1998 DISK/TREND® REPORT

RIGID DISK DRIVES

June, 1998

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FOREWORD

Among the things you can safely say about the disk drive industry is that it is cyclical. The industry entered 1997 with many products on allocation, but it entered 1998 with excess inventories of most products. Disk drive shipments continue to increase each year, so the current problem hasn't been caused by weakening demand. Instead, the problems experienced by individual major drive manufacturers appear to have their roots in some internal weaknesses, combined with well executed programs by several non-U.S. competitors to speed up product development, improve manufacturing operations and expand sales activities. Not to be outdone, the leading disk drive manufacturers all have high priority projects to design, build and sell their products more efficiently. The net result of this frenzied activity is expected to be average prices even lower than previously forecasted, healthy growth in shipments combined with unhealthy growth in sales revenues, and negligible profitability for some manufacturers.

1998 is the 22nd year of the DISK/TREND Report on rigid disk drives, covering an industry which has a new look every year. The other annual editions of the DISK/TREND Report, which also cover rapidly changing segments of the data storage industry, include the report on disk drive arrays, published in October, removable data storage, published this year in July, and optical disk drives and libraries, published in August, a month later than in past years.

DISK/TREND ON DISK, statistical and specification tables on floppy disks, is again available to subscribers to the DISK/TREND Report. Instructions for using the disks are included at the end of this report.

We are always willing to help you at any time by providing additional information on the industry which we may have available, some of which you'll find on our Website (www.disktrend.com). Your suggestions for improvements in the DISK/TREND Report are always welcome and are sincerely appreciated.

James N. Porter
Robert H. Katzive

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INTRODUCTION

New product breakdowns by disk platform

In this year's edition of the DISK/TREND Report on rigid disk drives you will find new tables which break down shipment data by "platform". New tables in each product section and in the summary section provide individual shipment totals in each year for "mobile system drives", principally 2.5" drives used with notebook personal computers, "desktop system drives", 3.5" and 5.25" drives used with desktop personal computers, and "server system drives", mostly 3.5" and 5.25" drives used with file servers or other high-end applications. In the specifications section, we have also used mobile, desktop or server designations for each disk drive listed.

Another revision of the product groups

Due to the rapid disappearance of lower capacity disk drives from almost every manufacturer's product lines, we again found it necessary to revise the product groups used at the bottom and at the top of the capacity ranges used for fixed disk drives. We don't like to make changes in the way the report is organized, since we know that many companies organize their industry data accordingly, but the rapid realignment of the industry's product lines made the change appropriate. We established only a single product group for "less than 1 gigabyte" and split the previous top capacity product group into two new groups: "20-40 gigabytes" and "more than 40 gigabytes".

Removable data storage data may appear in two DISK/TREND Reports

The separate report on removable data storage will be published for the fourth year, this time in July. The removable data storage report includes some information also included in this volume on disk cartridge drives and on 1.8" PC Card disk drives -- plus coverage of PCMCIA flash cards, small optical disk drives and floppy drives. In the removable data storage report, the section on disk cartridge drives is substantially the same as the product group in this report on disk cartridge drives, and the data on 1.8" PC Card drives is extracted from two product groups in this report.

Please note how the DISK/TREND Report counts sales revenues

Various market studies report revenues and unit shipments in several ways, and you will find the information in this report much more helpful if you understand the basic ground rules we have followed with the DISK/TREND Report. We report all disk drive revenues at the level of the product's first public sale by the manufacturer, at the estimated transaction price, whether the sale occurs at the captive, Distributor or OEM/Integrator levels. This is the same method used by individual companies in published financial reports.

SUMMARY: RIGID MAGNETIC DISK DRIVES

Industry size

Worldwide shipments of rigid disk drives have established a continuous pattern of aggressive growth during the 1990's, a trend which is expected to continue, but the current DISK/TREND forecast for the industry's sales revenues has been lowered.

An intense renewal of competition between United States disk drive manufacturers and those with Asian owners has reduced average unit prices for most types of disk drives below expected levels, cutting sales revenues, with a severe impact on the profitability of several of the companies. Fujitsu, Samsung Electronics, Maxtor, Hitachi, NEC and Toshiba have expanded disk drive production facilities, expedited development of new drive models, and have become much more effective competitors than in recent years. It now appears that the result of these actions will be higher than normal downward pressure on average unit prices, a dampening influence on overall sales revenues, and an increasing share of sales for non-U.S. disk drive manufacturers. Non-U.S. manufacturers held 19.8% of 1996 worldwide sales revenues but are projected to secure 30% of the 2001 total.

1997 worldwide sales revenues for rigid disk drives were $31.7 billion, with $38.7 billion forecasted for 2001, an average annual increase of only 5.1%. Worldwide unit shipments for 1997 totaled 130.5 million drives, and 2001 shipments are projected at 232.5 million drives, increasing by an annual average of 15.5%. As areal densities increase at an average of 60% per year, and as disk drive markets continually absorb more storage capacity, the average disk drive capacity increases significantly each year. In 1997, the 2-3 gigabyte product group led the industry in shipments. In 2001, shipments of drives in the 20-40 gigabyte product group will lead the industry.

OEM/Integrator sales revenues provided 55.4% of the 1997 overall total, and revenues in the OEM/Integrator sales channel are projected to increase to 63.7% of 2001's total revenues. Sales revenues in the Distributor channel are declining modestly, from 24.7% of the overall 1997 total, to 20.7% in 2001. The aftermarket upgrade and add-on sales will continue, but will soften as PC manufacturers add larger drives, installed at the factory, to mid-range and high-end PC models.

TABLE 1

CONSOLIDATED WORLDWIDE REVENUES

RIGID MAGNETIC DISK DRIVES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1997 Revenues		Forecast 1998		1999		2000		2001	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Captive	2,940.5	4,434.6	2,493.9	3,723.8	2,458.7	3,618.5	2,446.6	3,658.5	2,761.0	4,208.6
Distributor	3,223.2	6,506.3	3,891.0	6,853.3	4,614.3	7,363.5	4,869.0	7,482.4	4,298.0	6,475.9
OEM/Integrator	7,870.8	13,625.4	9,232.7	14,628.7	10,432.7	16,085.9	11,259.4	16,991.4	10,991.8	16,441.0
TOTAL U.S. REVENUES	14,034.5	24,566.3	15,617.6	25,205.8	17,505.7	27,067.9	18,575.0	28,132.3	18,050.8	27,125.5
Non-U.S. Manufacturers										
Captive	282.7	1,880.1	240.1	1,963.4	276.5	1,800.5	340.3	1,750.0	418.5	1,836.1
Distributor	632.2	1,336.7	687.3	1,322.6	672.4	1,277.9	708.3	1,313.0	840.2	1,539.3
OEM/Integrator	1,685.2	3,953.2	2,496.7	5,737.5	3,233.2	6,947.9	3,645.4	7,425.9	4,132.8	8,171.5
TOTAL NON-U.S. REVENUES	2,600.1	7,170.0	3,424.1	9,023.5	4,182.1	10,026.3	4,694.0	10,488.9	5,391.5	11,546.9
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	16,634.6	31,736.3	19,041.7	34,229.3	21,687.8	37,094.2	23,269.0	38,621.2	23,442.3	38,672.4

Marketing channels

As always in recent years, the annual DISK/TREND list of rigid disk drive manufacturers is slightly shorter. 20 companies remain on the list, consisting of 12 U.S. firms, 6 headquartered in Asia, with 2 in Europe.

Micropolis stopped operations suddenly in November, 1997, when Singapore Technologies, the government owned enterprise which had bought the company in 1996, decided to cut its losses and withdraw from the disk drive business. Sequel phased out the last of its end-of-life manufacturing programs for old Maxtor 5.25" drives, and Sagem phased out its ruggedized disk drive manufacturing activities for French military applications. The only addition to the list is Castlewood Systems, the new manufacturer of 3.5" disk cartridge drives.

Captive revenues generated by sales of disk drives by system manufacturers which manufacture the drives and sell them along with their systems have been declining for many years, as many system manufacturers phased out disk drive production programs. That trend is currently continuing, but with increased fluctuations, as IBM limits captive desktop drive production levels and NEC converts most captive production to drive models licensed from IBM. By 2001, captive shipments of high capacity drives are expected to raise the captive sales ratio. The OEM vs. Distributor revenue ratio will be affected by conflicting forces. Growing sales of low end PCs with minimum features will stimulate later add-on disk drive sales and the use of higher capacity disk drives as original equipment in higher level PCs will tend to reduce aftermarket add-on sales. Overall, the OEM/Integrator share of overall disk drive sales is expected to increase, and the Distributor share is expected to soften.

It is helpful to understand the relative price levels of captive, Distributor and OEM/Integrator drives when interpreting DISK/TREND statistics, to avoid an exaggerated impression of captive revenues. Each drive's price is the estimated value the first time it is sold to a nonaffiliated buyer, at captive end user, Distributor or OEM/Integrator levels. For example, captive drive revenues for 1997 totaled almost $6.3 billion, 19.9% of the overall revenue total. But 1997 captive unit shipments totaled 8.9 million drives, only 6.8% of the total. The reason for the large difference in the percentages is found in the higher prices at which captive drives are sold and the fact that many captive drives are high-end models.

TABLE 2

CONSOLIDATED WORLDWIDE REVENUES
RIGID MAGNETIC DISK DRIVES
MARKET CLASS REVIEW

REVENUE SUMMARY

WORLDWIDE REVENUES BY MANUFACTURER TYPE	1997 Revenues $M	1997 Revenues %	1998 Forecast $M	1998 Forecast %	1999 Forecast $M	1999 Forecast %	2000 Forecast $M	2000 Forecast %	2001 Forecast $M	2001 Forecast %
U.S. Manufacturers										
Captive	4,434.6	13.9%	3,723.8	10.8%	3,618.5	9.7%	3,658.5	9.4%	4,208.6	10.8%
	-3.9%		-16.0%		-2.8%		+1.1%		+15.0%	
Distributor	6,506.3	20.5%	6,853.3	20.0%	7,363.5	19.8%	7,482.4	19.3%	6,475.9	16.7%
	+5.0%		+5.3%		+7.4%		+1.6%		-13.5%	
OEM/Integrator	13,625.4	42.9%	14,628.7	42.7%	16,085.9	43.3%	16,991.4	43.9%	16,441.0	42.5%
	+18.9%		+7.4%		+10.0%		+5.6%		-3.2%	
Total U.S. Manufacturers	24,566.3	77.3%	25,205.8	73.5%	27,067.9	72.8%	28,132.3	72.6%	27,125.5	70.0%
	+10.1%		+2.6%		+7.4%		+3.9%		-3.6%	
Non-U.S. Manufacturers										
Captive	1,880.1	5.9%	1,963.4	5.7%	1,800.5	4.8%	1,750.0	4.5%	1,836.1	4.7%
	+25.4%		+4.4%		-8.3%		-2.8%		+4.9%	
Distributor	1,336.7	4.2%	1,322.6	3.8%	1,277.9	3.4%	1,313.0	3.3%	1,539.3	3.9%
	+15.7%		-1.1%		-3.4%		+2.7%		+17.2%	
OEM/Integrator	3,953.2	12.6%	5,737.5	17.0%	6,947.9	19.0%	7,425.9	19.6%	8,171.5	21.4%
	+31.1%		+45.1%		+21.1%		+6.9%		+10.0%	
Total Non-U.S. Manufacturers	7,170.0	22.7%	9,023.5	26.5%	10,026.3	27.2%	10,488.9	27.4%	11,546.9	30.0%
	+26.5%		+25.9%		+11.1%		+4.6%		+10.1%	
Worldwide Recap										
Captive	6,314.7	19.9%	5,687.2	16.6%	5,419.0	14.6%	5,408.5	14.0%	6,044.7	15.6%
	+2.6%		-9.9%		-4.7%		-.2%		+11.8%	
Distributor	7,843.0	24.7%	8,175.9	23.9%	8,641.4	23.3%	8,795.4	22.8%	8,015.2	20.7%
	+6.7%		+4.2%		+5.7%		+1.8%		-8.9%	
OEM/Integrator	17,578.6	55.4%	20,366.2	59.5%	23,033.8	62.1%	24,417.3	63.2%	24,612.5	63.7%
	+21.5%		+15.9%		+13.1%		+6.0%		+.8%	
Total All Manufacturers	31,736.3	100.0%	34,229.3	100.0%	37,094.2	100.0%	38,621.2	100.0%	38,672.4	100.0%
	+13.4%		+7.9%		+8.4%		+4.1%		--	

Note: Percentage figures with plus/minus signs refer to year-to-year growth rates.

Product mix

Product statistics in the DISK/TREND Report are broken down by capacity groups and by disk diameter -- and starting with this edition, by "platform", providing separate data for desktop, mobile and server drives. This section will review the data broken down by disk diameter and capacity groups, and a separate section will analyze the platform statistics.

Relentless demand for higher disk drive capacities for all of the industry's major application areas is expected to continue beyond the current forecast period. Individual personal computer users are using more disk capacity for Windows and a parade of new application programs, travelers want to be able to do everything on their notebook computers that they can do with their office PC's, new Internet servers are continually added, network file servers must be constantly upgraded with more disk capacity, the disk capacity used with mainframe computers is still expanding, and more disk storage is utilized each year for video, imaging, medical and other specialized applications. The result is continuous upward movement in the typical capacities of individual disk drives used for most applications.

Despite the continuous increase in the size of disk storage markets, the rate of improvement in disk areal density during the 1990's has been high enough to force into obsolescence all drives with larger disk sizes. No significant future production of drives with disks larger in diameter than 5.25" is expected. After initially dominating the desktop personal computer market, 3.5" drives benefited from the disk drive industry's widely discussed pattern of 60% annual increases in recording density during the 1990's, and now have large enough capacities to be the predominant choice for network servers and mainframe data storage requirements.

Although shipments of 5.25" drives for enterprise systems applications are relatively modest, 5.25" drives designed for very low manufacturing costs are now being offered in competition with 3.5" drives for personal computer markets at very competitive prices. Only one major drive manufacturer is involved in developing the personal computer market for 5.25" drives, and the level of shipments, although attractive to a single manufacturer, is a very small proportion of disk shipments for PC applications.

3.5" disk drives, in separate desktop and server configurations, have become the dominant disk drive standards for both desktop personal computer and server markets. An interesting variation in this pattern is the appearance of 3" drives in some of the 10,000 RPM server drives which have appeared in the last year. This technique apparently reduces vibration problems and minimizes power consumption in 10,000 RPM drives, and will probably become standard in the industry.

At the start of 1997, it appeared that 3" disks would become widely used in 2.5" drives designed for notebook computer markets, as a method to increase drive capacities while reducing the number of disks used. However, in mid-1988 the 3" surge for this market has disappeared as each of the three drive manufacturers with announced products stopped production for various reasons. Only Integral Peripherals remains committed to 3" drives, but is not currently in production while the company is being refinanced. That firm was the leading manufacturer of 1.8" PC Card drives, but weak sales brought financial problems, and a cessation of manufacturing, leaving Calluna as the single remaining drive manufacturer with 1.8" drives. In the meantime, shipments of 2.5" drives enjoy continuous growth with 28.5 million drives forecasted for 2001.

Average drive capacities relentlessly move higher each year. In 1997, 2-3 gigabyte drives were shipped in higher quantities than any other group. This year 3-5 gigabyte drives have assumed leadership in shipments, and by 2001 the lead will be captured by the 20-40 gigabyte capacity range. Rapid obsolescence will characterize each capacity range, as the data storage requirements for all major computer markets increase each year, and as each capacity range peaks in shipments.

New products and new market initiatives have generated a greatly increased level of shipments for removable media drives. Established graphics, prepress and security markets have been joined by a range of applications for video and multimedia editing, plus a variety of personal computer applications, to create new sales momentum. 1997 shipments were 1.4 million drives, and 2001 shipments are forecasted at 6.52 million.

Figure 1

CHANGING PRODUCT MIX

Worldwide Rigid Disk Drive Revenue

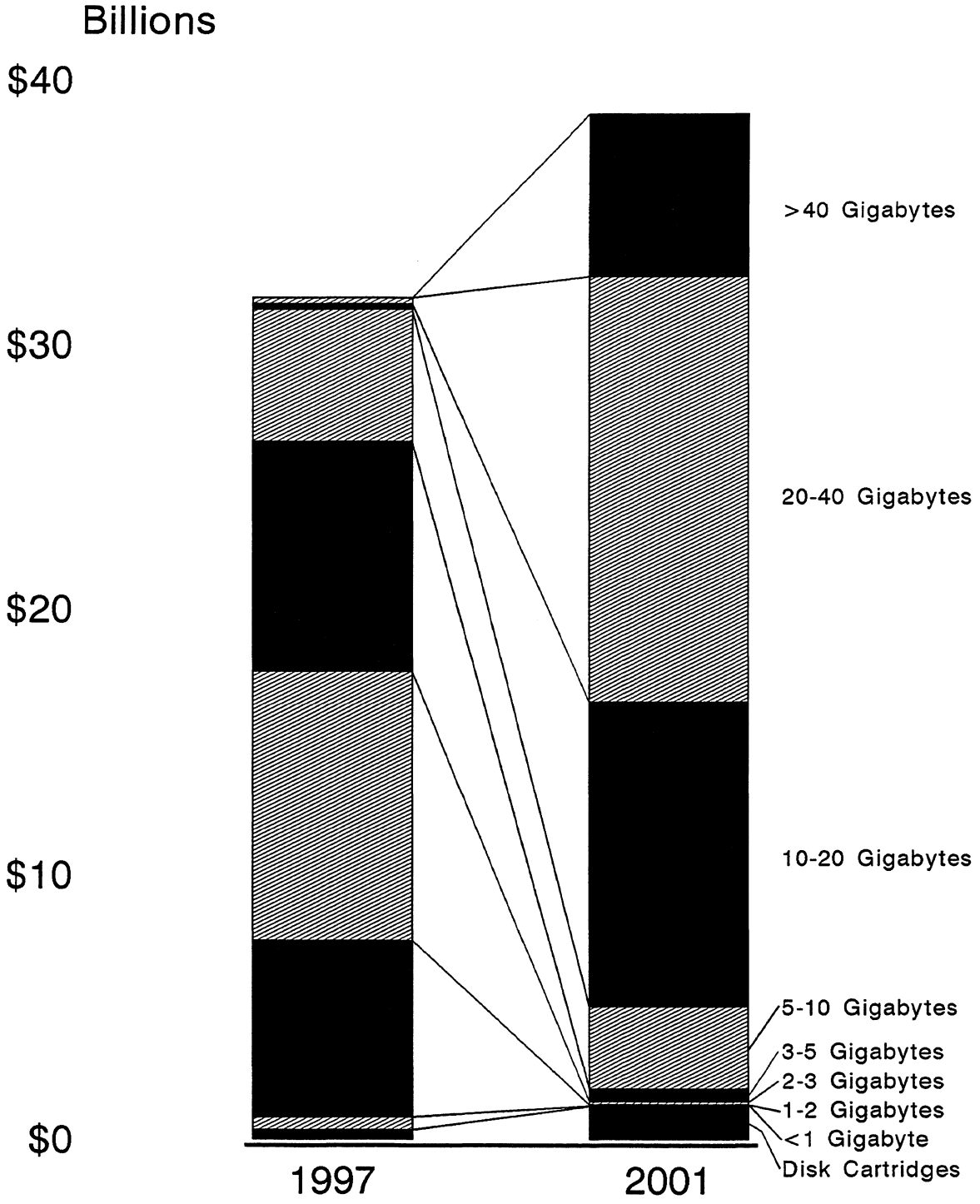


TABLE 3

CONSOLIDATED WORLDWIDE REVENUES
RIGID DISK DRIVES
PRODUCT GROUP REVIEW

REVENUE SUMMARY

WORLDWIDE REVENUES ALL MANUFACTURERS	1997 Revenues $M	 %	1998 $M	 %	1999 $M	 %	2000 $M	 %	2001 $M	 %
DISK CARTRIDGE DRIVES	346.1 +46.0%	1.1%	657.2 +89.9%	1.9%	916.8 +39.5%	2.5%	1,102.2 +20.2%	2.9%	1,234.6 +12.0%	3.2%
FIXED DISK DRIVES less than 1 Gigabyte	492.9 -88.9%	1.6%	98.3 -80.1%	.3%	46.1 -53.1%	.1%	31.3 -32.1%	.1%	28.0 -10.5%	.1%
FIXED DISK DRIVES 1 - 2 Gigabytes	6,687.9 -39.5%	21.1%	582.4 -91.3%	1.7%	99.3 -82.9%	.3%	34.5 -65.3%	.1%	42.0 +21.7%	.1%
FIXED DISK DRIVES 2 - 3 Gigabytes	10,108.3 +83.5%	31.9%	5,082.5 -49.7%	14.8%	1,435.3 -71.8%	3.9%	344.4 -76.0%	.9%	117.3 -65.9%	.3%
FIXED DISK DRIVES 3 - 5 Gigabytes	8,701.3 +71.7%	27.4%	11,970.1 +37.6%	35.0%	6,260.1 -47.7%	16.9%	1,822.5 -70.9%	4.7%	471.6 -74.1%	1.2%
FIXED DISK DRIVES 5 - 10 Gigabytes	4,956.2 +198.4%	15.6%	11,283.4 +127.7%	33.0%	14,468.4 +28.2%	39.0%	8,201.5 -43.3%	21.2%	3,110.0 -62.1%	8.0%
FIXED DISK DRIVES 10 - 20 Gigabytes	215.6 --	.7%	4,114.4 --	12.0%	11,928.3 +189.9%	32.2%	16,735.4 +40.3%	43.3%	11,477.4 -31.4%	29.7%
FIXED DISK DRIVES 20 - 40 Gigabytes	228.0 --	.6%	241.9 +6.1%	.7%	1,675.4 +592.6%	4.5%	9,236.1 +451.3%	23.9%	16,040.6 +73.7%	41.5%
FIXED DISK DRIVES more than 40 Gigabytes	-- --	--	199.1 --	.6%	264.5 +32.8%	.6%	1,113.3 +320.9%	2.9%	6,150.9 +452.5%	15.9%
Total Worldwide Revenue	31,736.3 +13.4%	100.0%	34,229.3 +7.9%	100.0%	37,094.2 +8.4%	100.0%	38,621.2 +4.1%	100.0%	38,672.4 --	100.0%

Note: Percentage figures with plus/minus signs refer to year-to-year growth rates.

Figure 2

UNIT SHIPMENT SUMMARY

Worldwide Shipments in Millions of Units

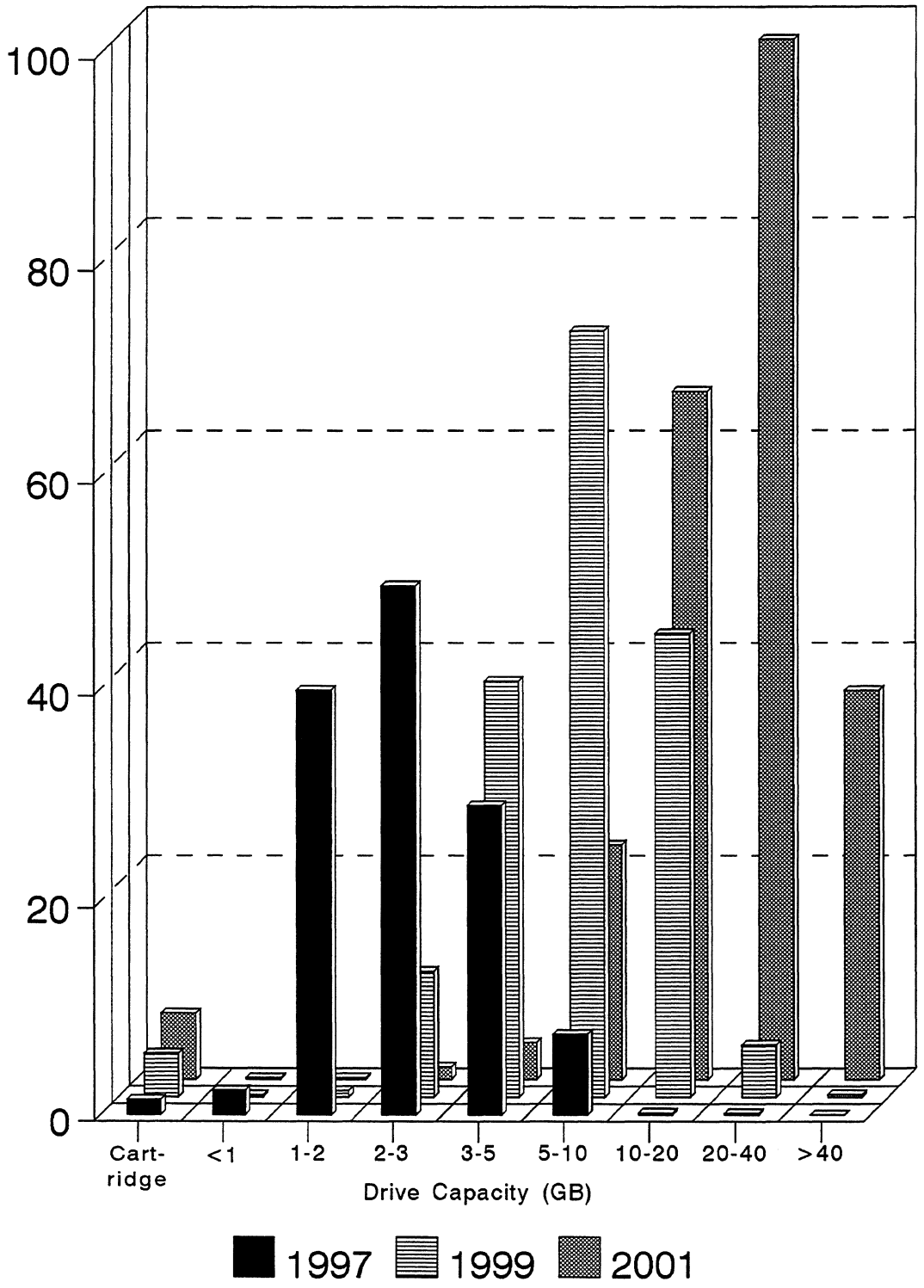


TABLE 4

CONSOLIDATED WORLDWIDE SHIPMENTS
RIGID DISK DRIVES
PRODUCT GROUP REVIEW

UNIT SHIPMENT SUMMARY

UNIT SHIPMENTS IN THOUSANDS	1997 Shipments Units	1997 Shipments %	1998 Forecast Units	1998 Forecast %	1999 Forecast Units	1999 Forecast %	2000 Forecast Units	2000 Forecast %	2001 Forecast Units	2001 Forecast %
DISK CARTRIDGE DRIVES	1,438.7 +37.8%	1.1%	2,761.0 +91.9%	1.8%	4,120.0 +49.2%	2.3%	5,260.0 +27.7%	2.6%	6,210.0 +18.1%	2.7%
FIXED DISK DRIVES less than 1 Gigabyte	2,315.8 -91.0%	1.8%	391.2 -83.1%	.3%	205.0 -47.6%	.1%	160.0 -22.0%	.1%	150.0 -6.2%	.1%
FIXED DISK DRIVES 1 - 2 Gigabytes	39,934.4 -25.0%	30.6%	3,552.2 -91.1%	2.3%	625.0 -82.4%	.4%	115.0 -81.6%	.1%	160.0 +39.1%	.1%
FIXED DISK DRIVES 2 - 3 Gigabytes	49,756.4 +183.3%	38.1%	31,490.0 -36.7%	20.6%	11,805.0 -62.5%	6.7%	3,250.0 -72.5%	1.6%	1,160.0 -64.3%	.5%
FIXED DISK DRIVES 3 - 5 Gigabytes	29,101.9 +429.4%	22.3%	66,732.5 +129.3%	43.7%	39,110.0 -41.4%	22.1%	13,350.0 -65.9%	6.6%	3,490.0 -73.9%	1.5%
FIXED DISK DRIVES 5 - 10 Gigabytes	7,603.0 +857.9%	5.8%	40,701.6 +435.3%	26.7%	72,075.0 +77.1%	40.8%	46,540.0 -35.4%	22.9%	22,080.0 -52.6%	9.5%
FIXED DISK DRIVES 10 - 20 Gigabytes	192.9 --	.1%	6,606.2 --	4.3%	43,580.0 +559.7%	24.7%	83,930.0 +92.6%	41.3%	64,700.0 -22.9%	27.8%
FIXED DISK DRIVES 20 - 40 Gigabytes	155.0 --	.1%	235.0 +51.6%	.2%	4,940.0 --	2.8%	46,600.0 +843.3%	22.9%	97,980.0 +110.3%	42.1%
FIXED DISK DRIVES more than 40 Gigabytes	-- --	--	134.0 --	.1%	255.0 +90.3%	.1%	4,060.0 --	1.9%	36,560.0 +800.5%	15.7%
Total Worldwide Shipments	130,498.1 +25.6%	100.0%	152,603.7 +16.9%	100.0%	176,715.0 +15.8%	100.0%	203,265.0 +15.0%	100.0%	232,490.0 +14.4%	100.0%
% U.S. Manufacturers	74.7%		69.7%		69.4%		68.6%		66.4%	
Total Capacity (Terabytes)	338,061.4		772,275.4		1,534,068.4		3,279,513.8		6,141,889.4	

Note: Percentage figures with plus/minus signs refer to year-to-year growth rates.

Figure 3

DISK DIAMETER SUMMARY

Worldwide Shipments in Millions of Units

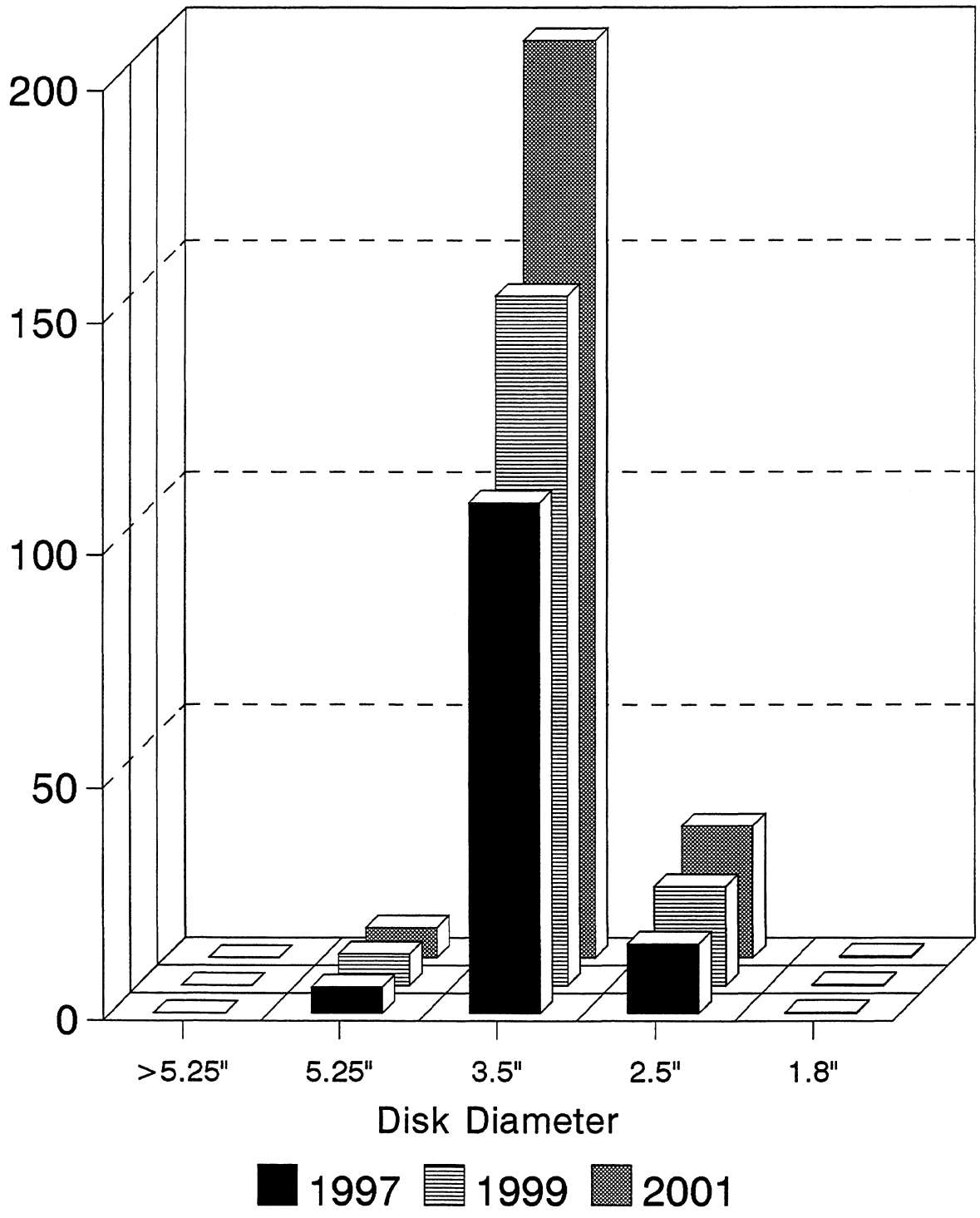


TABLE 5

CONSOLIDATED WORLDWIDE SHIPMENTS
RIGID DISK DRIVES
SUMMARY BY DISK DIAMETER

UNIT SHIPMENTS IN THOUSANDS	1997 Shipments Units	%	1998 Forecast Units	%	1999 Forecast Units	%	2000 Forecast Units	%	2001 Forecast Units	%
> 5.25 INCH	1.5	--	--	--	--	--	--	--	--	--
	-85.0%		--		--		--		--	
5.25 INCH	5,628.3	4.3%	6,234.0	4.1%	6,810.0	3.9%	6,630.0	3.3%	6,460.0	2.8%
	+21.1%		+10.8%		+9.2%		-2.6%		-2.6%	
3.5 INCH	109,647.2	84.0%	127,938.8	83.8%	148,335.0	83.9%	171,650.0	84.5%	197,270.0	84.9%
	+25.7%		+16.7%		+15.9%		+15.7%		+14.9%	
2.5 INCH	15,018.0	11.5%	18,246.4	12.0%	21,340.0	12.1%	24,710.0	12.2%	28,450.0	12.2%
	+27.6%		+21.5%		+17.0%		+15.8%		+15.1%	
1.8 INCH	203.1	.2%	184.5	.1%	230.0	.1%	275.0	.1%	310.0	.1%
	-12.6%		-9.2%		+24.7%		+19.6%		+12.7%	
Total Worldwide Shipments	130,498.1	100.0%	152,603.7	100.0%	176,715.0	100.0%	203,265.0	100.0%	232,490.0	100.0%
	+25.6%		+16.9%		+15.8%		+15.0%		+14.4%	

Notes: Percentage figures with plus/minus signs refer to year-to-year growth rates.

3.5 inch totals include 3 inch and 2.5 inch server platform drives.

2.5 inch totals include 3 inch mobile platform drives.

Platform trends

The table summarizing overall disk drive shipments by platform provides an overview of the entire industry's shipments of desktop, mobile and server drives, and specific data for each of the nine product groups is in individual platform summary tables included in the section for each group. Please note that the modest number of 3" drives shipped to date that are intended for notebook computer applications have been combined with the mobile drive data, and drives using 3" disks which are intended for high performance applications have been combined with the server drive data. Shipments of the new 12,000 RPM server drives recently introduced by Hitachi have also been combined with 3.5" server drive data. The 2.5" and 3" server drive statistics may be listed separately in future DISK/TREND Reports if warranted by shipment levels.

The rate of annual increases for each platform group are influenced by expected patterns of development for individual types of systems, as well as disk drive development cycles. Continuous growth is expected for drives intended for desktop personal computers, by far the industry's largest market, in terms of unit shipments. There is considerable uncertainty in the computer industry regarding the potential impact of various "thin clients", such as the network computer, to be supplied without disk drives, or with very limited disk capability. 1999 will probably be the first year that the NC or other thin clients could have a significant impact, and the desktop drive forecast for 1999 has been held to a conservative growth level, with a more optimistic outlook for the following years. Based on the penetration of 5.25" drives in the desktop market to date, most of the disk drive growth in this market is expected to go to 3.5" drives.

The growth pattern of 2.5" mobile drives for notebook computer markets is well established and is expected to continue, with continuous capacity upgrades. The 1.8" PC Card market has never reached the expected potential, and total shipments are forecasted at conservative levels, pending the arrival of a breakthrough application.

Server drive forecasts have been shaped by expected product introduction cycles, and in the 2000-2001 period by the availability of ever-larger disk drive capacities. It is assumed that total drive shipment quantities will be depressed to some extent by the enormous capacities available on individual drives.

TABLE 6

CONSOLIDATED WORLDWIDE SHIPMENTS
RIGID DISK DRIVES
SUMMARY BY PLATFORM

UNIT SHIPMENTS IN THOUSANDS	1997 Shipments Units	%	1998 Forecast Units	%	1999 Forecast Units	%	2000 Forecast Units	%	2001 Forecast Units	%
MOBILE SYSTEM DRIVES	15,221.1	11.6%	18,430.9	12.0%	21,570.0	12.2%	24,985.0	12.2%	28,760.0	12.3%
	--		+21.0%		+17.0%		+15.8%		+15.1%	
2.5 INCH	15,018.0		18,246.4		21,340.0		24,710.0		28,450.0	
1.8 INCH	203.1		184.5		230.0		275.0		310.0	
DESKTOP SYSTEM DRIVES	98,787.0	75.7%	115,040.7	75.3%	126,145.0	71.3%	144,060.0	70.8%	170,780.0	73.4%
	--		+16.4%		+9.6%		+14.2%		+18.5%	
5.25 INCH	5,430.2		6,021.0		6,635.0		6,480.0		6,425.0	
3.5 INCH	93,356.8		109,019.7		119,510.0		137,580.0		164,355.0	
SERVER SYSTEM DRIVES	16,490.0	12.6%	19,132.1	12.5%	29,000.0	16.4%	34,220.0	16.8%	32,950.0	14.1%
	--		+16.0%		+51.5%		+18.0%		-3.7%	
>5.25 INCH	1.5		--		--		--		--	
5.25 INCH	198.1		213.0		175.0		150.0		35.0	
3.5 INCH	16,290.4		18,919.1		28,825.0		34,070.0		32,915.0	
Total Shipments	130,498.1	100.0%	152,603.7	100.0%	176,715.0	100.0%	203,265.0	100.0%	232,490.0	100.0%
	--		+16.9%		+15.8%		+15.0%		+14.3%	

Notes: Percentage figures with plus/minus signs refer to year-to-year growth rates.

Mobile 2.5 inch totals include mobile platform 3 inch drives.

Server 3.5 inch totals include server platform 3 inch and 2.5 inch drives.

Figure 4

CAPACITY SHIPMENT SUMMARY

Worldwide Shipments in Terabytes

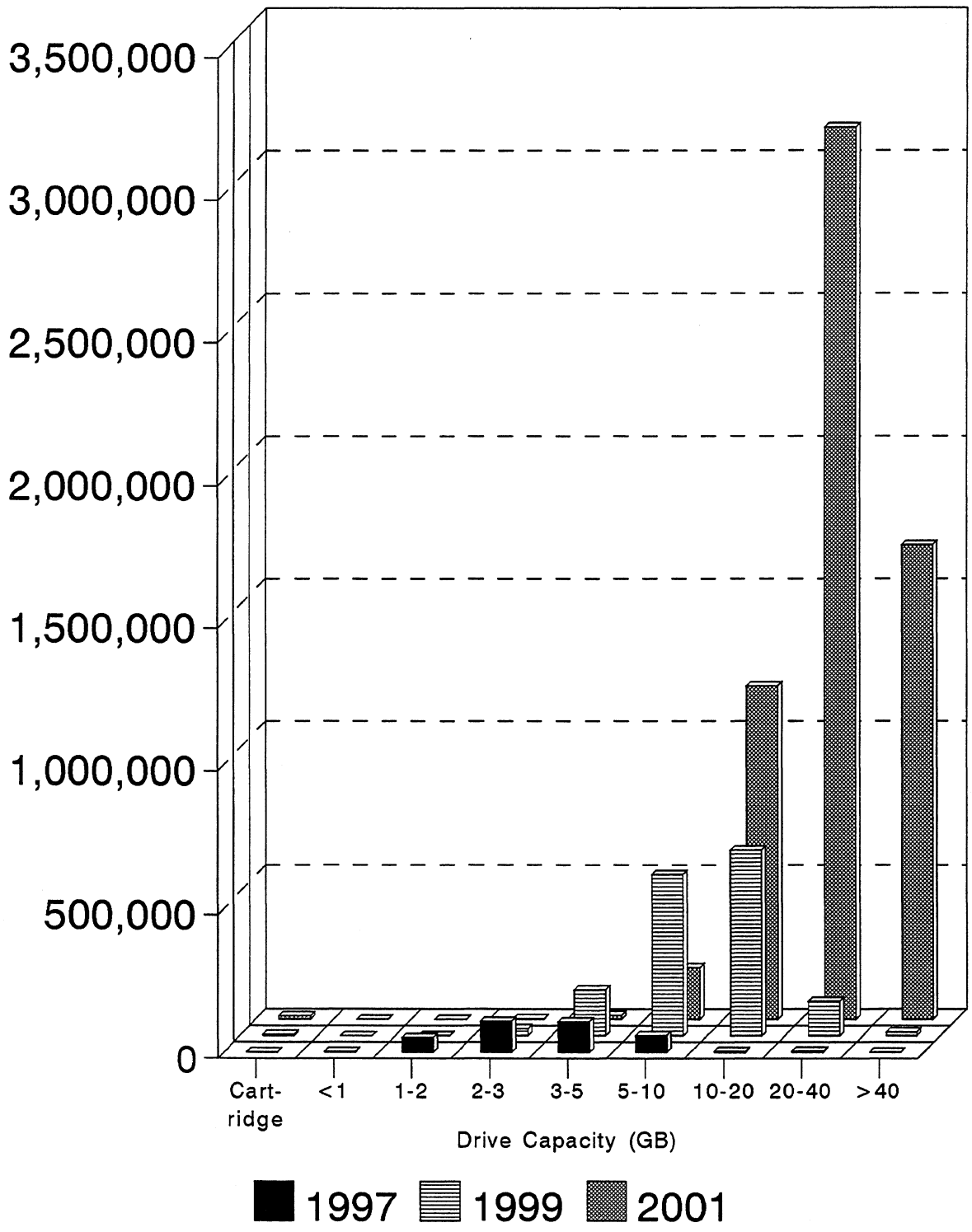


TABLE 7

CONSOLIDATED WORLDWIDE SHIPMENTS
RIGID DISK DRIVES
PRODUCT GROUP REVIEW

CAPACITY SHIPMENT SUMMARY

CAPACITY SHIPMENTS IN TERABYTES	1997 Shipments Tbytes	%	1998 Forecast Tbytes	%	1999 Forecast Tbytes	%	2000 Forecast Tbytes	%	2001 Forecast Tbytes	%
DISK CARTRIDGE DRIVES	1,114.1	.3%	3,147.1	.4%	4,887.0	.3%	8,109.0	.2%	11,414.2	.2%
	--		+182.5%		+55.3%		+65.9%		+40.8%	
FIXED DISK DRIVES less than 1 Gigabyte	1,493.5	.4%	202.3	--	86.6	--	65.6	--	70.0	--
	-87.7%		-86.5%		-57.2%		-24.2%		+6.7%	
FIXED DISK DRIVES 1 - 2 Gigabytes	51,948.2	15.4%	4,974.7	.6%	698.1	--	119.6	--	166.4	--
	-22.4%		-90.4%		-86.0%		-82.9%		+39.1%	
FIXED DISK DRIVES 2 - 3 Gigabytes	108,914.5	32.2%	71,097.5	9.2%	25,575.5	1.7%	7,047.5	.2%	2,515.2	--
	+181.4%		-34.7%		-64.0%		-72.4%		-64.3%	
FIXED DISK DRIVES 3 - 5 Gigabytes	107,700.2	31.9%	267,735.2	34.7%	160,741.7	10.5%	54,325.2	1.7%	14,046.0	.2%
	+389.5%		+148.6%		-40.0%		-66.2%		-74.1%	
FIXED DISK DRIVES 5 - 10 Gigabytes	59,753.1	17.7%	314,667.5	40.7%	561,203.9	36.6%	370,762.9	11.3%	180,194.6	2.9%
	+768.8%		+426.6%		+78.3%		-33.9%		-51.4%	
FIXED DISK DRIVES 10 - 20 Gigabytes	3,510.8	1.0%	98,502.5	12.8%	646,168.5	42.1%	1,361,261.0	41.5%	1,159,500.0	18.9%
	--		--		+556.0%		+110.7%		-14.8%	
FIXED DISK DRIVES 20 - 40 Gigabytes	3,627.0	1.1%	5,981.0	.8%	120,722.0	7.9%	1,289,913.0	39.3%	3,117,958.0	50.8%
	--		+64.9%		--		+968.5%		+141.7%	
FIXED DISK DRIVES more than 40 Gigabytes	--	--	5,967.6	.8%	13,985.0	.9%	187,909.9	5.7%	1,656,025.0	27.0%
	--		--		+134.3%		--		+781.3%	
Total Capacity (Terabytes)	338,061.4		772,275.4		1,534,068.4		3,279,513.8		6,141,889.4	
	+130.1%		+128.4%		+98.6%		+113.8%		+87.3%	
% U.S. Manufacturers	77.8%		73.8%		73.2%		70.7%		67.6%	

Note: Percentage figures with plus/minus signs refer to year-to-year growth rates.

Price per megabyte

The price per megabyte tables in the DISK/TREND Report this year have an additional digit -- the tables in this summary section and in each product section now show prices down to a tenth of a cent. Please note that the data shown in the tables is not merely an average of the price per megabyte of all individual disk drive models offered, but represents the estimated total sales revenues for each product type divided by the total capacity of all drives of that type. Also, please keep in mind that values for desktop, mobile and server drives are combined.

The industry's relentless improvement in areal density underlies much of the annual changes, of course. But other influences, such as the exceptional growth in the personal computer market, have accelerated the trend. The rapid migration to higher capacities for personal computers, driven by new software, expanded application programs, multimedia, and storage of data from the Internet, has brought new levels of competition to the markets for personal computer disk drives, each year at higher capacity levels. As higher capacity drive groups are overwhelmed by the personal computer market, high performance disk drives at relatively high prices become minor contributors to the pricing averages.

Average prices in the lower capacity fixed disk drive groups will increase in future years because the only remaining drives in these groups will be 1.8" drives, which have a higher parts count at each capacity level than the larger diameter disk drives, are produced in smaller quantities, and are priced at higher levels. In the capacity groups above 2 gigabytes, average prices are falling faster than previously forecasted, due to intensified levels of competition between U.S. and Asian disk drive manufacturers, affecting most intensively the desktop and server drive markets. By 2001, the average price per megabyte for noncaptive drives in the drive capacity group with highest shipments, 20-40 gigabytes, is projected to be .5 cents.

Captive drive price per megabyte also will fall rapidly, as captive drive producers respond to prices in the noncaptive market, as noncaptive drives are resold by other system manufacturers at aggressive prices. IBM is the largest captive disk drive producer, has aggressively lowered its pricing to stay competitive, and has moved to newer, smaller drives, at lower costs.

Figure 5

PRICE PER MEGABYTE SUMMARY

Noncaptive Worldwide Shipments ($/MB)

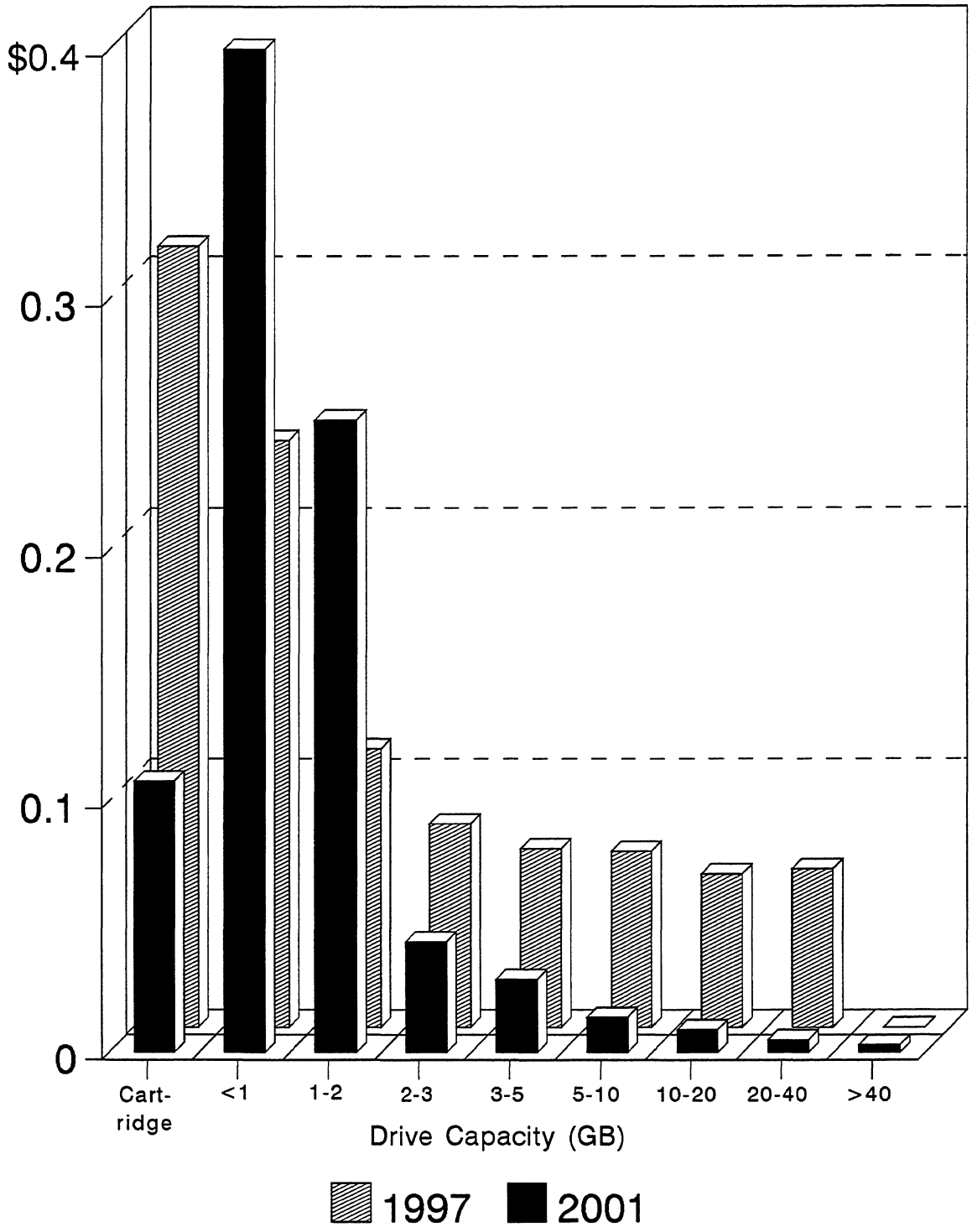


TABLE 8

NONCAPTIVE WORLDWIDE SHIPMENTS
RIGID DISK DRIVES
PRODUCT GROUP REVIEW

PRICE PER MEGABYTE SUMMARY ($/MB)

		Forecast			
	1997	1998	1999	2000	2001
DISK CARTRIDGE DRIVES	.311 -97.9%	.209 -32.8%	.188 -10.2%	.136 -27.5%	.108 -20.4%
FIXED DISK DRIVES less than 1 Gigabyte	.234 -23.0%	.404 +73.1%	.518 +28.1%	.477 -7.9%	.400 -16.2%
FIXED DISK DRIVES 1 - 2 Gigabytes	.111 -23.6%	.087 -21.4%	.123 +40.8%	.288 +134.3%	.252 -12.5%
FIXED DISK DRIVES 2 - 3 Gigabytes	.081 -38.5%	.059 -26.3%	.048 -19.1%	.045 -5.2%	.044 -2.3%
FIXED DISK DRIVES 3 - 5 Gigabytes	.071 -57.2%	.040 -43.2%	.034 -16.5%	.030 -10.6%	.029 -4.2%
FIXED DISK DRIVES 5 - 10 Gigabytes	.070 -45.8%	.033 -53.4%	.023 -28.5%	.019 -18.1%	.014 -24.8%
FIXED DISK DRIVES 10 - 20 Gigabytes	.061 --	.037 -39.1%	.017 -53.8%	.011 -33.7%	.009 -22.4%
FIXED DISK DRIVES 20 - 40 Gigabytes	.063 -22.6%	.039 -37.7%	.013 -68.1%	.007 -46.7%	.005 -30.3%
FIXED DISK DRIVES more than 40 Gigabytes	-- --	.033 --	.019 -43.3%	.005 -71.7%	.003 -35.8%

Note: Percentage figures with plus/minus signs refer to year-to-year growth rates.

Price per megabyte calculations represent estimated total sales revenues for each product type divided by the total yearly shipped capacity of all drives of that type.

TABLE 9

CAPTIVE WORLDWIDE SHIPMENTS
RIGID DISK DRIVES
PRODUCT GROUP REVIEW

PRICE PER MEGABYTE SUMMARY ($/MB)

		Forecast			
	1997	1998	1999	2000	2001
DISK CARTRIDGE DRIVES	--	--	--	--	--
	--	--	--	--	--
FIXED DISK DRIVES	.598	.631	.589	--	--
less than 1 Gigabyte	-79.1%	+5.6%	-6.8%	--	--
FIXED DISK DRIVES	.463	.303	.244	--	--
1 - 2 Gigabytes	-29.0%	-34.5%	-19.4%	--	--
FIXED DISK DRIVES	.270	.224	.176	.144	.128
2 - 3 Gigabytes	-22.1%	-16.9%	-21.3%	-18.2%	-11.3%
FIXED DISK DRIVES	.193	.123	.112	.087	.078
3 - 5 Gigabytes	-65.1%	-36.1%	-9.7%	-21.6%	-10.5%
FIXED DISK DRIVES	.172	.082	.061	.048	.038
5 - 10 Gigabytes	-79.4%	-52.5%	-25.6%	-20.8%	-20.3%
FIXED DISK DRIVES	.151	.089	.042	.028	.022
10 - 20 Gigabytes	--	-41.2%	-52.7%	-34.5%	-18.4%
FIXED DISK DRIVES	--	.044	.031	.021	.014
20 - 40 Gigabytes	--	--	-29.2%	-34.2%	-30.6%
FIXED DISK DRIVES	--	--	--	.013	.009
more than 40 Gigabytes	--	--	--	--	-28.7%

Note: Percentage figures with plus/minus signs refer to year-to-year growth rates.

Price per megabyte calculations represent estimated total sales revenues for each product type divided by the total yearly shipped capacity of all drives of that type.

Noncaptive market

For many years, the number of computer system manufacturers which also produce disk drives has declined, eliminating many sources of captive drives. At the same time, the rapid development of the personal computer industry has created an enormous market for low cost disk drives, dispersed among a large number of system manufacturers. The combination of these factors has caused a sustained annual reduction in the share of the disk drive industry's shipments and sales revenues held by captive disk drives and healthy growth in the share for noncaptive drives. The growth in noncaptive share is expected to continue during the forecast period of this report until 2001, when captive drive producers' emphasis on high-end products will probably result in stabilizing the captive share, with a slight gain.

Noncaptive unit shipments were 93.2% of the 1997 worldwide total for all disk drives, and the noncaptive share is forecasted to peak at 93.9% in 2000, with a slight decline to 93.4% in 2001. The worldwide share for noncaptive sales revenues is expected to follow a similar pattern, starting at 80.1% in 1997 and ending at 84.4% in 2001.

Independent disk drive manufacturers have quickly exploited technology advances during the last decade which have enabled them to respond with competitive drives for the computer industry's fastest growth sectors: Desktop and portable personal computers, engineering workstations and network file servers. In the process, they led the industry in developing high volume production capability for small drive formats, starting with 5.25", then 3.5", and more recently with 2.5" drives. OEM drives in each of these form factors arrived in the market well before captive drives and set the patterns for the entire industry.

Most segments of the market for noncaptive disk drives are dominated by U.S. based companies, which were able to successfully sell to rapidly growing system manufacturers because they were able to deliver new disk drive configurations early in each product life cycle. The noncaptive drive leaders now face new challenges, as they adjust to continually lower prices, increasing production and demanding product development requirements. New competitive alignments will also change the picture, forced by acquisitions, vertical integration programs and technology advances.

TABLE 10

NONCAPTIVE WORLDWIDE REVENUES
RIGID DISK DRIVES
PRODUCT GROUP REVIEW

REVENUE SUMMARY

WORLDWIDE REVENUES ALL MANUFACTURERS	1997 Revenues $M	 %	1998 $M	 %	1999 $M	 %	Forecast 2000 $M	 %	 2001 $M	 %
DISK CARTRIDGE DRIVES	346.1 +46.0%	1.4%	657.2 +89.9%	2.3%	916.8 +39.5%	2.9%	1,102.2 +20.2%	3.3%	1,234.6 +12.0%	3.8%
FIXED DISK DRIVES less than 1 Gigabyte	256.6 -92.9%	1.0%	52.4 -79.6%	.2%	35.8 -31.7%	.1%	31.3 -12.6%	.1%	28.0 -10.5%	.1%
FIXED DISK DRIVES 1 - 2 Gigabytes	5,493.6 -41.4%	21.7%	375.1 -93.2%	1.3%	72.4 -80.7%	.2%	34.5 -52.3%	.1%	42.0 +21.7%	.1%
FIXED DISK DRIVES 2 - 3 Gigabytes	8,202.5 +70.8%	32.2%	3,911.6 -52.3%	13.8%	1,151.7 -70.6%	3.7%	310.1 -73.1%	1.0%	109.0 -64.9%	.3%
FIXED DISK DRIVES 3 - 5 Gigabytes	7,037.5 +130.9%	27.7%	10,245.4 +45.6%	35.9%	5,057.0 -50.6%	16.0%	1,541.4 -69.5%	4.6%	367.4 -76.2%	1.2%
FIXED DISK DRIVES 5 - 10 Gigabytes	3,642.8 +388.1%	14.4%	9,577.0 +162.9%	33.6%	12,222.5 +27.6%	38.6%	6,335.3 -48.2%	19.2%	2,272.6 -64.1%	6.9%
FIXED DISK DRIVES 10 - 20 Gigabytes	214.5 --	.8%	3,350.4 --	11.7%	10,560.1 +215.2%	33.4%	14,673.1 +38.9%	44.1%	9,483.0 -35.4%	29.2%
FIXED DISK DRIVES 20 - 40 Gigabytes	228.0 --	.8%	173.9 -23.7%	.6%	1,394.4 +701.8%	4.4%	8,258.7 +492.3%	24.9%	13,686.5 +65.7%	41.9%
FIXED DISK DRIVES more than 40 Gigabytes	-- --	--	199.1 --	.6%	264.5 +32.8%	.7%	926.1 +250.1%	2.7%	5,404.6 +483.6%	16.5%
Total Worldwide Revenues	25,421.6 +16.5%	100.0%	28,542.1 +12.3%	100.0%	31,675.2 +11.0%	100.0%	33,212.7 +4.9%	100.0%	32,627.7 -1.8%	100.0%

Note: Percentage figures with plus/minus signs refer to year-to-year growth rates.

TABLE 11

NONCAPTIVE WORLDWIDE SHIPMENTS
RIGID DISK DRIVES
PRODUCT GROUP REVIEW

UNIT SHIPMENT SUMMARY

UNIT SHIPMENTS IN THOUSANDS	1997 Shipments Units	1997 Shipments %	1998 Forecast Units	1998 Forecast %	1999 Forecast Units	1999 Forecast %	2000 Forecast Units	2000 Forecast %	2001 Forecast Units	2001 Forecast %
DISK CARTRIDGE DRIVES	1,438.7 +37.8%	1.2%	2,761.0 +91.9%	1.9%	4,120.0 +49.2%	2.5%	5,260.0 +27.7%	2.8%	6,210.0 +18.1%	2.9%
FIXED DISK DRIVES less than 1 Gigabyte	1,665.6 -93.1%	1.4%	276.1 -83.4%	.2%	180.0 -34.8%	.1%	160.0 -11.1%	--	150.0 -6.2%	--
FIXED DISK DRIVES 1 - 2 Gigabytes	37,957.3 -24.7%	31.3%	3,082.8 -91.9%	2.2%	550.0 -82.2%	.3%	115.0 -79.1%	.1%	160.0 +39.1%	.1%
FIXED DISK DRIVES 2 - 3 Gigabytes	46,559.0 +180.1%	38.3%	29,129.3 -37.4%	20.4%	11,065.0 -62.0%	6.7%	3,140.0 -71.6%	1.6%	1,130.0 -64.0%	.5%
FIXED DISK DRIVES 3 - 5 Gigabytes	26,908.5 +490.6%	22.1%	63,232.1 +135.0%	44.3%	36,335.0 -42.5%	22.0%	12,500.0 -65.6%	6.6%	3,135.0 -74.9%	1.5%
FIXED DISK DRIVES 5 - 10 Gigabytes	6,697.9 +950.3%	5.5%	38,167.6 +469.8%	26.7%	67,350.0 +76.5%	40.6%	41,705.0 -38.1%	21.9%	19,455.0 -53.4%	8.9%
FIXED DISK DRIVES 10 - 20 Gigabytes	192.5 --	.2%	6,055.0 --	4.2%	41,400.0 +583.7%	25.0%	79,180.0 +91.3%	41.5%	59,610.0 -24.7%	27.6%
FIXED DISK DRIVES 20 - 40 Gigabytes	155.0 --	--	165.0 +6.5%	--	4,600.0 --	2.7%	45,000.0 +878.3%	23.6%	92,335.0 +105.2%	42.5%
FIXED DISK DRIVES more than 40 Gigabytes	-- --	--	134.0 --	--	255.0 +90.3%	.1%	3,775.0 --	1.9%	34,945.0 +825.7%	16.0%
Total Worldwide Shipments	121,574.5 +25.0%	100.0%	143,002.9 +17.6%	100.0%	165,855.0 +16.0%	100.0%	190,835.0 +15.1%	100.0%	217,130.0 +13.8%	100.0%
% U.S. Manufacturers	75.3%		70.3%		70.4%		68.8%		66.3%	
Total Capacity (Terabytes)	311,767.5		721,268.9		1,448,766.5		3,100,012.1		5,782,828.5	

Note: Percentage figures with plus/minus signs refer to year-to-year growth rates.

TABLE 12

NONCAPTIVE WORLDWIDE SHIPMENTS
RIGID DISK DRIVES
PRODUCT GROUP REVIEW

CAPACITY SHIPMENT SUMMARY

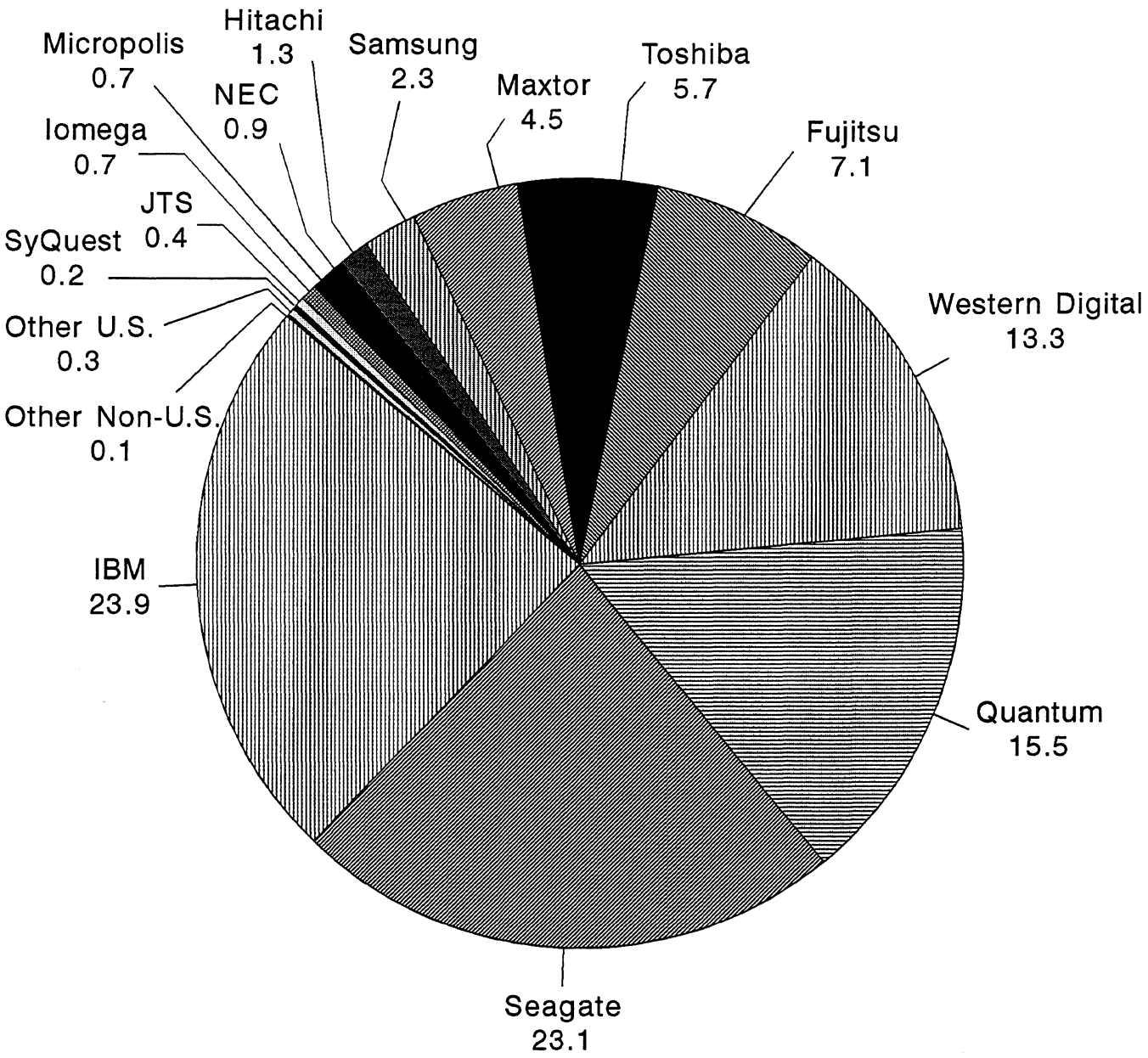
CAPACITY SHIPPED IN TERABYTES	1997 Capacity Units	1997 Capacity %	Forecast 1998 Units	1998 %	1999 Units	1999 %	2000 Units	2000 %	2001 Units	2001 %
DISK CARTRIDGE DRIVES	1,114.1	.4%	3,147.1	.4%	4,887.0	.3%	8,109.0	.3%	11,414.2	.2%
	--		+182.5%		+55.3%		+65.9%		+40.8%	
FIXED DISK DRIVES less than 1 Gigabyte	1,098.3	.3%	129.6	.1%	69.1	--	65.6	--	70.0	--
	-90.7%		-88.2%		-46.7%		-5.1%		+6.7%	
FIXED DISK DRIVES 1 - 2 Gigabytes	49,367.4	15.9%	4,291.2	.5%	588.1	.1%	119.6	--	166.4	--
	-23.3%		-91.3%		-86.3%		-79.7%		+39.1%	
FIXED DISK DRIVES 2 - 3 Gigabytes	101,851.7	32.7%	65,873.5	9.2%	23,967.7	1.6%	6,809.9	.2%	2,450.4	--
	+177.8%		-35.3%		-63.6%		-71.6%		-64.0%	
FIXED DISK DRIVES 3 - 5 Gigabytes	99,094.3	31.8%	253,770.0	35.3%	149,948.0	10.4%	51,106.5	1.6%	12,713.5	.3%
	+439.7%		+156.1%		-40.9%		-65.9%		-75.1%	
FIXED DISK DRIVES 5 - 10 Gigabytes	52,111.2	16.7%	293,774.2	40.7%	524,225.0	36.5%	331,973.5	10.7%	158,368.0	2.7%
	+801.0%		+463.7%		+78.4%		-36.7%		-52.3%	
FIXED DISK DRIVES 10 - 20 Gigabytes	3,503.5	1.1%	89,874.7	12.5%	613,536.5	42.5%	1,286,173.0	41.6%	1,070,529.0	18.6%
	--		--		+582.7%		+109.6%		-16.8%	
FIXED DISK DRIVES 20 - 40 Gigabytes	3,627.0	1.1%	4,441.0	.6%	111,730.0	7.7%	1,242,385.0	40.1%	2,952,962.0	51.1%
	--		+22.4%		--		--		+137.7%	
FIXED DISK DRIVES more than 40 Gigabytes	--	--	5,967.6	7%	13,985.0	.9%	173,270.0	5.5%	1,574,155.0	27.1%
	--		--		+134.3%		--		+808.5%	
Total Capacity (Terabytes)	311,767.5	100%	721,268.9	100%	1,442,936.5	100%	3,100,012.1	100%	5,782,828.5	100%
	+127.1%		+131.3%		+100.1%		+114.8%		+86.5%	
% U.S. Manufacturers	77.6%		73.6%		73.4%		71.0%		67.5%	

Note: Percentage figures with plus/minus signs refer to year-to-year growth rates.

Figure 6

1997 ESTIMATED MARKET SHARE

Worldwide Percentage Revenues



1997 Revenues: $31,736,300,000

TABLE 13

1997 ESTIMATED MARKET SHARES

WORLDWIDE REVENUES OF ALL RIGID MAGNETIC DISK DRIVES
(Value of non-U.S. currencies estimated at average 1997 rates)

	CAPTIVE		DISTRIBUTOR		OEM/INTEGRATOR		TOTAL INDUSTRY	
	$M	%	$M	%	$M	%	$M	%
U.S. MANUFACTURERS								
IBM	4,434.7	70.2	298.0	3.8	2,858.8	16.3	7,591.5	23.9
Iomega	--	--	194.4	2.5	34.8	.2	229.2	.7
JTS	--	--	110.8	1.4	31.2	.2	142.0	.4
Quantum	--	--	1,483.5	18.9	3,437.6	19.6	4,921.1	15.5
Seagate Technology	--	--	2,809.0	35.8	4,475.9	25.5	7,284.9	23.1
Syquest Technology	--	--	60.4	.8	6.3	--	66.7	.2
Western Digital	--	--	1,478.9	18.9	2,757.4	15.7	4,236.3	13.3
Other U.S.	--	--	71.3	.9	23.4	.1	94.6	.3
U.S. Total	4,434.6	70.2	6,506.3	83.0	13,625.4	77.6	24,566.3	77.4
NON-U.S. MANUFACTURERS								
Fujitsu	487.0	7.7	--	--	1,779.8	10.1	2,266.8	7.1
Hitachi	60.4	1.0	94.8	1.2	261.1	1.5	416.3	1.3
Maxtor	--	--	478.4	6.1	943.2	5.4	1,421.6	4.5
Micropolis	--	--	112.6	1.4	113.2	.6	225.8	.7
NEC	217.5	3.4	--	--	59.2	.3	276.7	.9
Samsung Electronics	73.1	1.2	509.7	6.5	148.2	.8	731.0	2.3
Toshiba	1,042.1	16.5	124.5	1.6	646.6	3.7	1,813.2	5.7
Other Non-U.S.	--	--	16.7	.2	1.9	--	18.6	.1
Non-U.S. Total	1,880.1	29.8	1,336.7	17.0	3,953.2	22.4	7,170.0	22.6
WORLDWIDE TOTAL	6,314.7	100.0	7,843.0	100.0	17,578.6	100.0	31,736.3	100.0

Note: 1. Drives sold in the Distributor market by other than the original manufacturer are valued at Distributor prices above, to avoid distortion of total market value

2. The DISK/TREND estimates of revenue for each disk drive manufacturer include net sales of disk drives only and do not represent total revenues for individual companies

Codes: 1.8 = 1.8" C = Captive
2 = 2.5" D = Distributor
3 = 3.5" O = OEM
5 = 5.25"
8 = 6.5"-9.5"

TABLE 14

CURRENT PRODUCT LINES
MANUFACTURERS OF RIGID MAGNETIC DISK DRIVES

DISK/TREND PRODUCT GROUP		1	2	3	4	5	6	7	8	9
U.S. Manufacturers (12)	Type	Disk Cartridge Drives	Fixed Disk Drives <1 GB	Fixed Disk Drives 1 GB-2 GB	Fixed Disk Drives 2 GB-3 GB	Fixed Disk Drives 3 GB-5 GB	Fixed Disk Drives 5 GB-10 GB	Fixed Disk Drives 10 GB-20 GB	Fixed Disk Drives 20 GB-40 GB	Fixed Disk Drives >40 GB
Avatar Peripherals	D,O	2								
Belfort Memory International	D,O					5	5			
Castlewood Systems	D,O	3								
IBM	C,D,O			2	2,3	2,3	2,3	3		
Integral Peripherals	O					3				
Iomega	D,O	3								
JTS	D,O				3	3	3			
Quantum	D,O			3	3,5	3,5	3,5	3,5		
Raymond Engineering	O		3							
Seagate Technology	D,O			3	3	2,3	3,5	3	5	5
SyQuest Technology	D,O	3,5								
Western Digital	D,O				3	3	3			
Asian Manufacturers (6)										
Fujitsu	C,D,O		2,5	2,3,5	2,3,5	2,3	3	3		
Hitachi	C,D,O			2,3	2,8	2,3	2,3,8	3		
Maxtor	D,O				3	3	3	3		
NEC	C,D,O			3	3					
Samsung Electronics	C,D,O			3	3	3	3			
Toshiba	C,D,O		2	2	2	2	2			
European Manufacturers (2)										
Calluna Technology	D,O		1.8	1.8						
Nomai	D,O	3								

Note: 2.5 inch includes mobile platform 3 inch drives.
3.5 inch includes server platform 3 inch and 2.5 inch drives.

TECHNICAL REVIEW

Competing technologies

The rush to higher areal density and lower cost per gigabyte continues, assuring rigid disk drives of a pre-eminent role in storage technology. The first glimmerings of serious competition from hybrid optical and rigid disk drive designs are becoming apparent. Still, rapid increases in areal density and performance continue to reinforce the position of the rigid magnetic disk drive industry against its challengers. The improvements in drive performance contribute to making it nearly impossible for any competing storage technology to broadly displace the rigid magnetic disk drive, except in a few niche applications. Manufacturers continue to provide smaller, faster, more reliable, higher capacity, less expensive disk drives, well supported by a magnetic storage industry supplier infrastructure.

During the early 1990's, the disk drive industry was able to increase areal density at a 60% average annual rate, provide thinner disk substrates, greater functionality chips, smaller heads, lower flying heights, smaller motors and many other improvements in disk drive and recording technology. While the annual rate of areal density increase dipped to 45% at mid-decade as manufacturers focussed upon mechanical issues, it surpassed the 60% average in 1997 and appears likely that improvements in areal densities will sustain at least the 60% annual average through this report's forecast period, through 2001.

With annual areal density improvements back on the 60% slope, 20 gigabit per square inch areal density by 2001 appears likely. While some technologists expect the rate of increase in areal density to decline towards the end of the decade as increases in data channel rates required by higher linear bit density become harder to achieve, a more probable outcome is the development of drive families optimized for either maximum aerial density or maximum performance, but not both simultaneously.

As areal densities approach the superparamagnetic limit (somewhere between 20 and 70 gigabits per square inch for longitudinal recording, depending on which expert you believe) in the next decade, the decreasing size of the resultant magnetic domains may cause intractable stability problems that require

the disk drive industry to switch from longitudinal recording to perpendicular recording (or optical recording using a flying optical head) to further increase attainable areal density. The superparamagnetic limit for these advanced recording techniques is expected to lie above 100 gigabits per square inch. Valdemar Poulsen (1869-1942), the Danish engineer who invented the first magnetic recording device 100 years ago, would be amazed to learn just what he had initiated when he tried to take his first wire based recording devices to market.

A limited number of alternatives to magnetic disk recording (such as flash memory) exist, but only where the substitute technology has been significantly better, faster, smaller, less expensive or demonstrated some other overwhelming advantage in a particular niche application. Those few technologies which do provide competition to magnetic disk drives in applications where characteristics such as speed, removability, or environmental tolerance give them unique advantages, are discussed in the following sections.

* Semiconductor memory -- applications and trends: Semiconductor memory offers fast response time (typically under 100 microseconds) and high reliability, characteristics that have won it a secondary data storage role in both large and small computer systems. When very fast access to data or programs is required, semiconductor memory can serve as an effective, though expensive, substitute for rigid drives. Larger systems frequently have large auxiliary semiconductor storage units performing as virtual disk drives or as cache between the host processor and disk storage. Personal computer operating systems also allow part of main memory to be designated for use as a fast virtual disk.

  Where only small amounts of mass storage are required, semiconductor memory can be a cost-effective competitor to rigid disk storage, and when added to a disk drive, semiconductor memory can serve as a fast, low power cache that significantly improves system performance. The use of semiconductor memory in a cache can extend portable system battery life, because the disk drive can be shut down after data needed by the current application is loaded into the cache. If the cache memory (and some system memory) is nonvolatile, the system can be turned off and on, returning to the point where operation was halted without expending power on the disk drive.

  Fast semiconductor memory is expensive, ranging from $1/megabyte to over $1000/megabyte depending upon configuration and distribution channel, which limits its use to situations where its high speed or lack of moving parts are vitally necessary to meet system requirements. The least expensive semiconductor memories are volatile, and require the continu-

ous availability of power to avoid loss of data. Nonvolatile semiconductor memory is more expensive, usually slower, and usually does not match the capacity per chip of DRAM, the most common form of volatile semiconductor memory. Some companies package semiconductor memory in disk drive form factors with electrical and logical interfaces similar to commonly used disk drive interfaces. For instance, Quantum offers up to 1.6 gigabytes in a full height 5.25" disk drive form factor and up to 804 megabytes in a standard 3.5" form factor. SCSI interfaces are provided.

The Personal Computer Memory Card International Association (PCMCIA) has standardized the logical and electrical interface for plug-in cards (similar to a credit card) used to expand system memory, emulate a disk drive, or provide other peripheral functions for small portable computers. The associated physical package has been adopted as the PC Card standard. PC Card pin interconnect and packaging standards have been worked out, with the final result being a 68 pin connector and a family of package heights: 3.3 millimeters (Type I), 5 millimeters (Type II) and 10.5 millimeters (Type III). The cards are available with a variety of memory forms, including disk drives, PROM, ROM, SRAM, DRAM, and flash memory. Even smaller form factors for use with industrial equipment, cameras and consumer applications appeared in 1995 and 1996. Three small form factors (CompactFlash, Miniature Card and Solid State Floppy Disk Card), typically containing flash memory, are the major contenders for acceptance, each backed by a consortium of card manufacturers and equipment manufacturers. The Solid State Floppy Disk Card is also known as SSFDC or SmartMedia. Additional new form factors, such as SanDisk's MultiMedia Card (MMC) and Sony's MemoryStick have been developed for applications requiring even smaller physical size.

The PCMCIA/PC Card effort has been a major factor in promoting the acceptance of plug-in semiconductor memory as a disk drive alternative, although some disk drives, including 1.8" drives, have been packaged in PC Card form factors with the capability to be plugged into a PC Card Type III card slot. Most issues regarding software support of the PCMCIA interface have been worked out, but the use of the PCMCIA interface does not fully guarantee functional interchange among older devices that are electrically and physically PCMCIA compliant. PC cards emulating the ATA/IDE interface are more broadly interchangable.

In many industrial applications, flash memory cards are used in configurations that are not PCMCIA compliant or only partially compliant, as such applications rarely require the full PCMCIA feature set, and design simplification can significantly reduce costs. Some modules are not in card format: Memories up to 240 megabytes are packaged to fit within the physical envelope of the discontinued 1.3" Hewlett-Packard disk drive.

Will semiconductor memory technology improve during the rest of the decade at the same rate exhibited in the last 20 years? As the complexity,

packaging problems, and performance requirements of semiconductor memory have increased, so also have the investments in time and capital required to produce succeeding generations of chips. The pace of semiconductor memory price decreases is consequently expected to slow, and high investment costs are already inspiring increasing numbers of companies to pool resources to contain development expenses.

* Volatile semiconductor memories: DRAM is the most commonly employed form of semiconductor memory. It is used in systems of all sizes for general purpose system memory, video memory, and other applications where its volatility is not a major handicap. It is also used on large systems as a supplement to magnetic storage to provide fast mass storage. Access times are in the range of .1 microsecond or less. DRAM chips are readily available in 16 megabit configurations, but large quantity production of 64 megabit DRAM chips is well underway and customers are transitioning to the higher density.

  SRAM memory chips are in volume production in 1 megabit to 4 megabit configurations. Power requirements are less than DRAM requires and speed is high, permitting SRAM to be used as a memory add-on in portable, power limited equipment. SRAM is sometimes used in removable memory cards that contain a small battery which provides the power needed by SRAM memories to retain data. However, SRAM is more expensive than DRAM and flash memory.

* Nonvolatile semiconductor memories: Flash memory, a form of EEPROM in which a block of memory cells can be erased by an electrical signal, is nonvolatile and can be used as fixed or removable storage. Flash memory can provide adequate mass storage where capacity need be only a few megabytes, power limitations are severe, a hostile environment exists, and product price is not a paramount factor.

  Flash memory is often discussed as a prospective competitor to rotating memory, but its more significant computer applications will be for program storage, peripheral equipment updatable firmware and as a reprogrammable BIOS in computer systems. In this role, flash memory can provide obsolescence protection by allowing periodic code updates, and provide functionality changes in printers, fax machines, modems, and other electronic equipment. Removable flash memory has found a stronger market in consumer products such as digital cameras than it has in computer oriented markets.

  While flash memories are rugged, portable, reliable and use little power, they have some functional disadvantages. When rewriting, it is not possible to change only a few bits; an entire block must be erased and rewritten, and this can take from 10 milliseconds to as long as half a second for the equivalent of a disk sector in some flash memories. Whatever is in the cell block must be saved to RAM and restored after the erase/write cycle on the flash memory chip. As a result, read operations can be very fast

compared to a magnetic disk drive, but writing is just now starting to approach the 1.5 megabyte per second range. There is also a limit to the number of times the memory device can be rewritten. At present, most flash memory devices are specified for 100,000 write/erase cycles, though some claim 1,000,000 cycles. Some flash memories still require 12 volt power, but more recent products operate on 5 volts, 3.3 volts, or both.

Flash memories using 1 to 64 megabit chips are currently in production, manufactured by Intel, AMD, SanDisk, Samsung, Atmel, Seeq Technology, Toshiba and other firms, with more 64 megabit chips currently being introduced. Most flash memory cards have capacities under 10 megabytes, but average capacities are expected to increase rapidly as digital cameras with megapixel resolutions enter the market. Digital cameras are also creating pressure for improved write performance, even at the expense of cost. Flash disk cards, some with capacities in excess of 100 megabytes, that mimic the 512 byte sector organization of a magnetic disk drive and include an IDE interface, appear as a disk drive to the host system. "Linear flash" appears as additional system RAM memory. Both are available in card and module packages.

1998 flash memory OEM prices have declined to the range of 3 to 10 dollars per megabyte, but are still much higher than magnetic disk drives. Memory chips using multiple bit storage cells, which entered the market in late 1997, contributed to the decline, but are too slow to achieve broad acceptance in some applications. Still, where less than 50 megabytes of storage are required and the rate of rewrites is not too high, flash memory can be economically attractive as a competitor to rigid disk drives.

Ferroelectric memories (FRAM) use the electrically reversible polarization of ferroelectric materials to form a capacitor, which is required in the circuitry of semiconductor memories. Proper design can produce a nonvolatile memory cell that can be fabricated with conventional planar processes but has smaller dimensions than cells made with silicon dioxide capacitor dielectrics. Submicrosecond access times are possible. The number of write/erase cycles possible exceeds a trillion cycles for the best materials, and a billion cycles may eventually be routinely achieved. Operating speed is equivalent to that of typical DRAM, but not quite as fast as conventional SRAM. FRAM does not have the limitations on write speed characteristic of flash memory. The fabrication techniques required to construct ferroelectric chips are substantially the same as used for CMOS, which is a well understood technology, although some process changes are needed to accommodate the different materials used.

Ramtron, which has long been the most visible developer of ferroelectric memory technology, has licensed it to NMB Semiconductor Company, ITT and Seiko, and more recently added Rohm, IBM, Toshiba, Samsung and SGS-Thompson as licensees. Ramtron and Hitachi are jointly developing 256 kilobit, 1 megabit and 4 megabit ferroelectric memory chips. Ramtron

also has a joint development effort with Fujitsu aimed at production of 1 megabit chips, to be followed eventually by 16 megabit chips. National Semiconductor also has a ferroelectric memory development effort. Ramtron currently offers chips from 4 to 64 kilobits, and with its licensees has begun to produce 256 kilobit chips. The chips are being sold for a variety of applications, including electronic games and smart cards. Chips up to 16 megabits are planned for 1999.

Ferroelectric and flash memories will contend for acceptance in portable computers, consumer equipment, "smart cards" and in industrial applications where loss of memory due to a power lapse is a critical problem. Ferroelectric memory will probably compete with magnetic drives in applications where the environment is stressful and rapid access is required. This includes military, industrial, and some high value commercial applications, but does not embrace the broader classes of nonvolatile memory requirements served by rotating memory. Development of ferroelectric memory technology is lagging that of flash memory, and it isn't clear that both can succeed.

* Holographic storage: Holographic storage is a type of storage in which an array of bits is stored in an optically sensitive medium as a pattern scattered throughout the volume of the medium. A scanned laser generated writing (object) beam and reference beam create an interference pattern throughout the storage element, which in turn modifies the index of refraction throughout the storage medium in a similar pattern. Many bit pattern images can be stored in a single piece of storage media, limited largely by the need to maintain an adequate signal to noise ratio. As images are added, there is some tendency for interference between them. The location of the image is determined by the angle at which the reference beam impinges upon the storage medium. When the medium is illuminated by the reference beam only, the data can be projected upon a detector.

  Holographic storage media can be fixed or removable, and both write-once and rewritable forms are possible. Current media designs employ crystals fabricated from iron doped lithium niobate, barium titanate, strontium barium niobate and organic polymer materials. In general, the materials are not interchangeable. While some of these materials permit degradation of stored data due to the effect of read operations, temperature cycling can make the data permanent while still permitting further writing operations. Acousto-optical modulators are used to scan the laser beams. The deflected object beam used for writing is directed through a spatial light modulator (SLM) to create the bit stream to be stored. The SLM is typically a liquid crystal array with the bit pattern imaged upon it. A CCD sensor array is used as an output detector for data readback.

  Because holographic storage systems have no moving mechanical parts, they have applications in military, industrial, and other applications where

ruggedized storage is essential. If practical, holographic storage can virtually eliminate the current limitations on throughput caused by mechanical drives, and must be considered as having the potential to compete with magnetic and optical rotating disk drives for selected applications after the turn of the century.

Early attempts to develop holographic storage for use in computer memories were unsuccessful due to technical difficulties (many due to a lack of suitable components), such as a tendency of read operations to degrade the stored data, and inability to meet cost and performance constraints. But the very high storage densities and fast access times theoretically achievable have encouraged continuing research and development efforts by many organizations worldwide, and many of the early problems have been reduced or eliminated.

One of the more ambitious holographic storage programs was conducted by MCC (Microelectronics and Computing Corporation), a research consortium sponsored by major U.S. technology firms. Supporters of the MCC effort included DEC, NCR, Eastman Kodak, General Dynamics and E-Systems. MCC demonstrated working prototypes of write-once holographic memories in a 5.25" form factor in 1992 and established a subsidiary corporation, Tamarack Storage Devices, to commercialize the technology. MCC's devices targeted capacities in the range of 200 megabytes to 10 gigabytes, average access times in the 1 to 10 microsecond range and data transfer rates in the gigabyte per second range.

While Tamarack's efforts did not result in a salable product, other companies and universities are working as a consortium on the HDSS (Holographic Data Storage System) to develop prototype holographic storage equipment or required components by the year 2000. Much of this effort is funded by a $32 million program jointly funded by NSIC (National Storage Industry Consortium) and DARPA (Defense Advanced Research Project Agency), which is associated with the U.S. Department of Defense. The goal of HDSS is a capacity of at least a trillion bits and at least a one gigabit per second data transfer rate.

A second consortium started in 1994, designated PRISM (Photo Refractive Information Storage Materials) is concentrating upon development of suitable holographic media. Both write-once and rewritable media are anticipated. The consortium is focusing upon creating a storage device with a terabyte of memory (using several media units), one gigabit per second data transfer rate and an access time of less than one millisecond within a single medium unit. A mechanical transport mechanism will switch storage crystals, with a typical transport time of 30 milliseconds anticipated. Packaging of the device within a standard 5.25" form factor is expected. Current cubic storage density is under 50 megabytes/cubic centimeter, but the target is storage media with 10 gigabytes/cubic centimeter capability.

Among the organizations participating in the HDSS consortium are IBM, Optitek, GTE, Eastman Kodak, Rochester Photonics, SDL and several universities, including Stanford, Carnegie Mellon, the University of Arizona and the University of Dayton. PRISM members include IBM, Optitek, GTE, Hughes, Rockwell, SRI and Stanford University. Nonconsortium organizations are also developing holographic memories, including Holoplex and NTT. Consortium members don't expect to have salable products available until 1999, although a few evaluation prototypes may be completed sooner. Rockwell and Holoplex have created operating prototypes with limited storage capabilities for the purpose of evaluating the technology.

Research related to nonholographic three-dimensional optical storage continues, but many of the same temperature and material problems must be overcome. For instance, the University of California at Irvine disclosed an experimental device capable of storing 6.5 trillion bits in an organically doped plastic module the size of a sugar cube. Two different lasers are needed to write and read data, and the device must be operated at cryogenic temperatures to avoid data loss.

* Optical disk drives: Optical drives range from 2.5" units with 140 megabyte capacity to 14" drives with up to 25 gigabytes of capacity. In recent years, optical recording has increased its areal density at "only" an average 40% per year compared to the average 60% annual growth exhibited by rigid disk drives and has become increasingly disadvantaged compared to rigid disk drives from a storage density standpoint. With track densities of 18,000 to 34,000 tracks per inch and linear bit densities of 25,000 to 90,000 bits per inch or more, some optical disk drives remain capable of higher areal densities than magnetic disk drives now in use, although yet unannounced magnetic disk drives exceeding 5 gigabits per square inch areal density are expected to close the gap. However, the performance of optical disk drives compared to rigid disk drives is markedly inferior due to their longer seek times and latencies.

  Optical disk drives have the potential to become more significant challenges to rigid disk drives, as TeraStor, Quinta and other firms developing very high capacity magneto-optic drives introduce expected products in 1998 and 1999. None of the firms has yet announced full details of its designs, but near-rigid disk drive performance is anticipated. TeraStor has announced that its initial products will be 5.25" drives with 10 or 20 gigabytes per disk surface. This new class of optical drives achieves its capacity through the use of hybrid heads, actuators and electronics using technology developed for rigid drives. The heads (which, in the case of TeraStor, employ solid immersion lens technology developed at Stanford University to produce very small bit size) fly only microinches from the media. Coupled with shorter wavelength red lasers and optimized media, the new drives are expected to achieve areal densities well in excess of those obtainable today with conventional rigid disk drive designs.

Development of blue diode lasers capable of room temperature operation could further improve areal density, but suitable devices are not expected to be available for several years. However, the red lasers now appearing in newer conventional optical drives are expected to improve typical areal density over the next year. The ultimate limit of optical areal density may be much higher than today's practice. In mid-1992, Bell Laboratories reported they had written data in the laboratory at 45 gigabits per square inch using fiber optics to replace conventional optical elements.

Although the areal density of optical drives is high, the volumetric density is inferior to that of magnetic drives because optical media is thick, head assemblies are large, only one disk is typically present, and typically only one head is present in the drive. Very high capacity drives, such as the anticipated TeraStor design, may eliminate much of optical's volumetric disadvantage, especially if the technology proves suitable for fixed media applications. Current optical drive technologies cannot provide performance equivalent to current magnetic disk technology, nor can optical drives yet compete on a product cost basis. Therefore, conventional optical disk drives will continue to be preferred only where removability of the media is an advantage, such as use in an automated library or for security concerns. The very high capacity, high performance optical drives anticipated during the next few years may well define a new niche in the storage performance hierarchy, located between rigid disk drives and conventional optical drives.

Even in some removable applications, high capacity 3.5" magnetic cartridge drives compete strongly with 230 megabyte and 640 megabyte 3.5" magneto-optical drives, offering better performance, lower price and higher capacity. Magnetic disk cartridge products such as the 1 gigabyte Iomega "Jaz" and SyQuest 1 gigabyte "SparQ" drives compare well against 3.5" optical drives. The 4.7 gigabyte "Quest" removable disk cartridge drive expected from SyQuest in late 1998 will put further pressure on optical drives if successful. Accordingly, optical drives seem more likely to complement rigid magnetic disk drives rather than replace them, serving as vehicles for backup, software distribution, and off-line or library storage.

Manufacturers of optical disk media now claim that their disks will provide archival lives which equal or exceed those of magnetic media, with 10 to 30 years being commonly encountered specifications for archival life of the media. Lifetime is limited by the gradual appearance of defects on the recording layer due to the corrosive effects of water and oxygen on the metal films used in the recording layers of the media. The termination point of media lifetime occurs when the error correction capability of the drive can no longer cope with the gradually increasing media defect density. Media using organic dyes as the recording material have no metallic films and may offer improved stability.

Because existing optical drives have removable media, large automated libraries using optical drives can provide random access to many disks, making the use of large-scale optical storage attractive for users such as governmental agencies, banks, insurance companies and other organizations with massive records that must be easily accessed. Library systems coupled with storage management software and operating system support make optical storage practical in the larger system environments typical of networks.

* Nonreversible optical disks: The first optical disk recording systems to enter the market were "nonreversible" or "write-once" systems. The initial products manufactured were 12" in diameter, but the trend is to 12 centimeter diameter drives. 12 centimeter (4.72") CD-ROM compatible write-once drives for professional use were introduced by Yamaha in 1989 and by Sony in 1990, and lower cost 12 centimeter write-once drives from Philips, Sony and JVC entered the market in 1992. 12 centimeter CD-R drives became the dominant form of write-once drives in 1994 as a result of the displacement of 5.25" write-once drives by multifunction and rewritable optical disk drives. CD-R drives are now being displaced by CD-RW drives offering rewritability, with the transition now proceeding rapidly as CD-RW drive prices approach CD-R prices. CD-RW and CD-R drive capacity and performance do not compete against rigid drives and they pose no significant competitive threat. DVD-R and DVD-RAM drives, anticipated in the 1998-1999 time frame, will offer competitive capacity, but inferior performance compared to rigid drives and are not expected to be significant competition.

  The market for "pure" write-once optical disk drive systems is limited to the niches which emphasize nonreversibility. In some applications, the ability of write-once optical disk storage systems to maintain an audit trail or indicate whether or not stored data has been modified is perceived as a significant benefit. Archiving is a significant application for CD-R.

  Virtually no displacement of magnetic disk drives by nonreversible optical storage will occur in the foreseeable future, and the growth of write-once technology is being capped by competition from rewritable or multifunctional optical drive technology.

* Rewritable optical disks: As cost-effective rewritable drives with improved performance become available, the possibility for eventual inroads into the market for magnetic disk drives exists. Some rewritable optical drives have reached performance levels typical of small rigid magnetic drives in the mid-1980s, but cost, capacity, power consumption and packaging improvements have lagged.

  Magneto-optical (MO) recording has been evolving for more than twenty years, and rewritable phase change optical recording emerged as a

competitor in 1990. Magneto-optical drives which entered production in 1997 can finally overwrite in place. In older designs, a complete sector must be erased before the sector can be rewritten. Phase change media can be directly overwritten, but limits the number of write erase cycles, typically to a few hundred thousand. MO media can be rewritten indefinitely, although it is subject to thermal fatigue effects observed after 10-20 million write-erase cycles.

Some rewritable drives have exceeded 4,000 RPM spin rates and Fujitsu has announced a 5,400 RPM model. However, average seek times are having difficulty moving below 20 milliseconds, and it remains to be seen if the performance of the TeraStor and Quinta designs can approach the best magnetic drive technology. Improved head design, shorter wavelength, higher power lasers and other improvements will gradually permit closing the performance gap.

Today's 5.25" MO drives now offer 2.6 gigabytes per side. Maxoptix, Sony, Nikon and others have already introduced such drives, while Pinnacle Micro has announced both 1.3 gigabyte per side and 2.3 gigabyte per side drives. Next generation media issues (9-10 gigabytes per 5.25" cartridge) are currently under consideration in several standards technical subcommittees, with related drives expected in 1999-2000. However, the low shipment volumes of 5.25" MO drives leave them open to competition from lower cost 120 millimeter format writable and rewritable drives expected to be shipping in large quantities in the 1998-1999 time frame, including anticipated MO drives using 120 millimeter media.

ISO standard 3.5" drives now offer over 640 megabytes per surface. 3.5" drives are expected to move to the 1.3 gigabyte per surface mark towards the end of the decade, and Fujitsu has demonstrated an experimental 4 gigabyte 3.5" drive.

Sony's 140 megabyte 2.5" drive production began in late 1994, but the drive did not receive wide acceptance due to its relatively high price, power consumption and excessively large package. The form factor is now used mostly for consumer AV applications.

The first rewritable phase change drive was introduced by Matsushita Electric in 1990, and was backward compatible with previous write-once drives from the same firm. The PD drive, a 650 megabyte rewritable phase change drive with CD-ROM read capability began shipping in 1995 from Matsushita and NEC. While inferior to rigid magnetic drives in performance, it has won a limited role as an auxiliary storage and data exchange and backup device. Companies producing CD format drives began shipping rewritable drives (CD-RW) using phase change media in late 1996. If produced at a low enough price, such drives could achieve significant market penetration as auxiliary storage. While unlikely to displace rigid disk drives because of limitations in performance and reliability, they are expected to slowly displace write-once CD-R drives.

Individual firms working on other proposed reversible optical recording technologies have yet to overcome technical problems that include slow completion of the reversal cycle, degradation of stored data with the passage of time, sensitivity to ambient light, limitations on the number of reversals which may be accomplished before degradation, temperature sensitivity, expensive optical or laser components, poor shelf life, and low recording density.

* Read-only optical disks: The read-only optical disk category is currently dominated by the CD-ROM, which has capacities of 550 to 680 megabytes, depending upon the format used, but slow access times. Performance has gradually improved, with data transfer rates increasing from 150 KB/second (1X) through 2X, 4X, 6X, 8X, 12X to 32X or more, even though most systems are incapable of using rates higher than 8X (1.2 MB/second). DVD-ROM drives, with capacity per surface of 4.7 gigabytes, began shipments in late 1996 and are expected to equal CD-ROM drive production rates in the latter part of 2000. If multiple layer media is used, 8.5 gigabytes per side is possible. Write-once (DVD-R) and rewritable (DVD-RAM) versions of DVD drives are also anticipated, but they will probably appear in the marketplace in volume after 1998 as the industry resolves competition between competing recording formats.

  Because they do not have recording capability, no significant displacement of magnetic disk drives by read-only optical drives is anticipated. They will retain a specialized role as a form of electronic publishing and will appear on computer systems as an adjunct to a rigid disk drive rather than as a replacement device. Rewritable CD or DVD format drives could take the place of some rigid disk drives in an auxiliary storage or data exchange and distribution role.

* High capacity flexible disk drives: The 5.25" Bernoulli disk drives offered by Iomega reached 230 megabytes in capacity and competed for a while with removable 5.25" rigid cartridge disk drives, but have been phased out. Iomega and its licensees are producing the highly successful 3.5" 100 megabyte "Zip" drive, and this technology is potentially extendible to the 200 megabyte range and beyond.

  The 20 megabyte 3.5" "Floptical" drives produced initially by Insite Peripherals and for a while by Iomega achieved limited acceptance, especially in the aftermarket. The floptical 20 megabyte drive has been displaced by a 120 megabyte version manufactured by Matsushita-Kotobuki Electronics and others. Like the 20 megabyte version, these drives are backward compatible with 1.44 megabyte floppy drives. 130 megabyte floppy drives, also backward compatible, expected from Swan Instruments and Mitsumi Electric had not been placed in volume production as of mid-1998. Sony's 200 megabyte floppy, which will also be backward compatible with the 1.44 MB floppy, appears poised to challenge all of the high density floppy drives currently announced.

Unfortunately, none of the 3.5" high capacity flexible disk drive formats are compatible with each other, although some provide read and write backward compatibility with 1.44 megabyte 3.5" floppy disks. Aggressively priced, high capacity floppy drives are expected to compete in the low end of magnetic and optical disk drive markets, and against tape drives for backup applications. With over 12 million shipped, Iomega's high capacity 3.5" Zip drives have proven successful in the marketplace, competing with various low-end rigid disk cartridge drive and optical disk drive formats for specific applications, and have been adopted by several computer manufacturers as options in desktop computers.

* Atomic force microscopy: AFM is being investigated by IBM as a possible future recording technique. It involves using a thermally activated microprobe to create submicroscopic pits in a sensitive disk layer. The pits are detected by a second probe attached to a piezoelectric sensor. IBM has obtained 50 gigabits per square inch in the laboratory, but at slow data rates. The read and write probes will eventually be integrated into a single unit.

Disk drive enhancements

Throughout its 42 year history, the magnetic disk drive industry has been characterized by continuous and rapid improvement in product technology. Disk drive product development leadership was maintained by IBM until the late 1970s, a period in which IBM was displaced from its leading position by aggressive competitors manufacturing small diameter drives. IBM reemerged as a product leader in the late 1980's, with new families of 2.5", 3.5" and 5.25" drives, and IBM has maintained a leading position in early implementation of high recording densities in new drive models.

IBM's leadership in implementing major advances in magnetic disk recording technology has helped the company maintain a leading position in the industry, and it has also provided a technology role model for competitors. During the 1990's, most of the industry has followed IBM's initiative in moving to magnetoresistive heads, which IBM first utilized in production drives in 1991, and PRML encoding. These and other refinements have made possible IBM's average annual improvement in areal density exceeding 60%. Other manufacturers have followed as closely behind as possible, limited mostly by availability of critical components and the time needed to refine new designs. In early 1997, Hitachi briefly captured the areal density lead with a 2.5" drive operating at 2 gigabits per

square inch areal density, before IBM moved ahead with other 2.5" drive designs, ending 1997 with production drives at 3.1 gigabits per square inch. With IBM's shipment of the first drives using giant magnetoresistive heads in early 1998, the competitors are racing to secure availability of GMR heads and implement the next wave of areal density advances.

The critical areas of technological change for rigid disk drives are discussed below.

* Areal density: Areal density has increased rapidly since the early 1990s. Increasing areal density reduces the number of disks and heads needed to achieve a given capacity in a specific form factor, which in turn lowers product costs. Following IBM's first MR head drive in 1991, with 107 megabits per square inch, drives using MR heads with areal densities exceeding 560 megabits per square inch went into production in 1994, and leading edge drives achieved over 900 megabits per square inch in late 1995. 2 gigabits per square inch was reached in early 1997, followed by drives exhibiting over 3 gigabits per square inch. 4.1 gigabits per square inch was achieved in early 1998, with areal density exceeding 5 gigabits per square inch anticipated by year end. 20 gigabits per square inch is expected before the end of 2001.

  TPI in excess of 8,000 is common and many of the newest small drives operate at or over 13,000 TPI. IBM's "Acadia" 2.5" drive operates at 16,000 TPI, while the 3.5" "Titan" operates at 13,700 TPI. IBM has shown the feasibility in the laboratory of creating media with very narrow tracks with submicron dimensions. However, considerable work will have to be done to develop heads capable of working with such narrow track widths. Hitachi's 2.3 gigabit per square inch demonstration featured 17,000 TPI, a figure that may soon be reached in a production drive. Hitachi's current 2.5" drives currently operate with track densities as high as 13,000 TPI. New head designs, new materials and designs being developed to improve vibration suppression damping in head gimbal assemblies and positioning mechanisms should assist in reaching higher track densities.

  BPI has also rapidly increased. IBM's 1989 1 gigabit per square inch demonstration operated at 158,000 bits per inch, which was exceeded slightly by Hitachi at 165,000 BPI. IBM's new 2.5" "Acadia" operates at 256,400 BPI, considerably more than IBM's 1989 laboratory demo. Many of today's small drives operate with bit densities above 120,000 BPI, and an increasing number have BPI in excess of 150,000 BPI. The areal densities of newer 2.5" drives typically exceed the areal densities of 3.5" drives.

  Another factor increasing disk capacity is the ability of more intelligent drives to dispense with much of the sector formatting information, reducing overhead and increasing the available area for user data.

* Limits to areal density: Today's rigid disk drives all use longitudinal recording, making use of magnetic domains oriented parallel to the surface of the recording medium. As areal density increases and bit sizes decrease, the stability of the stored data declines due to interdomain interference until it reaches the superparamagnetic limit (described by various authorities as somewhere between 20 to 70 gigabits per square inch), at which further increases in longitudinal recording density are not possible. Higher linear densities could theoretically be resolved by recording heads if magnetization were oriented in a plane perpendicular to the recording surface or by using smaller cylindrical domains that are isolated from each other by nonmagnetic material, and TPI could also be sharply increased, provided that head to disk spacing is minimized. As areal densities of longitudinal recording approach the superparamagnetic limit, interest in perpendicular recording and the use of isolated domains is likely to increase because it appears to be able to support higher areal densities than longitudinal recording, perhaps exceeding the 100 gigabits per square inch range.

  The use of hybrid optical/magnetic recording systems (which produce inherently cylindrical domains) also appears to offer a way around the superparamagnetic limit, although the increased complexity of the heads required may add enough mass to limit average seek times and available laser power may not be high enough to sustain writing at very high RPM, at least in initial designs for this type of drive. TeraStor says that its drive family will be able to operate reliably at areal densities close to the superparamagnetic limit for longitudinal recording and is expected to offer considerably higher areal density as laser wavelength decreases in future years, permitting ever smaller bit sizes.

* Head flying height: Because head flying height determines the achievable areal density, reductions are of critical importance. Head flying height is in the 2 microinch range for an increasing number of drives, and several firms are designing drives in which there is no measurable flying height.

  The virtual elimination of flying height requires a new level of sophistication in the preparation of disk substrates, plated layers, thin overcoatings, heads and test equipment. For instance, it appears that glass, exotic aluminum alloys or other alternative substrates may be necessary to obtain the required smoothness, rigidity and flatness for the lowest flying and glide heights. Determining reliable processes for manufacturing, coating, texturing and testing disk media using alternative substrates are major challenges, as are the needs for accurate, repeatable test instrumentation capable of dealing with decreasing flying height and bit sizes.

  Several approaches to contact recording have been tried. Censtor developed an unusual low mass, low contact area head design in which the head is normally in contact with the disk. While wear does occur, the rate

of wear of the critical parts of the head is low enough to permit head lifetimes to exceed expected drive lifetimes. The head area and loading is small enough to control stiction effects, and the in-contact thin film head is capable of operating at 200,000 to 300,000 BPI. VISqUS Technology, acquired by Conner Peripherals in 1991, developed a "waterskiing" technique in which the friction of head/disk contact is controlled by floating a head on a continually refreshed liquid bearing surface, but this technique did not prove successful in practice.

IBM's "tail dragging" approach suspended a small head from a larger flying head. The large area of the flying head keeps the head at a stable height and orientation while positioning the smaller active head at the surface of the disk. The tail dragger has evolved into a series of virtual contact heads, variously called "Tri-pad" or "Proximity recording heads" by various manufacturers. These heads, which fly at 1.5 microinches or less, are the most commonly used type. They are employed for both inductive thin film and magnetoresistive heads, and are expected to be retained for use with GMR heads.

* Recording heads: Monolithic ferrite heads patterned after IBM's 3350 designs dominated early Winchester disk drive designs. In following years, PCM disk drives using heads with 3370 contours (minisliders) designed to compete against IBM's 3370, 3375, 3380, and other new drives with ferrite heads became common. The avalanche of small diameter disk drives from multiple OEM sources since the early 1980's has required smaller head contours and continues to drive the demand for higher performance smaller heads. These pressures have driven the development of composite, metal-in-gap ferrite heads, inductive thin film heads, and magnetoresistive thin film heads, but ferrite heads are all but phased out as areal density increases forced the transition to inductive thin film heads and, more recently, to magnetoresistive heads. A transition to heads using "Giant" magnetoresistance, (GMR), also known as spin valve heads, is currently under way as areal density approaches 5 gigabits per square inch.

  Heads used in current drives are required to fly at nearly constant altitudes only a few microinches above the disk surface and survive the occasional brush with a surface irregularity. They are also expected to maintain a proper altitude and attitude while the head is being positioned and while the disk is spun up and spun down. These requirements have required rapid evolution in the design of the slider's air bearing surfaces, negative pressure cavities, coatings and materials to provide the desired features, provide close adherence to required tolerances, and remain manufacturable at reasonable cost.

  As spacing between disks diminished, use of smaller sliders became mandatory, and sliders have continued to decline in size under the pressure to make ever smaller HDAs. After several years of dominance, the

70% form factor microslider (70% of the volume of a minislider) has been replaced by the 50% form factor nanoslider, which is now in wide use in 3.5", 2.5", and 1.8" disk drives. The 30% form factor picoslider is now supplied by several manufacturers for use in 2.5" drives, but 50% sliders are expected to be used with many drives for several years in the future. A limited use of sub-30% sliders began in 1996, and the femtoslider is expected to see increasing use as drives move past 5 gigabits per square inch density. As the form factor decreases in size, the difficulties in connecting MR or GMR heads, which have more leads and may require chip on slider fabrication, are starting to mount.

Additional advantages of the small sliders include less mass to inhibit rapid positioner movement or to cause damaging head/disk interference. The smaller size also relieves stiction problems, although some new drive designs also utilize ramp loaded heads, eliminating the possibility of stiction and reducing power requirements for starting drive motors. The very low flying heights now required also required improvements in head wear resistance. A diamond like carbon overcoating for the head first used by IBM is now used by other manufacturers to improve head life and reduce stiction.

Head suspensions have become a challenging design area as slider form factors continue to shrink and magnetoresistive heads, which require more wires, become increasingly prevalent. Expected improvements include the incorporation of chips, connecting leads and head bonding pads within the structure of the suspension itself, to reduce stray inductance and increase writing performance. While stainless steel remains the current material of choice for suspensions, other materials such as ceramics or silicon are being investigated. Advanced head actuator designs include compound (multistage) actuators, using the voice coil motor for approximate positioning and a second actuator for precision head positioning.

Magnetoresistive heads are now in use in both high performance and low cost disk drive designs. While internally generated noise, vulnerability to electrostatic discharge and low yield still remain challenges, MR heads are now available from at least 9 vendors, with many also produced by drive manufacturers such as IBM, Quantum, Fujitsu and Seagate. IBM introduced the first disk drives using MR heads in 1991, using them in 2.5" disk drives in 1993, as well as in the 3390-9. A few other disk drive manufacturers introduced drives with MR heads in 1994, and others have followed.

In August, 1993, IBM published information suggesting that advanced MR heads using "giant magnetoresistance" (GMR), which enhances head sensitivity and improves signal to noise ratios, was a key factor in moving recording density to 10 gigabits per square inch areal density and beyond, and IBM has demonstrated recording at 11.6 gigabits per square

inch in the laboratory. There appear to be several possible methods of constructing multilayer heads exhibiting enhanced magnetoresistance, with the more promising designated as the multilayer granular alloy approach and the spin valve, also a multilayer structure. The challenge is to fabricate a structure highly responsive to the lower field strengths typically seen by read heads as bit size declines. Giant magnetoresistance has moved out of the laboratory stage at IBM and other firms, and drives with GMR heads have begun to ship, with the first drives with GMR heads introduced by IBM, appearing at the end of 1997.

MR and GMR heads are usually fabricated in an assembly including an inductive thin film head for writing and the MR/GMR head for readback of data. The width of the write head is usually greater than the width of the read head to provide some protection against off track positioning and noise from adjacent tracks.

* Recording disks: Media is evolving to provide smoother surfaces, higher recording density, reduced tendency to stiction and surface damage and thinner substrates. Disk media production processes have undergone continuing refinement to achieve ever-thinner applications of more uniform recording layers. Progress in improving media surface lubricants and protective overcoatings has been equally impressive, if at times uneven. Fluorocarbon based lubricants are typically used in current drive designs. Carbon and silicon dioxide overcoatings have been getting thinner, to reduce head-recording layer separation. The thinnest are now down to about .2 microinch. Hydrogenated carbon is the most favored overcoat material. The emergence of virtual contact recording has created pressure to improve the durability of the thin overcoatings.

  Substrate smoothness has been a critical issue for several years as flying heights have diminished. Aluminum substrates require a layer, usually plated, of very smooth material to serve as a surface for the deposition of the magnetic recording layer. A typical layer is 300 to 400 microinches thick, and is textured to provide protection against stiction. The depth of the texturing is decreasing as flying heights decrease, but the texturing patterns are becoming more complex, increasing the sophistication and expense of texturing equipment. The "bump" type of laser texturing currently employed is expected to be replaced by finer geometric patterns that minimize interference with low flying heads.

  Some drives (typically used in mobile systems) use ramp loaded heads to avoid the need for a specially textured landing zone. Ramp loading also permits a faster spinup with less power due to the absence of head drag during spinup. The increasing complexity of the processes required to create good aluminum substrates are encouraging the use of glass and glass/ceramic hybrid materials as substrates, as the surfaces tend to be inherently smooth and texturing can be added in the process of making the basic substrate.

The oxide coated media of early disk drives has been displaced by thin film media, because oxide coated media was unable to satisfy increasing areal density requirements. Even IBM, a longtime oxide champion, abandoned oxide coated media after 1989. Plating was the primary method used to produce early generations of thin film disks, but plating has been supplanted by sputtering as the preferred production technique for disk magnetic surfaces. The sputtering process is more capable of producing the higher coercivities, thin layers and tight tolerances required by disk drives operating at high areal densities and low flying heights. Media producers also find the sputtering process easier to control and capable of substantially higher yields than the plating process. Plating retains a role in the preparation of aluminum substrates, being used to place a nickel-phosphorus alloy passivating and smoothing layer on the substrate before the magnetic layer is applied by sputtering.

As areal density moves above the 5 gigabit per square inch level, media design will become more complex, with more specialized layers sputtered onto the surface to provide higher linear bit density and faster bit switching. Media coercivity will increase, requiring stronger write fields. Process designers will be challenged to maintain current process yields and media costs as complexity increases. The decreasing bit size will also require a reduction in the number and size of surface defects in order to keep yields at an appropriate level.

Media with coercivity above 2,000 oersteds is routinely produced, and media with coercivities exceeding 2,500 oersteds is expected to increasingly appear in new high end and mobile system drive designs. Media suitable for operation at 10 gigabits per square inch is expected to require 3,000 oersted media, while 5,000 oersted media is anticipated as the superparamagnetic limit is approached.

Most high capacity 2.5" disk drives use glass or glass/ceramic as a substrate material, and some 1.8" drives have also used glass media. (3.5" and larger drives have continued to use aluminum substrates.) Glass substrates are potentially smoother, stiffer and flatter (especially in very thin substrates) than aluminum, have fewer impurities that can cause defects, and can be made very thin. These characteristics allow for lower flying heights and the inclusion of more disks in a stack, both highly desirable features. However, glass is more difficult to laser texture. Because glass is more resistant to damage from shock induced head slap, glass substrates are attractive in drives for mobile systems. However, because of lower production volume, glass disks still cost significantly more than aluminum substrates and industry production capacity is limited at present. Aluminum is likely to remain the substrate of choice for some years for 3.5" and larger media, and the use of 30% sliders, which are less likely to damage media as the result of head slap, may make aluminum a stronger contender in the sub-3.5" drive arena as well.

In 1993, Seagate Technology and Corning announced that Seagate had agreed to use Corning's canasite glass/ceramic substrates in volume production. Technical problems involving degradation of the magnetic coating by substrate contamination have delayed the use of canasite in production drives. Other alternative substrate materials have been proposed, including carbon, plastic, titanium, aluminum-boron-carbide and silicon carbide, but none of these have yet won industry acceptance.

Disk substrate thickness is declining in order to allow placement of more disks in small diameter drive HDAs. In 1989, 50 mil substrates were standard practice for 3.5" diameter drives, but 31.5 mil substrates have assumed the lead position since IBM introduced them in the "Lightning" 3.5" drive in 1989. 2.5" drive substrates, now predominantly at 25 and 35 mils, will also migrate to thinner disks, probably 15 mils, but that is likely to take several years and may require stiffer materials.

* Performance: Significant improvements in data transfer rates and average access times are expected during the next few years. Important factors in initiating these improvements will be the increase in disk rotation rate, (which both decreases latency and increases data transfer rate) and increases in linear bit density (which also increases data transfer rate at a given RPM), albeit at the expense of a higher performance read/write channel.

  3,600 RPM was the standard drive specification for many years, but drive RPM began an upward trend in 1989 when Imprimis announced a family of high capacity 5.25" drives operating at 5,400 RPM. Seagate pioneered 7,200 RPM drives in late 1992 with the "Barracuda" series, and extended its leadership in late 1996 with the 10,000 RPM "Cheetah". Hitachi recently introduced a 2.5" drive operating at 12,000 RPM. The heat, runout, power consumption and bearing wear problems generated by higher spin rates used in server class drives present a significant challenge to both disk drive and system designers, who are expected to begin adopting hydrodynamic motor bearings (in which a thin viscous film substitutes for ball bearings) as spin rates move above 12,000 RPM. These fluid bearings also exhibit superior resistance to shock damage, being able to withstand shock in the 1,000 G range without damage. Smaller disk diameters, practical as areal density continues to expand, are being employed in high performance server class drives to greatly reduce the amount of heat produced and reduce bearing stresses.

  As RPM and track density increase, it becomes increasingly difficult to maintain head position relative to the recording track. The higher servo bandwidths required probably cannot be accommodated by pivoting the actuator arm around its bearing, and compound actuators are expected to appear, perhaps as early as 1999, as companies begin acquiring manufacturing experience with the technique. Suspension mounted

microactuators capable of moving the head over a range of a few tracks for purposes of track following or fine motion positioning are expected to be the solutions of choice for most companies. Micro-voice coil motors and piezoelectric elements appear to be the most commonly considered solutions at the present time.

The availability of high speed data channels that connect the heads to the drive controller may be a factor that paces the rate of performance advances. While the electronics used to write data is fairly straightforward, the ever increasing write speeds required are causing parasitic head inductances/capacitances/resistance and bit switching time in media to require attention as potential performance obstacles. Readback circuitry can be quite complex and is usually the limiting factor in establishing the bandwidth of the data channel, a situation complicated by the declining signal to noise ratio observed as bit density increases. While the majority of drive read channels currently use peak detection and have bandwidths under 100 megabits per second, advanced drives employ PRML (Probable Response, Maximum Likelihood) channels and have moved past 100 megahertz in read channel bandwidth. One of the fastest read channels is offered by Silicon Systems, which specifies operation at up to 200 megahertz. As areal densities approach 10 gigabits per second, channel data rates are expected to require 400 to 500 megahertz data channels. While PRML channels are fast, they also require significant power, making them less desirable in small drives destined for use in notebook computers, although aggressive power management strategies can minimize the average power required.

Average seek times have now dipped down to the 5-7 millisecond range for the fastest drives, and sub-10 millisecond seek times are becoming more common in high performance 3.5" drives. Higher energy magnetic materials used in actuators and lower mass heads are contributing to the improved performance. In some cases, special alloys permitting lighter positioning mechanisms that help reduce seek time are being considered. Some drives are specified with read seek times that are a millisecond or two faster than the write seek time as a result of drive intelligence permitting usable readback signals to be acquired before the head has fully settled after a seek.

The requirements of digital audio and digital video based systems require a different view of performance. While data processing systems can specify performance in terms of average response times and throughput, multimedia oriented systems require specification of the maximum sustained performance in terms of throughput and response times so that system designers can obtain the smooth flow of audio/video content required by end users. The continuity of output requirement has implications as to how intelligent drive controllers manage potentially disruptive operations such as periodic recalibration, head degaussing, and other internal, and usually invisible, housekeeping functions. Drives employing

embedded servo tracking schemes may have an inherent advantage in providing an uninterrupted data flow.

* Form factor: Sub-3.5" drives are an increasingly significant part of the market as manufacturers of notebook computers require small footprint, low height, low power drive designs. Drive height has steadily declined, and competition in providing higher capacity and thinner sub-3.5" disk diameter drives is keen. One inch height is standard for most 3.5" desktop drives, but 15 to 19 millimeter heights are available for new low-end drives for desktop computers, so that half of an existing "half high" disk drive bay can be free for other peripheral devices. 3" drives for use in notebook computers were briefly in production during the last year, before being withdrawn for various reasons. They were seen by many notebook producers as a good compromise between size, capacity and power drain. 2.5" drives are already available in the 8.5 to 12.7 millimeter high range, to allow maximum volume for batteries in notebook computers. 1.8" drives conforming to the 10.5 millimeter PCMCIA Type III height requirement are in production, although their limited capacity and higher price per megabyte has confined them to a narrow market niche.

  Despite the move to smaller form factors, 5.25" drives are not dead yet. In 1995 Belfort Memory International announced a single platter 1.1 gigabyte 5.25" drive, and in 1996 Quantum announced "Bigfoot", a family of one and two platter 5.25" drives with capacities of 1.2 and 2.2 gigabytes, (since expanded to three platters and over 12 gigabytes) taking advantage of minimal parts count and the larger surface area of the disk to obtain a lower cost per megabyte. Depending on the ferocity of the competitive response, such drives have the potential to be shipped in significant numbers over the next few years.

  Technologically, form factor reduction is being driven by improvements in areal density, smaller heads, thinner media, greater IC functionality, and higher energy magnetic materials that permit fabrication of smaller motors and actuators without reducing performance. One of the most critical factors is the reduction in the surface area required to mount electronics needed by the drive. An increasing degree of functional integration in chips is needed and is being provided. In some drive designs, fewer than 7 chips are needed and drive designs requiring only 5 chips (or less) on the circuit board are expected to be common in the future.

* Power reduction: Another aspect of form factor reduction is the need to operate the drive at low power to conserve battery life in portable systems or to meet the requirements of energy efficient desktop systems. Smaller form factor drives typically need less power to rotate the disks and move the heads. Portable systems require the drive to have several operating modes to conserve power when not in use. Typically, the drive does not spin when data is not being transferred and other power consuming functions may also be shut down when the drive is inactive. A related need is

for the drive to quickly come up to operating speed when needed. A few designs incorporate ramp loaded heads, enabling removal of the heads from disk contact when the drive spins down. The removal of head drag on the disk enables the drive to spin up faster with less power demand and lessens the danger of a stiction caused malfunction.

* Interfaces and controllers: Most of today's disk drives have intelligent embedded controllers and are able to communicate directly with a host system data bus or host bus adaptor. Embedded SCSI and PC/AT (IDE) controllers are widely used in drives for personal computer applications, and embedded SCSI is also used with the majority of drives used with workstations, servers and equivalent applications. SCSI is also used as an interface to other types of peripheral products, including tape drives, optical drives, libraries, scanners and others. Ultra-SCSI drives are now in volume production, and Ultra 2 SCSI (LVDS) drives are now entering the market.

  While the IDE interface (frequently known as the ATA, or AT Attachment interface in standards committees) was originally limited to rigid drives with 528 megabytes or less, the Enhanced IDE (EIDE) specification sponsored by Western Digital and other firms expanded support to drives with capacities to 8.4 gigabytes, provided 1 or 2 data channels, and also accommodates other devices such as CD-ROMs and tape drives. The IDE family of standards evolved to handle data transfer rates to over 16 megabytes per second in processor I/O mode and DMA mode, allowing EIDE to substitute for SCSI if only a few peripheral devices are needed in a system. The Ultra DMA extension to EIDE shipping in current drives doubles the DMA data transfer rate to 33.3 megabytes per second, and further extension of the IDE standard to 66 megabytes per second has been announced.

  For 1.8" and smaller drives, the standards for pin connections used for ATA (AT Attachment) cards that fit physically into PCMCIA sized slots and connectors exist but various manufacturers have implemented them in ways leading to incompatibility between cards. However, some companies have agreed to informal interchange standards: In September of 1993, IBM, Maxtor, Seagate, SanDisk and Toshiba announced that mass storage cards using the PCMCIA interface and supplied by those companies would be interchangeable and would also comply with the ATA standard.

  SCSI interfaces are most frequently encountered in workstations, file servers (especially those using disk drive arrays) and some Apple Macintosh computers. The SCSI interface continues to evolve, with the SCSI-2 command set now in general use. SCSI-3 (Ultra-SCSI), the next version, is now incorporated in many high end rigid drives. (However, SCSI is implemented in different ways by different peripheral manufacturers, and is not the ironclad standard that many would prefer.) SCSI has been

upgraded to accommodate 20 megahertz bus clock rates, permitting 20 megabyte per second byte wide transfers (Fast-20) or 40 megabyte per second transfers (Fast-40) if two bytes are transmitted at a time. LVDS (Low Voltage Differential SCSI), which further doubles the data rate, and also permits a longer SCSI bus, is becoming the SCSI bus of choice in many servers.

Serial interfaces are a relatively new family of small drive interfaces. Three interface designs are vying for acceptance: SSA (Serial Storage Architecture), Fibre Channel Arbitrated Loop (FC-AL) and the IEEE sponsored P1394 interface, sometimes known as Firewire. The serial interface proposals have some common features, including SCSI command sets, ability to hot plug drives, smaller and less expensive connectors and cables, and data transfer rates exceeding IDE and SCSI rates, but differ in their efficiency with different size data blocks, number of drives or other devices, physical size of storage subsystem and other factors. Ultimately, the choice of serial interface used will be made by the system integrator dependent upon the application and processing platform selected.

SSA, originally supported by IBM, Conner, Micropolis, Dell, Adaptec and others was earliest to appear in drives and controllers, and seemed destined for a major role in large and midrange systems. However, with the acquisition of Conner by Seagate Technology and the sale of the Micropolis disk drive operation to Singapore Technologies, wide industry support for SSA vanished, and the market has been reluctant to perceive SSA as truly "open" and not an IBM marketing ploy.

Fibre Channel now appears to be the serial interface of choice for most system producers, and an increasing amount of support from chip and controller producers has materialized. FC-AL has been championed by Seagate, Quantum, and many supporters of open systems. However, with Seagate the only source for FC-AL interfaced drives until mid-1998, many system and subsystem manufacturers elected to stay with SCSI family drives for the time being. As additional disk drive manufacturers initiate actual production of announced FC-AL server drives during 1998, acceptance is broadening, competition is lowering prices, and the expected start of the Fibre Channel era is apparently underway, although it is expected to take years for FC-AL to become the leader in server drive interfaces.

Apple, Intel and video equipment producers have been the most visible supporters of P1394, which is expected to find its primary role in home based systems and/or multimedia applications. However, there has been little chip support for P1394 until recently, when interface chips became available from Symbios and Texas Instruments.

Intelligent interfaces and embedded controllers provide disk drive suppliers with a chance to add value, but more importantly allow engineers to design the drive to meet various needs while maintaining a common inter-

face to the host system. Embedded intelligent interfaces (usually implemented with microcode) permit varying bit density by zones over the band of recording tracks and advanced data coding transparent to the host system. Other features, such as on-board error monitoring and diagnostics, error correction, exclusive-OR computations, digital servos, segmented caching, zero latency read/write and multiport buffering can be included and also made transparent to the host system. However, there is a balance between overall system performance and the design of the intelligent controller. For instance, the use of too large a buffer can slow data retrieval if all of the buffer contents must be examined to service each request for data from the system. Intelligent controllers can also provide indications of impending drive failure to a system, permitting a system administrator to initiate the orderly replacement of the drive with minimum disruption to operations.

* Digital servos: Digital servos are increasingly popular as VLSI density improves, track density increases, and smaller disk drive form factors make printed circuit board space a scarcer commodity. The ability to incorporate programmable servo functions in a single chip or chip set provides both functional and economic advantages. Typical servo control chips employ digital signal processors coupled with a standard microprocessor. Digital servo chips may include motor power control functions as well as servo functions.

* Encoding and error correction: Effective linear bit density can be improved beyond the raw flux change density by the use of appropriate data encoding schemes. Run-length-limited codes such as 1,7 and 2,7 RLL were the industry's standard for many years, but the Probable Response Maximum Likelihood (PRML) code introduced by IBM, and its many variations is becoming more widely used as it becomes well understood by the rest of the industry and appropriate chips become available from independent semiconductor vendors.

  In-line error correction of the read-back data stream is expected to become increasingly common, because as areal density becomes higher, the size of a media defect required to cause an error becomes smaller and the number of error causing defects per unit area increases. The Reed-Solomon codes used in optical disk drives to perform error correction are migrating to the rigid disk drive world, permitting the reliable use of media that would otherwise have to be discarded. The effective improvement in media yield provides an incentive to adopt error correction techniques. However, the error correction process will become increasingly stressed due to the need to increase speed to keep up with higher data transfer rates.

* Internal processing: If other in-line processing of data within the drive is performed, data compression within the drive might also be incorporated

as an internal drive capability. In addition to improving capacity, the internal data transfer rate may be improved. The degree of compression obtainable is highly influenced by the format of the data and the degree of processing allowable by real time requirements on drive performance. In any event, the compression algorithms used will be restricted to lossless compression techniques. Another type of internal drive processing was exemplified by Western Digital's SPX design, which interfaces to CD-ROM drives and provides much of the buffering and interface function required by the CD-ROM drive, thereby providing greatly improved performance and a lower cost for the optical drive. Seagate also offers augmented drives, in this case drives that perform the exclusive OR logical function required for disk drive arrays. These drives are expected to find usage in arrays operating from serial interfaces.

* Storage management software: As rigid disk drives move to higher capacity levels and are attached in large numbers to individual systems and network file servers, the ability of system managers to control and monitor the flow, availability, and residence time of data in data storage subsystems is becoming increasingly important. While such software is not an integral part of the drive, its presence, availability and usability are becoming important influences in determining market acceptance rates for high capacity, high performance 3.5" drives in networked systems.

* Multiple spindle arrays: A single high capacity drive can be replaced with an array of smaller capacity drives having aggregate equivalent capacity and a file organization that appears to the host system to be similar to that of the larger drive. Data, plus parity information, is typically striped, mirrored, or both, across each drive in the array. In some array configurations, the drives operate with the drive rotation rate and phase synchronized to minimize the skew between related bits. Disk drive arrays are usually implemented with specialized controllers and software, but some arrays achieve low cost by using software to control array functionality and minimize hardware content. The software approach to contolling array function lowers cost, but performance usually suffers. Arrays are available for a variety of systems, ranging from PC's serving as file servers to mainframes and supercomputers.

  The term RAID (Redundant Array of Independent Disks) denotes multiple drive configurations generically, with specific configurations ranging from multiple, uncoordinated disk drives to striped, synchronized drives defined within the RAID designation as RAID-0, RAID-1, RAID-2, etc., through RAID-6. The RAID nomenclature, which derives from papers published by the University of California, Berkeley, has been formally defined only up to the RAID-6 level, but various firms offer advanced redundant architectures informally defined with RAID designations of their own invention. The RAID Advisory Board, an industry association, has developed a standardized nomenclature for disk drive arrays. Attention is shifting away from the

specific RAID architecture to the degree of data availability provided by the overall storage subsystem, including the array components.

The multispindle array can offer significant advantages compared to drives limited by a single actuator. Depending upon the way the array is configured and upon the degree of sophistication of associated subsystems, it can provide fault tolerance, very high data transfer rates, or volumetric efficiencies, compared to single drives. Options such as cache and multiple data paths can also improve performance. Disk arrays, except for the RAID-0 (striping only) type, improve fault tolerance. However, optimizing for performance means less than optimum reliability and cost, while optimizing for fault tolerance or cost may degrade array performance significantly.

A number of companies provide array products that operate simultaneously in several RAID modes, providing users with operational flexibility. Arrays are more costly than single large disks, and require that each drive in the array have superior reliability to provide an acceptable service rate for the array. Furthermore, while arrays can improve the fault tolerance of the system, data availability is not assured unless every portion of the system is made redundant so that a failure of a controller, a power supply or a cable cannot disable the array.

Disk array markets have grown to a significant size. While product complexity and proliferation, lack of standardization, customer confusion and ignorance of array capabilities could be expected to suppress market development, the array market is actually on a healthy growth pattern and has already passed the $12 billion level.

* Low cost disk drives: With the prices of personal computers sinking faster than the Titanic, in many cases the most important technical specification for a disk drive is its price to the OEM. Every disk drive manufacturer is responding to requests (often insistent) from their OEM customers for reduced cost drives, even at the expense of performance and useful features, for use in sub-$1000 computers. Such drives can be expected to have an absolute minimum parts count, with single disk, single head drives expected to be favored when higher areal density permits the storing of multiple gigabytes on a single recording surface.

  Another strategy that may be employed is simplification of drive electronics by offloading some functions currently performed in intelligent embedded drive controllers to host processor resident software. However, such drives will take longer to test and require more production test equipment, and may also cause processor resource conflicts because of demands from other real time functions that need to be accomplished and which may also have been offloaded from other peripherals to the processor.

DEFINITIONS

Many basic terms have varying meanings within the computer industry, depending upon the role of the person speaking. In this report, such terms are used in the way most disk drive manufacturers use them.

Market classification

Market class is used here, arbitrarily, to differentiate captive, Distributor and OEM/Integrator disk drive marketing activities.

Captive: Disk drives manufactured internally or by a subsidiary of a computer manufacturer, and sold or leased primarily for use with systems offered by the manufacturer. Note that the term is used to describe the products, not the manufacturer. Drives sold to Distributor or OEM/Integrator market classes are classified accordingly, but the term still pertains to the disk drives involved, not the manufacturer.

Examples:

* Drives sold by IBM, Hitachi or Fujitsu with computer systems to end users are considered captive, if internally manufactured.

Noncaptive: Any public sale or lease by any disk drive manufacturer, except sales or leases of internally manufactured disk drives by computer system manufacturers primarily for use with their own systems. Both OEM/Integrator and Distributor shipments are included in the noncaptive sales channel.

Examples:

* Shipments by Hitachi are noncaptive, except for drives sold with computers made by the parent company or other subsidiaries.

* Shipments made by Seagate or Western Digital are noncaptive.

Distributor: Disk drives sold in the "aftermarket" -- shipments by drive manufacturers to subsystem producers, value-added resellers, distributors, retail chains, mail-order firms and individual dealers. Also includes disk drives sold or leased by "plug compatible manufacturers" or their distributing organizations directly to end users for use with systems sold by another manufacturer. Includes drives to be connected to systems of all types, including personal computers, minicomputers and mainframes, or drives sold as add-on devices by distributors and dealers. In order to simplify the description, the acronym "PCM" used in previous DISK/TREND Reports for plug compatible manufacturers has been eliminated.

Examples:

* Disk drives sold by Fujitsu or Maxtor through distributors or major retailers to computer end users.

* On an arbitrary basis, disk drives manufactured by Seagate, Fujitsu or Hitachi and resold in the plug compatible market by other companies are included in Distributor totals, to avoid distortion of total PCM activity.

OEM/Integrator: Drives sold by the original producer to system manufacturers which resell them as part of complete computer systems. Also includes sales to system integrators which combine finished system components and software to provide complete systems for specific applications. Sales by a disk drive manufacturer to a second drive manufacturer for resale are included only in shipment totals for the originating manufacturer, except when drives are produced on a contract manufacturing basis with a design supplied by the disk drive manufacturer which finally sells the drive to a third party.

Examples:

* Drives produced by IBM, Seagate or Western Digital for sale to system manufacturers.

* Drives sold by Quantum Corporation to system manufacturers but manufactured to Quantum designs by Matsushita-Kotobuki Electronics.

Geographic classification

Geographic analysis is based upon U.S. and non-U.S. regions. Together, these two regions comprise the worldwide market.

U.S. vs. Worldwide SHIPMENTS: Shipments are classified U.S. or worldwide depending on the country in which the headquarters of the purchasing company is located.

Examples:

* An OEM shipment by a U.S. disk drive manufacturer to a European system manufacturer is included in worldwide totals, even if the drive is integrated into a system within the U.S.

* An OEM shipment by a Japanese drive manufacturer to a U.S. based system manufacturer is included in U.S. totals, even if the drive is integrated into a system in Taiwan, regardless of the final destination of systems in which the drives are used.

U.S. vs. Non-U.S. MANUFACTURERS: Disk drive manufacturers are classified U.S. or non-U.S., depending on the location of the firm's headquarters, regardless of the location of individual manufacturing plants.

Example:

* Western Digital is considered a U.S. manufacturer, even though the firm manufactures disk drives in non-U.S locations.

Units of measurement

Spindles: The basic unit in counting disk drives. One spindle or spindle disk assembly consists of the disk drive mechanism required to utilize a single disk or disk stack. All DISK/TREND unit totals are counted in spindles.

Revenue: Based on sales of disk drives alone, as normally sold by individual manufacturers. Controllers sold as separate units are not included in disk drive revenue, nor are spare parts or service. When individual disk drive models include integral control functions, such as may be required for the first drive on a string of drives, the actual value of the complete unit is used. Sale prices are estimated public sale transaction prices, whether at Captive end user, Distributor or OEM/Integrator levels. All prices are in 1998 constant dollars.

Forecasts: Expected shipments and revenues for current or announced disk drives in new production. Evolutionary improvements within existing disk drive formats are included, but completely new configurations or technologies are not included.

Examples:

* Product enhancements such as double density versions of existing single density configurations and revised encoding schemes are anticipated in DISK/TREND forecasts.

* Innovations such as nonstandard size disks or new physical configurations may require establishment of new DISK/TREND product groups.

Application classification

Shipments of disk drives are classified by the following computer applications:

Specialized high performance systems: Attached directly to the processor or to a terminal associated with a supercomputer, video server or editing system, or a high-end imaging system.

Mainframe systems: Attached directly to the processor or to a terminal associated with a general purpose mainframe computer system.

Networks/midrange systems: Used with network file servers, minicomputers and other midrange multiuser systems. Examples: IBM AS/400, Hewlett-Packard 3000, Compaq ProLiant, Data General CLARiiON series, workstations used for engineering, graphics, medical and other application.

Desktop personal computers: Used with a personal computer intended primarily for nonconsumer applications. Examples: IBM PC series, Dell Dimension series, Apple Macintosh.

Consumer computers: Desktop personal computers sold to consumers primarily for nonbusiness purposes, and dedicated application systems for computer games and other applications.

Portable computers: Laptop, notebook, subnotebook and smaller general purpose and specialized computer systems.

Other applications: Any application not included above, including nonconventional uses such as intelligent fax machines, copiers, scanners, intelligent personal communication devices, automotive navigation systems, digital cameras, factory data collection equipment, etc.

DISK CARTRIDGE DRIVES

1998 DISK/TREND REPORT

DISK CARTRIDGE DRIVES

Coverage

Examples of disk drives in this group include:

5.25" disk diameter

SyQuest Technology	SQ5200C, Quest 4.7

3.5" disk diameter

Castlewood Systems	ORB2
Iomega	Jaz 1, Jaz 2
Nomai	MCD-I, 750.c
SyQuest Technology	EZFlyer 230, SyJet, SparQ

2.5" disk diameter

Avatar Peripherals	2250i, 3250i

All types of disk drives using removable media in the form of rigid disk cartridges have been included in this section. Until 1995, 5.25" disk drives provided the majority of shipments in the disk cartridge drive product group. However, SyQuest's 3.5" drives have been available since 1992, with capacities up to 1.5 gigabytes available in drives currently in production, and total shipments of 3.5" drives passed up the 5.25" form factor in 1995.

In response to the Iomega initial market success with the Zip 100 megabyte high capacity 3.5" floppy drive, SyQuest introduced in 1995 the "EZ" single head 3.5" disk cartridge drive designed for very low cost, with capacity initially at 135 megabytes, followed by the 230 megabyte EZFlyer in mid-1996. The capacity range of disk cartridge drives was significantly increased in December, 1995, with the Iomega introduction of the 1 gigabyte Jaz 3.5" drive, using a two disk cartridge. In response, SyQuest offered the SyJet, a 3.5" drive with a capacity of 1.5 gigabytes using a two disk cartridge, with deliveries starting in December, 1996.

The race to offer higher capacities in 3.5" rigid disk cartridge drives is destined to continue, exploiting the availability of advanced heads, disks and other critical components being continually developed for fixed disk drives. In late 1997, SyQuest started shipments of its 3.5" 1 gigabyte SparQ single disk cartridge drive, and in the first quarter of 1998 Iomega shipped Jaz 2, a 2 gigabyte model using a two disk cartridge. Castlewood Systems is expected to ship a 2

gigabyte 3.5" single platter drive in 1998. There is also the possibility that the capacity leadership now held by 3.5" drives may be surpassed by 5.25" rigid disk cartridge drives, if SyQuest is able to obtain the financial resources needed to start production of the company's planned Quest series of 5.25" drives, starting with a 4.7 gigabyte model.

Avatar Systems' 2.5" disk cartridge drives, in a series of models with various capacities, have been in production since 1993, with volume production of the current 250 megabyte models at the company's Thailand plant. SyQuest also initiated a 2.5" disk cartridge drive program, with initial shipments in 1993, but has since discontinued the product. In addition, SyQuest placed considerable emphasis on development of an 80 megabyte drive in a PCMCIA Type III PC Card format, using 1.8" disks in a cartridge which could be removed from the removable drive. However, the 1.8" project was dropped in early 1996.

Market status

Although the sales revenue and shipment growth achieved by disk cartridge drives during the last few years has fallen below generally expected levels, the product group remains in a growth mode, fueled by increasing disk capacities and aggressive pricing. After topping 1 million units for the first time in 1996, 1997's unit shipment total was 1.4 million drives, up 37.8%, and the DISK/TREND forecast for 1998 is 2.7 million units, a 91.9% increase. 1997 sales revenues for the product group were $346.1 million, with 1998 projected at $657.2 million.

The current shipment growth in this product group continues to be derived mostly from 3.5" drives, with a modest assist from 2.5" disk drives. The availability of drives with capacities in the 1 to 2 gigabyte range, combined with intense competition between Iomega and SyQuest, has significantly expanded the market available to disk cartridge drives. The role of 5.25" drives continues to diminish, limited by capacities that are too low and prices that are too high, until the arrival of new high-end models, expected next year.

Several types of disk drives compete in the same markets addressed by rigid disk cartridge drives. It must be noted that the majority of personal computer users are satisfied with the generous capacities now available on the fixed disk drives which are standard equipment on their PCs. For PC owners with a func-

tional or perceived need for a removable media drive, they have a choice of magnetic disk cartridge drives, high capacity floppy drives and various types of rewritable optical disk drives.

For years the most aggressive competition for SyQuest's pioneering rigid disk cartridge drives was provided by the Iomega 5.25" high capacity Bernoulli floppy disk drive. Iomega's Bernoulli drives increased in capacity over the years, up to 230 megabytes, with the result that SyQuest and Iomega competed directly in both the Macintosh and IBM personal computer markets for the same graphics and desktop publishing applications. Until 1995, SyQuest's disk cartridge drives held a clear lead in these markets, due to a successful strategy of concentrating on the Macintosh market, the leader in desktop publishing. SyQuest's EZ drive series, initially with 135 and now with 230 megabytes, was intended for many of the same markets as Iomega's successful Zip high capacity floppy drive, currently at 100 megabytes with a higher capacity version expected. SyQuest's disastrous financial results during recent years illustrate the difficulty in competing against a high capacity floppy drive optimized for low production cost with a rigid disk equivalent. With the advent of the 1 gigabyte 3.5" Jaz drive at the end of 1995, followed by additional drives in the 1-2 gigabyte range from both SyQuest and Iomega, rigid disk drives have been able to address a broader range of applications, resulting in increased sales.

There is also a vigorous contest between 3.5" rigid disk cartridge drives and 3.5" magneto-optic drives, but the 3.5" rigid disk cartridge drives appear to be holding their own in this contest. Shipments of both types of drives are increasing, but rigid disk cartridge drives remain at higher shipment levels, due to lower prices and continuing increases in the disk capacities available.

Although SyQuest's initial growth in disk cartridge drive shipments was built on the company's original 3.9" drives, the 44 megabyte 5.25" model introduced in 1987 became the dominant "prepress" interchange standard, for graphics, typography and other original material used in printing, as projects move from designers, art departments and advertising agencies to typographers and printers. But despite capacity upgrades eventually reaching 200 megabytes in 1994, the market growth for 5.25" rigid disk cartridge drives slowed down, as customers' appetites for even higher capacities became stronger. 5.25" drive shipments started declining in 1995 and in 1998 are projected at only 31,000 drives.

The first 2.5" disk cartridge drive shipments began in 1993. SyQuest's previously announced 2.5" drive was dropped, but Avatar Systems introduced a 2.5" rigid disk cartridge drive, with capacity now up to 250 megabytes, intended for a variety of personal computer and specialized system applications. After a series of management changes and a revision of the company name to Avatar Peripherals, the company strategy moved from targeting the OEM market to distribution sales. Sales reached almost 200,000 drives in 1997, but the current outlook is unclear due to the economic challenges now facing Thailand, where Avatar's drives are produced in a locally owned factory.

Iomega passed up SyQuest in unit shipment market share in 1996 and enhanced the lead in 1997. Iomega's Jaz 1 drive held 66.4% of worldwide unit shipments of rigid disk cartridge drives in 1997, with an estimated 955,000 drives. SyQuest, going through a model transition year, declined to 237,200 units, for 16.5% of the worldwide total. In 1997, all disk cartridge drives were shipped in noncaptive market channels, predominantly in the Distributor channel.

Marketing trends

Continued growth in both unit shipments and sales revenues are forecasted for rigid disk cartridge drives. 6.2 million drives are projected for 2001, representing an average annual increase in the 1999-2001 period of 31.7%. Sales revenues are expected to achieve a somewhat more modest average annual increase of 23.9%, yielding 2001 revenues of $1.2 billion, limited by falling average unit prices.

Due to the current volatile nature of the industry structure, competitive product offerings and the status of the individual competitors, shipment forecasts for rigid disk cartridge drives must be regarded as somewhat speculative. The market is currently beginning a transition to increased OEM/Integrator sales, as specialized system manufacturers add higher capacity 3.5" drives to their product lines. It is clear the established competitors and Castlewood Systems, the newcomer, will increase drive capacity, but the timing of capacity improvements for rigid disk cartridge drives is uncertain, depending less on technical feasibility than on competitive tactics. By the end of the forecast period, it is also possible that major improvements in optical disk recording densities could pro-

vide major new competitive threats. The financial viability of individual disk drive manufacturers will also influence their ability to produce planned new drives.

Technical trends

The basic recording technologies now in use for products in this group will continue to predominate for years. The smaller drives in quantity production embody the mechanical design lessons accumulated during years of production of larger removable disk drives, and will be able to exploit the rapid advances in recording technology from other segments of the disk drive industry. The 3.5" and 2.5" disk cartridge drives now available may be expected to increase continually in capacity during the coming years, following closely the rapid improvements in areal density expected with fixed disk drives.

Iomega's Jaz drive family provides an illustration of the benefits which accrue to this product group from the much higher production levels now achieved with fixed disk drives manufactured for the desktop personal computer market. The Jaz 1 drive uses two 500 megabyte disks in each cartridge -- the same type of disks which were manufactured for the highest volume fixed disk drives produced in 1995. Jaz 2 uses two 1 gigabyte disks per cartridge, the type used in the highest volume fixed disk drives in 1996. As recording capacities increase at the expected 60% per year, disks, heads and semiconductors manufactured for the industry's highest volume fixed disk drives will become available to the manufacturers of disk cartridge drives at low costs. With these components available, it is to be expected that capacities available in 3.5" disk cartridge drives will track the same upward trend, probably following fixed disk drives by a year or two. Iomega's major challenge for the Jaz series will be to keep product cost low enough to be competitive, while utilizing a two platter cartridge design in competition with rivals' single platter drives.

Forecasting assumptions

1. Significant shipment increases of 3.5" and 2.5" disk cartridge drives will continue, with further increases in drive capacity available, with successful sales to both system manufacturers and the aftermarket.
2. Production for 5.25" disk cartridge drives will increase starting in 1999, with introduction of high capacity models.

TABLE 15

DISK CARTRIDGE DRIVES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1997		Forecast							
	Revenues		1998		1999		2000		2001	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Distributor	208.5	294.3	413.1	553.9	552.5	744.8	629.9	863.0	673.8	938.3
OEM/Integrator	37.3	42.4	73.1	85.3	126.9	147.9	168.6	202.5	200.2	246.2
TOTAL U.S. REVENUES	245.8	336.7	486.2	639.2	679.4	892.7	798.5	1,065.5	874.0	1,184.5
Non-U.S. Manufacturers										
Distributor	1.8	9.4	6.0	18.0	9.3	24.1	15.7	36.7	22.5	50.1
TOTAL NON-U.S. REVENUES	1.8	9.4	6.0	18.0	9.3	24.1	15.7	36.7	22.5	50.1
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	247.6	346.1	492.2	657.2	688.7	916.8	814.2	1,102.2	896.5	1,234.6
OEM Average Price ($000)		.242		.241		.227		.215		.203

TABLE 16

DISK CARTRIDGE DRIVES

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1997 Shipments		Forecast 1998		1999		2000		2001	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Distributor	874.7	1,217.1	1,740.0	2,318.0	2,487.0	3,340.0	3,010.0	4,110.0	3,385.0	4,700.0
OEM/Integrator	154.6	174.6	305.0	353.0	560.0	650.0	787.0	940.0	990.0	1,210.0
TOTAL U.S. SHIPMENTS	1,029.3	1,391.7	2,045.0	2,671.0	3,047.0	3,990.0	3,797.0	5,050.0	4,375.0	5,910.0
Non-U.S. Manufacturers										
Distributor	9.0	47.0	30.0	90.0	50.0	130.0	90.0	210.0	135.0	300.0
TOTAL NON-U.S. SHIPMENTS	9.0	47.0	30.0	90.0	50.0	130.0	90.0	210.0	135.0	300.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	1,038.3	1,438.7	2,075.0	2,761.0	3,097.0	4,120.0	3,887.0	5,260.0	4,510.0	6,210.0
Total Capacity (Terabytes)		1,114.1		3,147.1		4,887.0		8,109.0		11,414.2
Cumulative Shipments (Units in millions)										
WORLDWIDE TOTAL	4.3	6.6	6.4	9.3	9.5	13.5	13.4	18.7	17.9	24.9

TABLE 17

DISK CARTRIDGE DRIVES

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1997 Revenues			Forecast										
				1998			1999			2000			2001	
	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"
U.S. MANUFACTURERS															
Distributor	14.3	240.5	39.5	2.8	518.1	33.0	11.4	700.0	33.4	20.7	808.3	34.0	32.6	872.3	33.4
OEM/Integrator	4.9	36.3	1.2	6.9	76.3	2.1	25.1	119.4	3.4	37.5	160.5	4.5	43.1	198.0	5.1
TOTAL U.S. REVENUES	19.2	276.8	40.7	9.7	594.4	35.1	36.5	819.4	36.8	58.2	968.8	38.5	75.7	1,070.3	38.5
NON-U.S. MANUFACTURERS															
Distributor	--	9.4	--	--	18.0	--	--	24.1	--	--	36.7	--	--	50.1	--
TOTAL NON-U.S. REVENUES	--	9.4	--	--	18.0	--	--	24.1	--	--	36.7	--	--	50.1	--
WORLDWIDE RECAP															
Distributor	14.3	249.9	39.5	2.8	536.1	33.0	11.4	724.1	33.4	20.7	845.0	34.0	32.6	922.4	33.4
	-45.0%	+25.4%	--	-80.4%	+114.5%	-16.5%	+307.1%	+35.1%	+1.2%	+81.6%	+16.7%	+1.8%	+57.5%	+9.2%	-1.8%
OEM/Integrator	4.9	36.3	1.2	6.9	76.3	2.1	25.1	119.4	3.4	37.5	160.5	4.5	43.1	198.0	5.1
	--	+227.0%	+71.4%	+40.8%	+110.2%	+75.0%	+263.8%	+56.5%	+61.9%	+49.4%	+34.4%	+32.4%	+14.9%	+23.4%	+13.3%
Total Revenues	19.2	286.2	40.7	9.7	612.4	35.1	36.5	843.5	36.8	58.2	1,005.5	38.5	75.7	1,120.4	38.5
	-26.2%	+36.0%	--	-49.5%	+114.0%	-13.8%	+276.3%	+37.7%	+4.8%	+59.5%	+19.2%	+4.6%	+30.1%	+11.4%	--
ANNUAL SHARE, BY DIAMETER	5.5%	82.8%	11.7%	1.5%	93.3%	5.2%	4.0%	92.1%	3.9%	5.3%	91.3%	3.4%	6.1%	90.9%	3.0%

TABLE 18

DISK CARTRIDGE DRIVES

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DISK DIAMETER

	1997 Shipments			Forecast 1998			1999			2000			2001		
	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"
U.S. MANUFACTURERS															
Distributor	38.6	986.0	192.5	8.0	2,090.0	220.0	35.0	3,070.0	235.0	65.0	3,795.0	250.0	105.0	4,340.0	255.0
OEM/Integrator	16.6	151.0	7.0	23.0	315.0	15.0	85.0	540.0	25.0	130.0	775.0	35.0	155.0	1,015.0	40.0
TOTAL U.S. SHIPMENTS	55.2	1,137.0	199.5	31.0	2,405.0	235.0	120.0	3,610.0	260.0	195.0	4,570.0	285.0	260.0	5,355.0	295.0
NON-U.S. MANUFACTURERS															
Distributor	--	47.0	--	--	90.0	--	--	130.0	--	--	210.0	--	--	300.0	--
TOTAL NON-U.S. SHIPMENTS	--	47.0	--	--	90.0	--	--	130.0	--	--	210.0	--	--	300.0	--
WORLDWIDE RECAP															
Distributor	38.6	1,033.0	192.5	8.0	2,180.0	220.0	35.0	3,200.0	235.0	65.0	4,005.0	250.0	105.0	4,640.0	255.0
	-52.3%	+14.1%	--	-79.3%	+111.0%	+14.3%	+337.5%	+46.8%	+6.8%	+85.7%	+25.2%	+6.4%	+61.5%	+15.9%	+2.0%
OEM/Integrator	16.6	151.0	7.0	23.0	315.0	15.0	85.0	540.0	25.0	130.0	775.0	35.0	155.0	1,015.0	40.0
	--	+174.5%	+133.3%	+38.6%	+108.6%	+114.3%	+269.6%	+71.4%	+66.7%	+52.9%	+43.5%	+40.0%	+19.2%	+31.0%	+14.3%
Total Shipments	55.2	1,184.0	199.5	31.0	2,495.0	235.0	120.0	3,740.0	260.0	195.0	4,780.0	285.0	260.0	5,655.0	295.0
	-31.9%	+23.3%	--	-43.8%	+110.7%	+17.8%	+287.1%	+49.9%	+10.6%	+62.5%	+27.8%	+9.6%	+33.3%	+18.3%	+3.5%
ANNUAL SHARE, BY DIAMETER	3.8%	82.4%	13.8%	1.1%	90.5%	8.4%	2.9%	90.9%	6.2%	3.7%	91.0%	5.3%	4.2%	91.2%	4.6%

TABLE 19

DISK CARTRIDGE DRIVES

SUMMARY BY PLATFORM

UNIT SHIPMENTS IN THOUSANDS	1997 Shipments Units	1997 Shipments %	1998 Forecast Units	1998 Forecast %	1999 Forecast Units	1999 Forecast %	2000 Forecast Units	2000 Forecast %	2001 Forecast Units	2001 Forecast %
MOBILE SYSTEM DRIVES	199.5	13.8%	235.0	8.5%	260.0	6.3%	285.0	5.4%	295.0	4.7%
	--		+17.7%		+10.6%		+9.6%		+3.5%	
2.5 INCH	199.5		235.0		260.0		285.0		295.0	
DESKTOP SYSTEM DRIVES	1,239.2	86.1%	2,526.0	91.4%	3,860.0	93.6%	4,975.0	94.5%	5,915.0	95.2%
	--		+103.8%		+52.8%		+28.8%		+18.8%	
5.25 INCH	55.2		31.0		120.0		195.0		260.0	
3.5 INCH	1,184.0		2,495.0		3,740.0		4,780.0		5,655.0	
Total Shipments	1,438.7	100.0%	2,761.0	100.0%	4,120.0	100.0%	5,260.0	100.0%	6,210.0	100.0%
	--		+91.9%		+49.2%		+27.6%		+18.0%	

Notes: Percentage figures with plus/minus signs refer to year-to-year growth rates.

TABLE 20

DISK CARTRIDGE DRIVES

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1997 Estimate Units (000)	1997 Estimate %	2001 Projection Units (000)	2001 Projection %
SPECIALIZED HIGH PERFORMANCE Supercomputers, video and high end imaging	11.9	.8	31.1	.5
MAINFRAME SYSTEMS General purpose	--	--	--	--
NETWORK/MIDRANGE SYSTEMS Midrange systems, network servers and workstations	326.6	22.7	447.1	7.2
DESKTOP PERSONAL COMPUTERS Business and professional, single user	870.0	60.5	5,148.1	82.9
CONSUMER COMPUTERS Desktop PCs, game, and hobby computers	104.0	7.2	267.0	4.3
PORTABLE COMPUTERS Notebook and smaller mobile computers	107.4	7.5	291.9	4.7
OTHER APPLICATIONS	18.8	1.3	24.8	.4
Total	1,438.7	100.0	6,210.0	100.0

TABLE 21

DISK CARTRIDGE DRIVES

WORLDWIDE PRICE PER MEGABYTE ($/MB)

DISK DIAMETER	1997	Forecast 1998	1999	2000	2001
Distributor					
5.25"	1.855	1.167	.108	.068	.066
3.5"	.276	.203	.190	.142	.112
2.5"	.820	.600	.568	.453	.374
Distributor Average	.316	.212	.193	.142	.112
OEM/Integrator					
5.25"	1.459	1.000	.099	.061	.059
3.5"	.246	.173	.184	.138	.108
2.5"	.681	.553	.548	.437	.363
OEM/Integrator Average	.278	.189	.163	.113	.096

Note: Price per megabyte calculations represent estimated total sales revenues for each product type divided by the total yearly shipped capacity of all drives of that type.

TABLE 22

DISK CARTRIDGE DRIVES

MARKET SHARE SUMMARY
Worldwide Shipments of Noncaptive Disk Drives

	1997 Net Shipments									
	To United States Destinations					Worldwide				
	Units (000)				%	Units (000)				%
Drive Manufacturers	5.25"	3.5"	2.5"	Total		5.25"	3.5"	2.5"	Total	
Iomega	--	740.0	--	740.0	71.3	--	955.0	--	955.0	66.4
Syquest Technology	38.6	65.7	--	104.3	10.0	55.2	182.0	--	237.2	16.5
Avatar Peripherals	--	--	185.0	185.0	17.8	--	--	199.5	199.5	13.9
Nomai	--	9.0	--	9.0	.9	--	47.0	--	47.0	3.2
Other U.S.	--	--	--	--	--	--	--	--	--	--
Other Non-U.S.	--	--	--	--	--	--	--	--	--	--
TOTAL	38.6	814.7	185.0	1038.3	100.0	55.2	1184.0	199.5	1438.7	100.0

FIXED DISK DRIVES, LESS THAN 1 GIGABYTE

1998 DISK/TREND REPORT

FIXED DISK DRIVES, LESS THAN 1 GIGABYTE

Coverage

Examples of disk drives in this group include:

5.25" disk diameter	
Fujitsu	M2262H/HA
3.5" disk diameter	
Raymond Engineering	8440, 84300
2.5" disk diameter	
Fujitsu	M2635T/S***, M2722****
Toshiba	MK-0803MAT*****
1.8" disk diameter	
Calluna Technology	CT-261RM******, CT-520RM******

***Maximum 19.05 mm height, or less.
****Maximum 12.7 mm height, or less.
*****Maximum 9.5 mm height, or less.
******PC Card Type III (10.5 mm height).

Although numerous manufacturers shipped fixed disk drives in this capacity range using 14" disks in the 1970's and with 8" disks in the late 1970's and early 1980's, followed by 5.25" disks in the 1980's, the industry's continuing improvement in recording densities forced the withdrawal of drives with larger disks from the market. In the last few years, 3.5" and 2.5" drives also found rapidly shrinking markets below 1 gigabyte, due to the current demand for the higher capacities required for most applications, and the continually dropping prices for disk drives with higher capacities. 1997 was the last year of significant shipments for 5.25", 3.5" and 2.5" disk drives in this product group, and 1.8" disk drives are the only group forecasted to remain in production through 2001.

Market status

As recently as 1995, fixed disk drives with capacities less than 1 gigabyte led the industry in shipments. The situation today is very different, as the personal computer market's demand for high disk drive capacities has reduced this

product group's share of estimated 1998 shipments to only .3% of the worldwide total for all rigid disk drive product groups. Worldwide shipments of drives under 1 gigabyte declined 91% in 1997, to 2.3 million units, and are forecasted to sink to another 83.1% in 1998, to only 391,200 drives. 1997 sales revenues for the product group were $492.9 million, down 88.9%, with 1998 expected to decline another 80.1%, to $98.1 million.

Shipments of 3.5" drives for desktop personal computer markets were the dominant contributing factor in this capacity range's 1995 sales success. Faster PC processors, improved operating systems and application programs, data downloaded from the Internet, and wider personal computer usage all contributed to 1995's notable increase in drive shipments in the 1-2 gigabytes range. Just in time to exploit the new demand, the industry's incessant increases in areal density made possible 3.5" drives in this capacity range with only one or two disks, for which production could be quickly ramped to high levels, at low unit cost. With the availability of 1" high drives in this capacity range starting in 1992, shipments ramped up rapidly starting in 1994. The same phenomenon started to occur with 2.5" drives in 1995, as drives with 12.5 or 12.7 millimeter heights became available in the product lines of most 2.5" drive manufacturers.

But the growth period for both 3.5" and 2.5" drives was over in 1996, as the inevitable upward trend in the market's demand for disk capacity continued for both desktop personal computers and for notebook computers. In addition to the capacity limitations of this product group, sales have been hurt by the price per megabyte now available. The average OEM/Integrator price per megabyte for 3.5" drives is down to 11 cents in 1998, with 2.5" drives at 20 cents -- but equivalent drives in the capacity range now leading in the industry's shipments are available at a third of these prices.

1997 unit shipments for the product group were led by 2.5" drives, with 65.6% of the worldwide total. However, shipments for both 2.5" and 3.5" drives are continuing to fall rapidly in 1998, as the last 3.5" models are phased out and shipments of 2.5" drives fall an estimated 87.9%. 1.8" drives are expected to provide 42% of 1998's shipments for the product group. Seagate Technology held 36.3% of 1997 noncaptive unit shipments, with a mixture of 3.5" and 2.5" drives, followed by Toshiba with 25.8%, all 2.5" drives.

Marketing trends

1999 is expected to be the last year of shipments for 2.5" drives less than 1 gigabyte, leaving only 1.8" drives in production. After an expected 1999 peak in 1.8" drive shipments, total 2001 unit shipments for the product group are expected to be only 150,000, with sales revenues of $28 million.

Manufacturers of desktop personal computers have settled into a pattern of immediate movement to new disk capacity levels as soon as they become available, a phenomenon which will result in the withdrawal of all 3.5" drives in this product group during 1998. The notebook computer market which consumes most of the current generation of 2.5" drives follows the same pattern, with a timetable a bit slower. The last shipments of 2.5" drives are expected in 1999. The anticipated market for 1.8" drives in this capacity range will follow a different set of rules. The 1.8" market consists of a variety of specialized applications for PC Card drives, many of which will continue for an indefinite period, with the possibility that significant new applications may be developed.

Technical trends

Demand for the existing generation of 1.8" Type III PC Card drives in this capacity range is expected to peak in 1999, as the industry's recording densities move up. The remaining development programs for 1.8" drives will be aimed at two related objectives. Initially, cost reduction targets will stimulate efforts to utilize a single 1.8" disk to achieve 200-500 megabyte capacities. When single 1.8" disks can achieve this capacity, 5 millimeter thick Type II PC Card drives become practical, and Calluna has announced plans to produce a Type II drive by the end of 1998. The packaging for Type II drives will be difficult, but much of the work has already been done by drive manufacturers which deferred product introductions until the format could offer enough disk capacity to enjoy a broad market.

Forecasting assumptions

1. Shipments of 2.5" drives will end in 1999, as notebook computers move to higher disk drive capacities.
2. Shipments of 1.8" drives will peak in 1999, due to a transition to higher capacities, with negligible penetration of notebook computer markets, plus a variety of workstation and industrial applications.

TABLE 23

FIXED DISK DRIVES, LESS THAN 1 GIGABYTE

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1997		Forecast							
	Revenues		1998		1999		2000		2001	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Captive	96.0	144.0	--	--	--	--	--	--	--	--
Distributor	30.9	57.7	.8	1.0	--	--	--	--	--	--
OEM/Integrator	32.5	80.5	--	--	--	--	--	--	--	--
TOTAL U.S. REVENUES	159.4	282.2	.8	1.0	--	--	--	--	--	--
Non-U.S. Manufacturers										
Captive	20.0	92.3	6.8	45.9	--	10.3	--	--	--	--
Distributor	6.5	17.4	8.6	13.3	4.6	6.5	4.4	6.3	4.1	5.9
OEM/Integrator	31.5	101.0	19.5	38.1	18.2	29.3	16.5	25.0	14.4	22.1
TOTAL NON-U.S. REVENUES	58.0	210.7	34.9	97.3	22.8	46.1	20.9	31.3	18.5	28.0
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	217.4	492.9	35.7	98.3	22.8	46.1	20.9	31.3	18.5	28.0
OEM Average Price ($000)		.151		.180		.195		.192		.184

TABLE 24

FIXED DISK DRIVES, LESS THAN 1 GIGABYTE

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1997 Shipments		Forecast 1998		1999		2000		2001	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Captive	300.0	450.0	--	--	--	--	--	--	--	--
Distributor	177.0	387.5	3.5	4.5	--	--	--	--	--	--
OEM/Integrator	210.0	538.3	--	--	--	--	--	--	--	--
TOTAL U.S. SHIPMENTS	687.0	1,375.8	3.5	4.5	--	--	--	--	--	--
Non-U.S. Manufacturers										
Captive	40.0	200.2	15.0	115.1	--	25.0	--	--	--	--
Distributor	27.0	80.0	37.0	60.0	21.0	30.0	21.0	30.0	21.0	30.0
OEM/Integrator	208.2	659.8	97.1	211.6	90.0	150.0	86.0	130.0	78.0	120.0
TOTAL NON-U.S. SHIPMENTS	275.2	940.0	149.1	386.7	111.0	205.0	107.0	160.0	99.0	150.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	962.2	2,315.8	152.6	391.2	111.0	205.0	107.0	160.0	99.0	150.0
Total Capacity (Terabytes)		1,493.5		202.3		86.6		65.6		70.0
Cumulative Shipments (Units in millions)										
IBM	22.7	33.5	22.7	33.5	22.7	33.5	22.7	33.5	22.7	33.5
Non-IBM	175.5	338.2	175.7	338.6	175.8	338.8	175.9	339.0	176.0	339.1
WORLDWIDE TOTAL	198.3	371.8	198.4	372.1	198.6	372.3	198.7	372.5	198.8	372.7

TABLE 25

FIXED DISK DRIVES, LESS THAN 1 GIGABYTE

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1997 Revenues				Forecast						
					1998			1999		2000	2001
	5.25"	3.5"	2.5"	1.8"	3.5"	2.5"	1.8"	2.5"	1.8"	1.8"	1.8"
U.S. MANUFACTURERS											
Captive	--	--	144.0	--	--	--	--	--	--	--	--
Distributor	--	27.0	5.6	25.1	--	--	1.0	--	--	--	--
OEM/Integrator	--	17.7	46.4	16.4	--	--	--	--	--	--	--
TOTAL U.S. REVENUES	--	44.7	196.0	41.5	--	--	1.0	--	--	--	--
NON-U.S. MANUFACTURERS											
Captive	--	18.8	73.5	--	13.1	32.8	--	10.3	--	--	--
Distributor	--	--	10.2	7.2	--	1.5	11.8	--	6.5	6.3	5.9
OEM/Integrator	.5	15.7	82.9	1.9	--	14.0	24.1	1.9	27.4	25.0	22.1
TOTAL NON-U.S. REVENUES	.5	34.5	166.6	9.1	13.1	48.3	35.9	12.2	33.9	31.3	28.0
WORLDWIDE RECAP											
Captive	--	18.8	217.5	--	13.1	32.8	--	10.3	--	--	--
	--	-86.7%	-68.3%	--	-30.3%	-84.9%	--	-68.6%	--	--	--
Distributor	--	27.0	15.8	32.3	--	1.5	12.8	--	6.5	6.3	5.9
	--	-97.9%	-80.1%	+48.2%	--	-90.5%	-60.4%	--	-49.2%	-3.1%	-6.3%
OEM/Integrator	.5	33.4	129.3	18.3	--	14.0	24.1	1.9	27.4	25.0	22.1
	-91.4%	-98.0%	-74.5%	-45.7%	--	-89.2%	+31.7%	-86.4%	+13.7%	-8.8%	-11.6%
Total Revenues	.5	79.2	362.6	50.6	13.1	48.3	36.9	12.2	33.9	31.3	28.0
	-92.2%	-97.4%	-71.5%	-8.8%	-83.5%	-86.7%	-27.1%	-74.7%	-8.1%	-7.7%	-10.5%
ANNUAL SHARE, BY DIAMETER	.1%	16.1%	73.7%	10.1%	13.3%	49.2%	37.5%	26.6%	73.4%	100.0%	100.0%

TABLE 26

FIXED DISK DRIVES, LESS THAN 1 GIGABYTE

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DISK DIAMETER

	1997 Shipments				Forecast						
					1998			1999		2000	2001
	5.25"	3.5"	2.5"	1.8"	3.5"	2.5"	1.8"	2.5"	1.8"	1.8"	1.8"
U.S. MANUFACTURERS											
Captive	--	--	450.0	--	--	--	--	--	--	--	--
Distributor	--	245.0	40.0	102.5	--	--	4.5	--	--	--	--
OEM/Integrator	--	160.0	310.0	68.3	--	--	--	--	--	--	--
TOTAL U.S. SHIPMENTS	--	405.0	800.0	170.8	--	--	4.5	--	--	--	--
NON-U.S. MANUFACTURERS											
Captive	--	53.5	146.7	--	42.6	72.5	--	25.0	--	--	--
Distributor	--	--	55.0	25.0	--	10.0	50.0	--	30.0	30.0	30.0
OEM/Integrator	.3	133.8	518.4	7.3	.2	101.4	110.0	15.0	135.0	130.0	120.0
TOTAL NON-U.S. SHIPMENTS	.3	187.3	720.1	32.3	42.8	183.9	160.0	40.0	165.0	160.0	150.0
WORLDWIDE RECAP											
Captive	--	53.5	596.7	--	42.6	72.5	--	25.0	--	--	--
	--	-83.1%	-59.6%	--	-20.4%	-87.8%	--	-65.5%	--	--	--
Distributor	--	245.0	95.0	127.5	--	10.0	54.5	--	30.0	30.0	30.0
	--	-97.3%	-75.6%	+42.1%	--	-89.5%	-57.3%	--	-45.0%	--	--
OEM/Integrator	.3	293.8	828.4	75.6	.2	101.4	110.0	15.0	135.0	130.0	120.0
	-91.9%	-97.5%	-68.0%	-47.0%	-99.9%	-87.8%	+45.5%	-85.2%	+22.7%	-3.7%	-7.7%
Total Shipments	.3	592.3	1,520.1	203.1	42.8	183.9	164.5	40.0	165.0	160.0	150.0
	-92.9%	-97.2%	-65.9%	-12.6%	-92.8%	-87.9%	-19.0%	-78.2%	+.3%	-3.0%	-6.2%
ANNUAL SHARE, BY DIAMETER	--	25.7%	65.6%	8.7%	10.9%	47.1%	42.0%	19.5%	80.5%	100.0%	100.0%

TABLE 27

FIXED DISK DRIVES, LESS THAN 1 GIGABYTE

SUMMARY BY PLATFORM

UNIT SHIPMENTS IN THOUSANDS	1997 Shipments Units	1997 Shipments %	1998 Forecast Units	1998 Forecast %	1999 Forecast Units	1999 Forecast %	2000 Forecast Units	2000 Forecast %	2001 Forecast Units	2001 Forecast %
MOBILE SYSTEM DRIVES	1,723.2	74.4%	348.4	89.0%	205.0	100.0%	160.0	100.0%	150.0	100.0%
	--		-79.7%		-41.1%		-21.9%		-6.2%	
2.5 INCH	1,520.1		183.9		40.0		--		--	
1.8 INCH	203.1		164.5		165.0		160.0		150.0	
DESKTOP SYSTEM DRIVES	591.2	25.5%	42.8	10.9%	--	--	--	--	--	--
	--		-92.7%		--		--		--	
3.5 INCH	591.2		42.8		--		--		--	
SERVER SYSTEM DRIVES	1.4	--	--	--	--	--	--	--	--	--
	--		--		--		--		--	
5.25 INCH	.3		--		--		--		--	
3.5 INCH	1.1		--		--		--		--	
Total Shipments	2,315.8	100.0%	391.2	100.0%	205.0	100.0%	160.0	100.0%	150.0	100.0%
	--		-83.1%		-47.5%		-21.9%		-6.2%	

Notes: Percentage figures with plus/minus signs refer to year-to-year growth rates.

TABLE 28

FIXED DISK DRIVES, LESS THAN 1 GIGABYTE

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1997 Estimate Units (000)	1997 Estimate %	2001 Projection Units (000)	2001 Projection %
SPECIALIZED HIGH PERFORMANCE Supercomputers, video and high end imaging	--	--	--	--
MAINFRAME SYSTEMS General purpose	--	--	--	--
NETWORK/MIDRANGE SYSTEMS Midrange systems, network servers and workstations	2.3	.1	.2	.1
DESKTOP PERSONAL COMPUTERS Business and professional, single user	532.6	23.0	8.3	5.5
CONSUMER COMPUTERS Desktop PCs, game, and hobby computers	104.9	4.5	2.4	1.6
PORTABLE COMPUTERS Notebook and smaller mobile computers	1,664.4	71.9	129.7	86.5
OTHER APPLICATIONS	11.6	.5	9.4	6.3
Total	2,315.8	100.0	150.0	100.0

TABLE 29

FIXED DISK DRIVES, LESS THAN 1 GIGABYTE

WORLDWIDE PRICE PER MEGABYTE ($/MB)

DISK DIAMETER	1997	Forecast 1998	1999	2000	2001
Captive					
3.5"	.618	.562	--	--	--
2.5"	.596	.663	.586	--	--
Captive Average	.598	.631	.586	--	--
Distributor					
3.5"	.137	--	--	--	--
2.5"	.230	.221	--	--	--
1.8"	.788	.720	.606	.497	.416
Distributor Average	.245	.579	.606	.497	.416
OEM/Integrator					
5.25"	4.500	--	--	--	--
3.5"	.166	.110	--	--	--
2.5"	.228	.204	.179	--	--
1.8"	.751	.663	.574	.470	.395
OEM/Integrator Average	.229	.363	.502	.470	.395

Note: Price per megabyte calculations represent estimated total sales revenues for each product type divided by the total yearly shipped capacity of all drives of that type.

TABLE 30

FIXED DISK DRIVES, LESS THAN 1 GIGABYTE

MARKET SHARE SUMMARY
Worldwide Shipments of Noncaptive Disk Drives

	1997 Net Shipments											
	To United States Destinations						Worldwide					
	Units (000)					%	Units (000)					%
Drive Manufacturers	5.25"	3.5"	2.5"	1.8"	Total		5.25"	3.5"	2.5"	1.8"	Total	
Seagate Technology	--	140.0	50.0	--	190.0	30.5	--	405.0	200.0	--	605.0	36.3
Toshiba	--	--	115.0	--	115.0	18.5	--	--	430.0	--	430.0	25.8
Other U.S.	--	--	85.0	112.0	197.0	31.7	--	--	150.0	170.8	320.8	19.3
Other Non-U.S.	--	52.3	50.9	17.0	120.2	19.3	.3	133.8	143.4	32.3	309.8	18.6
TOTAL	--	192.3	300.9	129.0	622.2	100.0	.3	538.8	923.4	203.1	1665.6	100.0

FIXED DISK DRIVES, 1 - 2 GIGABYTES

1998 DISK/TREND REPORT

FIXED DISK DRIVES, 1 - 2 GIGABYTES

Coverage

Examples of disk drives in this group include:

5.25" disk diameter

Fujitsu	F6429H

3.5" disk diameter

Fujitsu	MPA3017AT**, M1623TAU**
Hitachi	DK326C-10**
NEC	DSE1700A**
Quantum	Fireball ST**
Samsung Electronics	WN31273A**, WU31605A**
Seagate Technology	Medalist 1722**

2.5" disk diameter

Fujitsu	M2724TAM****
Hitachi	DK225A-14****
IBM	DTNA-21800****
Toshiba	MK-1003MAV****, MK-1608MAT*****

1.8" disk diameter

Calluna Technology	CT-1040RM******

*Maximum 41.3 mm height, or less.
**Maximum 25.4 mm height, or less.
***Maximum 19.05 mm height, or less.
****Maximum 12.7 mm height, or less.
*****Maximum 9.5 mm height, or less.
******PC Card Type III (10.5 mm height).

There are still drives in this product group that were designed for mainframe computers, but shipments are no longer significant. IBM's 3380 was the core of this group during the first half of the 1980's, but the 3380 series moved to higher capacities in 1985, and the product group has seen little application in mainframe computer markets in the last decade. During this period, the industry has seen successive generations of 8"-10.5" drives, then 5.25" drives, and dominance during recent years by 3.5" drives -- which are also now rapidly declining in shipments. The first 2.5" drives with more than 1 gigabyte capacity appeared in the product lines of 7 manufacturers in 1995, but shipments of 2.5" drives in this capacity range peaked in 1997.

Most of the product changes for the 3.5" and 2.5" drives in this product group have centered on reducing the number of platters in each model to the minimum, to reduce costs. Many of the 3.5" drives, which have been subjected to continuous cost-cutting efforts, already use only one disk. Most of the 2.5" drives have been reduced to 12.7 millimeters in height or less, and one or two disks have been normal in most 2.5" models introduced during the last year. Toshiba's 8.5 millimeter high models are currently the thinnest 2.5" drives available.

During the last few years, it appeared that the traditional 2.5" drive markets would experience competition from the 3" drive family originally announced by JTS, with the intention of capturing notebook computer sales by using the additional recording area offered by 3" disks to reduce prices at each capacity level. Western Digital and Integral Peripherals also announced 3" drive models, but most activity for 3" drives ended during the last year, with cessation of the Western Digital and JTS 3" programs for various reasons. Only Integral Peripherals remains committed to 3" drives, but the firm's financial problems make production uncertain. The first shipments of 1.8" drives in this capacity range are expected during 1998, and 1.8" drives are the only type of disk drives expected to still be in production in 2001.

Market status

1997 was the last year of major shipments for drives in the 1-2 gigabyte capacity range, as the industry's movement to higher areal densities rapidly obsoletes yesterday's shipment leaders. After the 1-2 gigabyte product group produced the industry's highest shipments in 1996 with 53.2 million drives, 1997's worldwide total declined to 39.9 million units, with the 1998 total forecasted to drop 91.1% to 3.6 million units. The 1997 sales revenues for the product group declined 39.5% to $6.7 billion, with 1998 expected to be down 91.3%, at $582.4 million.

Incessant growth in the personal computer market's craving for more disk storage capacity generated the rapid growth of shipments in this capacity range through 1996. 3.5" drives were the primary beneficiaries of storage demand for desktop personal computers, with 44.3 million drives shipped in 1996, up 117.1%

over the previous year. The notebook computer market also saw a similar upward swing in demand for disk storage, with the result that 1995's shipments of 409,600 2.5" drives jumped to 6.4 million in 1996. While the movement to higher desktop PC disk capacities undermined the 1-2 gigabyte drive market for 3.5" and 5.25" desktop drives in 1997, shipments of 2.5" drives in that year enjoyed a modest increase of 10.9%, to 7.1 million units. 1997 was the peak for 1-2 gigabyte 2.5" drive shipments, however, with the total for 1998 falling sharply, to an estimated 1.1 million drives.

The advent of single disk 5.25" drives in 1996 provided a new competitive threat to 3.5" drives in the desktop PC market, but only 2.5 million 5.25" drives were shipped in 1996, a modest market entry. 5.25" shipments declined to 258,800 units in 1997, dropping faster than the product group's overall shipment trend, with only token shipments in 1998, as 5.25" drives in this product group are closed out.

As high volume personal computer applications have largely displaced the product group's traditional workstation, midrange and mainframe computer markets, average unit prices have continued to fall quickly. Although the first 3.5" drives with more than 1 gigabyte capacity did not ship until 1991, by 1996 3.5" drives provided 98% of total unit shipments for this product group. The average OEM/Integrator price per megabyte for 3.5" disk drives in this capacity class was 74 cents in 1993, but fell to 50 cents in 1994. By 1995, it had continued to decline to 20 cents, then 14 cents in 1996, 11 cents in 1997, and an estimated 8 cents in 1998.

Desktop personal computers utilized 72.6% of the drives in this product group in 1997 and consumer computers used 8.6% during the same, reflecting the disappearance of the mainframe, network server and midrange applications which once dominated the capacity range. 17.8% of 1997's shipments were used in portable computers. However, as shipments of drives used for desktop and notebook personal computers continues to decline, the mix of applications for which the product group is utilized will continue to evolve. By 2001, 1.8" drives will provide the only remaining 1-2 gigabyte drive shipments and a small minority of these drives will be used with any type of desktop personal computer. An estimated 86.9% are destined for portable computer applications of various types.

Seagate continued to lead in noncaptive unit shipments for 1997, with 28.9% of the worldwide total, still mostly 3.5" drives. Western Digital advanced to second with 18.9%, all 3.5" drives, Quantum fell to third position with 16%, a combination of 3.5" and 5.25" drives.

Marketing trends

An important measurement in the disk drive industry is the capacity which can be achieved on a single disk of a specified diameter when manufactured in large quantities with high production yields. In 1998 that level has moved above 2 gigabytes for 3.5" disks and it is approaching that point for 2.5" disks. As a result, shipment of all 1-2 gigabyte disk drives except 1.8" models will soon be history. Final shipments of 5.25" drives are occurring in 1998, and the last shipments of 3.5" and 2.5" drives are expected in 1999. After that, the only remaining products in the group are expected to be 1.8" drives, production of which is starting in 1998, due to the industry's areal density increases and availability of critical components.

The expected availability of 1.8" disk drives in 1998 is projected to keep this product group active through 2001. The first shipments of 1.8" drives in the 500 megabyte range started in 1997, with modest areal densities, by today's standards. If the market reception of those drives is favorable enough, the single remaining drive manufacturer active in the 1.8" product area, and any others which choose to participate, could move above the 1 gigabyte level within a year, taking advantage of head, disk and semiconductor component technology already developed for larger diameter drives.

Technical trends

Most of the industry's landmark new drives are now typically designed for capacity levels much higher than this product group's 1-2 gigabytes. During the last few years, developing disk drives for the 1-2 gigabyte range became a sophisticated exercise in applied engineering, in which nothing new had to be invented, but many leading edge components had to be available in large quantities, assembled with great precision, and delivered in a reliable, low-cost mechanism.

Much of the interesting technical developments in the product group during the last few years have involved miniaturization of 2.5" drives, with leadership currently held by Toshiba's 8.5 millimeter high models and the various 9.5" millimeter high IBM drives. Those 2.5" drive development programs have now evolved into drives with capacities above those in this product group, and the remaining challenges in product development for 1-2 gigabyte drives will primarily involve 1.8" drives. It is expected that the existing Type III PCMCIA card formats will continue to be used for disk drives in this capacity range, and that the challenges facing designers of these drives will not involve development of new mechanical designs, but the utilization of higher areal densities. Fortunately, the development already undertaken to produce critical components for drives using larger disks will greatly simplify the task.

Forecasting assumptions

1. The last shipments of low-cost 5.25" drives will occur in 1998, due to demand for higher capacities for personal computers.
2. Shipments of 3.5" drives will end in 1999, displaced by higher capacity drives in the desktop personal computer market.
3. 2.5" drive shipments will cease in 1999, impacted by the continuing movement to higher disk capacities for notebook computers.
4. The first shipments of 1.8" drives will occur in 1998.

TABLE 31

FIXED DISK DRIVES, 1 - 2 GIGABYTES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1997 Revenues		Forecast							
			1998		1999		2000		2001	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Captive	143.1	169.8	27.0	41.5	--	--	--	--	--	--
Distributor	537.3	1,590.7	41.8	93.2	5.2	11.4	--	--	--	--
OEM/Integrator	864.5	2,112.0	55.2	135.8	8.0	20.2	--	--	--	--
TOTAL U.S. REVENUES	1,544.9	3,872.5	124.0	270.5	13.2	31.6	--	--	--	--
Non-U.S. Manufacturers										
Captive	171.5	1,024.5	19.1	165.8	3.1	26.9	--	--	--	--
Distributor	129.5	424.4	4.0	36.4	3.6	9.4	6.2	9.3	6.7	10.7
OEM/Integrator	487.2	1,366.5	29.4	109.7	13.2	31.4	16.3	25.2	20.9	31.3
TOTAL NON-U.S. REVENUES	788.2	2,815.4	52.5	311.9	19.9	67.7	22.5	34.5	27.6	42.0
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	2,333.1	6,687.9	176.5	582.4	33.1	99.3	22.5	34.5	27.6	42.0
OEM Average Price ($000)		.148		.127		.135		.296		.260

TABLE 32

FIXED DISK DRIVES, 1 - 2 GIGABYTES

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1997 Shipments		Forecast 1998		1999		2000		2001	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Captive	295.0	350.0	65.0	100.0	--	--	--	--	--	--
Distributor	3,920.0	11,658.2	392.0	870.0	55.0	120.0	--	--	--	--
OEM/Integrator	5,780.0	14,564.0	469.0	1,185.0	85.0	215.0	--	--	--	--
TOTAL U.S. SHIPMENTS	9,995.0	26,572.2	926.0	2,155.0	140.0	335.0	--	--	--	--
Non-U.S. Manufacturers										
Captive	245.0	1,627.1	35.0	369.4	7.0	75.0	--	--	--	--
Distributor	884.0	2,884.0	18.0	293.0	10.0	50.0	20.0	30.0	25.0	40.0
OEM/Integrator	3,254.8	8,851.1	194.3	734.8	55.0	165.0	55.0	85.0	80.0	120.0
TOTAL NON-U.S. SHIPMENTS	4,383.8	13,362.2	247.3	1,397.2	72.0	290.0	75.0	115.0	105.0	160.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	14,378.8	39,934.4	1,173.3	3,552.2	212.0	625.0	75.0	115.0	105.0	160.0
Total Capacity (Terabytes)		51,948.2		4,974.7		698.1		119.6		166.4
Cumulative Shipments (Units in millions)										
IBM	4.0	5.8	4.1	5.9	4.1	5.9	4.1	5.9	4.1	5.9
Non-IBM	52.7	118.0	53.8	121.4	54.0	122.0	54.1	122.2	54.2	122.3
WORLDWIDE TOTAL	56.8	123.8	58.0	127.4	58.2	128.0	58.2	128.1	58.3	128.3

TABLE 33

FIXED DISK DRIVES, 1 - 2 GIGABYTES

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1997 Revenues			Forecast								
				1998				1999			2000	2001
	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"	1.8"	3.5"	2.5"	1.8"	1.8"	1.8"
U.S. MANUFACTURERS												
Captive	--	--	169.8	--	--	41.5	--	--	--	--	--	--
Distributor	12.5	1,547.1	31.1	1.2	85.9	6.1	--	11.4	--	--	--	--
OEM/Integrator	19.4	1,760.4	332.2	1.7	92.4	41.7	--	20.2	--	--	--	--
TOTAL U.S. REVENUES	31.9	3,307.5	533.1	2.9	178.3	89.3	--	31.6	--	--	--	--
NON-U.S. MANUFACTURERS												
Captive	3.9	236.3	784.3	--	74.3	91.5	--	11.4	15.5	--	--	--
Distributor	--	333.8	90.6	--	23.3	11.1	2.0	2.4	1.6	5.4	9.3	10.7
OEM/Integrator	6.5	782.9	577.1	--	32.7	71.0	6.0	4.7	9.6	17.1	25.2	31.3
TOTAL NON-U.S. REVENUES	10.4	1,353.0	1,452.0	--	130.3	173.6	8.0	18.5	26.7	22.5	34.5	42.0
WORLDWIDE RECAP												
Captive	3.9	236.3	954.1	--	74.3	133.0	--	11.4	15.5	--	--	--
	-84.5%	-70.0%	+9.3%	--	-68.6%	-86.1%	--	-84.7%	-88.3%	--	--	--
Distributor	12.5	1,880.9	121.7	1.2	109.2	17.2	2.0	13.8	1.6	5.4	9.3	10.7
	--	-38.0%	+37.4%	-90.4%	-94.2%	-85.9%	--	-87.4%	-90.7%	+170.0%	+72.2%	+15.1%
OEM/Integrator	25.9	2,543.3	909.3	1.7	125.1	112.7	6.0	24.9	9.6	17.1	25.2	31.3
	+428.6%	-44.6%	-28.8%	-93.4%	-95.1%	-87.6%	--	-80.1%	-91.5%	+185.0%	+47.4%	+24.2%
Total Revenues	42.3	4,660.5	1,985.1	2.9	308.6	262.9	8.0	50.1	26.7	22.5	34.5	42.0
	+40.5%	-44.6%	-11.3%	-93.1%	-93.4%	-86.8%	--	-83.8%	-89.8%	+181.3%	+53.3%	+21.7%
ANNUAL SHARE, BY DIAMETER	.6%	69.8%	29.6%	.5%	53.1%	45.1%	1.3%	50.6%	26.9%	22.5%	100.0%	100.0%

TABLE 35

FIXED DISK DRIVES, 1 - 2 GIGABYTES

SUMMARY BY PLATFORM

UNIT SHIPMENTS IN THOUSANDS	1997 Shipments Units	1997 Shipments %	1998 Forecast Units	1998 Forecast %	1999 Forecast Units	1999 Forecast %	2000 Forecast Units	2000 Forecast %	2001 Forecast Units	2001 Forecast %
MOBILE SYSTEM DRIVES	7,059.9	17.6%	1,115.5	31.4%	175.0	28.0%	115.0	100.0%	160.0	100.0%
	--		-84.1%		-84.3%		-34.2%		+39.1%	
2.5 INCH	7,059.9		1,095.5		110.0		--		--	
1.8 INCH	--		20.0		65.0		115.0		160.0	
DESKTOP SYSTEM DRIVES	32,545.7	81.4%	2,417.7	68.0%	450.0	72.0%	--	--	--	--
	--		-92.5%		-81.3%		--		--	
5.25 INCH	255.0		25.0		--		--		--	
3.5 INCH	32,290.7		2,392.7		450.0		--		--	
SERVER SYSTEM DRIVES	328.8	.8%	19.0	.5%	--	--	--	--	--	--
	--		-94.2%		--		--		--	
5.25 INCH	3.8		--		--		--		--	
3.5 INCH	325.0		19.0		--		--		--	
Total Shipments	39,934.4	100.0%	3,552.2	100.0%	625.0	100.0%	115.0	100.0%	160.0	100.0%
	--		-91.1%		-82.4%		-81.6%		+39.1%	

Notes: Percentage figures with plus/minus signs refer to year-to-year growth rates.

TABLE 34

FIXED DISK DRIVES, 1 - 2 GIGABYTES

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DISK DIAMETER

	1997 Shipments			Forecast								
				1998				1999			2000	2001
	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"	1.8"	3.5"	2.5"	1.8"	1.8"	1.8"
U.S. MANUFACTURERS												
Captive	--	--	350.0	--	--	100.0	--	--	--	--	--	--
Distributor	100.0	11,369.0	189.2	10.0	815.0	45.0	--	120.0	--	--	--	--
OEM/Integrator	155.0	12,479.0	1,930.0	15.0	875.0	295.0	--	215.0	--	--	--	--
TOTAL U.S. SHIPMENTS	255.0	23,848.0	2,469.2	25.0	1,690.0	440.0	--	335.0	--	--	--	--
NON-U.S. MANUFACTURERS												
Captive	.3	460.7	1,166.1	--	200.7	168.7	--	40.0	35.0	--	--	--
Distributor	--	2,455.0	429.0	--	228.0	60.0	5.0	25.0	10.0	15.0	30.0	40.0
OEM/Integrator	3.5	5,852.0	2,995.6	--	293.0	426.8	15.0	50.0	65.0	50.0	85.0	120.0
TOTAL NON-U.S. SHIPMENTS	3.8	8,767.7	4,590.7	--	721.7	655.5	20.0	115.0	110.0	65.0	115.0	160.0
WORLDWIDE RECAP												
Captive	.3	460.7	1,516.1	--	200.7	268.7	--	40.0	35.0	--	--	--
	-83.3%	-69.1%	+12.3%	--	-56.4%	-82.3%	--	-80.1%	-87.0%	--	--	--
Distributor	100.0	13,824.0	618.2	10.0	1,043.0	105.0	5.0	145.0	10.0	15.0	30.0	40.0
	--	-20.8%	+104.6%	-90.0%	-92.5%	-83.0%	--	-86.1%	-90.5%	+200.0%	+100.0%	+33.3%
OEM/Integrator	158.5	18,331.0	4,925.6	15.0	1,168.0	721.8	15.0	265.0	65.0	50.0	85.0	120.0
	--	-27.8%	+4.4%	-90.5%	-93.6%	-85.3%	--	-77.3%	-91.0%	+233.3%	+70.0%	+41.2%
Total Shipments	258.8	32,615.7	7,059.9	25.0	2,411.7	1,095.5	20.0	450.0	110.0	65.0	115.0	160.0
	--	-26.4%	+10.9%	-90.3%	-92.6%	-84.5%	--	-81.3%	-90.0%	+225.0%	+76.9%	+39.1%
ANNUAL SHARE, BY DIAMETER	.6%	81.8%	17.6%	.7%	68.0%	30.8%	.5%	72.1%	17.6%	10.3%	100.0%	100.0%

TABLE 36

FIXED DISK DRIVES, 1 - 2 GIGABYTES

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1997 Estimate Units (000)	1997 Estimate %	2001 Projection Units (000)	2001 Projection %
SPECIALIZED HIGH PERFORMANCE Supercomputers, video and high end imaging	--	--	--	--
MAINFRAME SYSTEMS General purpose	--	--	--	--
NETWORK/MIDRANGE SYSTEMS Midrange systems, network servers and workstations	383.4	1.0	.5	.3
DESKTOP PERSONAL COMPUTERS Business and professional, single user	29,004.4	72.6	10.1	6.3
CONSUMER COMPUTERS Desktop PCs, game, and hobby computers	3,458.2	8.6	1.1	.7
PORTABLE COMPUTERS Notebook and smaller mobile computers	7,088.4	17.8	139.0	86.9
OTHER APPLICATIONS	--	--	9.3	5.8
Total	39,934.4	100.0	160.0	100.0

TABLE 37

FIXED DISK DRIVES, 1 - 2 GIGABYTES

WORLDWIDE PRICE PER MEGABYTE ($/MB)

DISK DIAMETER		Forecast			
	1997	1998	1999	2000	2001
Captive					
5.25"	7.800	--	--	--	--
3.5"	.342	.247	.168	--	--
2.5"	.505	.348	.370	--	--
Captive Average	.463	.303	.245	--	--
Distributor					
5.25"	.097	.090	--	--	--
3.5"	.104	.072	.309	--	--
2.5"	.153	.123	.134	--	--
1.8"	--	.385	.343	.297	.259
Distributor Average	.106	.078	.287	.297	.259
OEM/Integrator					
5.25"	.126	.087	--	--	--
3.5"	.107	.079	.065	--	--
2.5"	.141	.113	.123	--	--
1.8"	--	.385	.329	.285	.251
OEM/Integrator Average	.115	.094	.100	.285	.251

Note: Price per megabyte calculations represent estimated total sales revenues for each product type divided by the total yearly shipped capacity of all drives of that type.

TABLE 38

FIXED DISK DRIVES, 1 - 2 GIGABYTES

MARKET SHARE SUMMARY
Worldwide Shipments of Noncaptive Disk Drives

	1997 Net Shipments									
	To United States Destinations					Worldwide				
	Units (000)				%	Units (000)				%
Drive Manufacturers	5.25"	3.5"	2.5"	Total		5.25"	3.5"	2.5"	Total	
Seagate Technology	--	3670.0	150.0	3820.0	27.6	--	10390.0	595.0	10985.0	28.9
Western Digital	--	2215.0	--	2215.0	16.0	--	7188.0	--	7188.0	18.9
Quantum	120.0	2280.0	--	2400.0	17.3	255.0	5810.0	--	6065.0	16.0
Fujitsu	--	1503.8	203.5	1707.3	12.3	.5	4064.0	726.6	4791.1	12.6
Toshiba	--	--	565.0	565.0	4.1	--	--	2105.0	2105.0	5.5
Samsung Electronics	--	415.0	--	415.0	3.0	--	2060.0	--	2060.0	5.4
Maxtor	--	944.0	39.0	983.0	7.1	--	1863.0	69.0	1932.0	5.1
IBM	--	--	1010.0	1010.0	7.3	--	--	1450.0	1450.0	3.8
Hitachi	1.5	1.0	316.0	318.5	2.3	3.0	20.0	524.0	547.0	1.4
Other U.S.	--	230.0	25.0	255.0	1.8	--	460.0	74.2	534.2	1.4
Other Non-U.S.	--	150.0	--	150.0	1.2	--	300.0	--	300.0	1.0
TOTAL	121.5	11408.8	2308.5	13838.8	100.0	258.5	32155.0	5543.8	37957.3	100.0

FIXED DISK DRIVES, 2 - 3 GIGABYTES

1998 DISK/TREND REPORT

FIXED DISK DRIVES, 2 - 3 GIGABYTES

Coverage

Examples of disk drives in this group include:

5.25" disk diameter

Fujitsu	F6429K
Quantum	Bigfoot CY***

3.5" disk diameter

Fujitsu	M2932*, M1638TAU**
IBM	DCAS-32160**
JTS	C2150-2AF**
Maxtor	82160D2**, 90288D2**
NEC	DSE2550A**
Quantum	Fireball SE**, Fireball EL**
Samsung Electronics	WN32543A**
Seagate Technology	Medalist 2122**
Western Digital	WDE2170**, WDAC12500**

2.5" disk diameter

Fujitsu	MHA2021****, MHD2021AT*****
Hitachi	DK225A-21****
IBM	DYKA-22160*****
Toshiba	MK-2103MAV****, MK-2105MAT*****

*Maximum 41.3 mm height, or less.
**Maximum 25.4 mm height, or less.
***Maximum 19.05 mm height, or less.
****Maximum 12.7 mm height, or less.
*****Maximum 9.5 mm height, or less.

The disk drive industry has a relatively short history in this capacity range. There was a brief period of activity in the mid-1980's, with a few drives designed for the mainframe market, but these were soon supplanted by drives with capacities above this range. Disk drives with individual spindles containing capacities above 2 gigabytes first appeared in 1985 with IBM's 3380-E, the double capacity model in the 3380 series. Most of the 6.5", 8", 9.5" and 10.5" drives which followed were intended for mainframe and supermini applications similar to IBM's, and most used standard industry technology.

5.25" drives above 2 gigabytes were shipped for the first time in 1991, and were once available from seven manufacturers, now down to two. The early

5.25" drives offered in this capacity range were intended for midrange and mainframe systems, with only one remaining. The 5.25" drives in this capacity range now in volume production are sold as low cost substitutes for 3.5" drives in the personal computer market.

The initial 3.5" drives in the 2-3 gigabyte range were intended for midrange and mainframe computer system applications, but these markets are almost gone, dwarfed by the rapid growth of demand in the desktop personal computer market, and the newer generation of low cost 3.5" drive families. Nine disk drive manufacturers now participate in the very competitive contest to secure customers among the leading personal computer makers for 3.5" 1" high drives. Only four disk drive manufacturers also now offer 2.5" drives with 2-3 gigabyte capacities, targeting the inevitable demand for disk capacity for notebook computers which always follows each upward step in capacities used with desktop personal computers.

Market status

Disk drive shipments in the 2-3 gigabyte product group peaked, as expected, in 1997, reaching a total of 49.8 million drives, but the shipment trend is headed down in 1998, also as expected, as the combination of rising areal densities and increasing demand for more personal computer disk storage boosts the current lead in disk drive capacities above 3 gigabytes. The product group's total unit shipments are forecasted at 31.5 million drives for 1998, down 36.7%. Intensified levels of competition during the past year held total sales revenues for the product group to a level lower than expected, at $10.1 billion, with only half that amount projected for 1998, at $5.1 billion.

As market requirements evolve, the transitional nature of the current applications for drives in this product group is reflected in the changing product mix. Shipments of 5.25", 6.5", 8", and 9.5" server drives for mainframe systems have faded, with final production last year. At the same time many network server and midrange system requirements are transitioning to higher capacities, and existing applications with the same capacity requirements moved to 3.5" server drives which were physically smaller and lower in price. The first significant shipments of 2-3 gigabyte 3.5" server drives did not occur until 1993, but 1997 shipments of

3.5" server drives were 4.3 million units. That leadership has already moved on to higher capacities, however, and 1998 shipments of 3.5" server drives are forecasted to decline to 515,000 units.

The 3.5" desktop drive market has been a bloody battleground during 1997 and 1998 as Fujitsu, Maxtor and Samsung Electronics intensify their efforts to expand market share through a combination of improved products and aggressive pricing, at the expense of the existing market leaders, Seagate, Quantum and Western Digital. The three Asian companies gained ground on the three U.S. companies in 1997, and the OEM average unit price for desktop 3.5" drives fell from $158 in 1997 to an estimated $124 in 1998, with 1999 expected to be well below $100. 1997's desktop 3.5" drive shipment total of 40.7 million drives is projected to drop to below 25 million in 1998. That decline would probably be higher without the emergency effort underway by several manufacturers of desktop 3.5" drives to design and produce extremely low cost single platter drives for use in the growing low-end personal computer market, with some PC models from major manufacturers expected to carry retail price tags of $500 to $600 by the end of 1998.

The reemergence of significant shipments of 5.25" desktop drives in 1996 was the result of new programs by Quantum and Belfort Memory International to divert sales from standard 3.5" drives designed for personal computers to new low-cost 5.25" models. A moderate level of success for these efforts was achieved, but market penetration was limited by the reluctance of other drive manufacturers to surrender customers to the new 5.25" drives, and their feisty response at the bargaining table. In this capacity range, Quantum remains the only 5.25" participant with drives intended for desktop personal computer applications, since BMI is concentrating its limited production capability on drives with higher capacities.

Desktop personal computers used 71.6% and consumer computers used 10% of the product group's 1997 worlwide unit shipments, and these shares are projected to be 62.9% and 19% in 2001. Portable computers utilized 9.9% of 1997 shipments and are forecasted to use 18.1% of 2001's much smaller shipments. Network/midrange systems used 8.5% of 1997 shipments, but there will be no requirement for disk drives in this capacity range with such systems in 2001.

Western Digital's 1997 concentration on 2-3 gigabyte drives provided the company the lead in noncaptive shipments for that year, with 23.6% of the worldwide total, all 3.5" drives. Seagate Technology declined to second place with 23.3%, including both 3.5" and 2.5" drives, and Quantum's shipments of 3.5" and 5.25" drives yielded a 23.1% share.

Marketing trends

Despite a renewed interest in developing single platter 3.5" desktop drives with the lowest possible product cost, the downward shipment trend for this product group will continue, as the industry's normal areal density increases moves the capacity target per 3.5" single platter drive above 3 gigabytes in the next year. During the 1999-2001 period worldwide unit shipments are projected to decline an average of 66.4% per year, with only 1.2 million drives forecasted for 2001. A slightly faster average annual decline of 71.2% is expected for sales revenues during the same period, with 2001 revenues projected at only $117.3 million.

Since peak demand for disk capacities in the notebook computer market frequently lags a year behind the capacities used in desktop personal computers, shipments of 2-3 gigabyte 2.5" drives are not expected to peak until 1998. However, as shipments for both desktop 3.5" and mobile 2.5" markets decline through 2001, the share of shipments held by 2.5" drives are not expected to rise above the 17-18% range, due to the lingering residual market for the very low cost 3.5" desktop drives now being developed. Server drive shipments are dropping fast, with the last sales for this product group expected in 2000.

Technical trends

As major personal computer manufacturers pursue their objective to lower the threshold price for a fully equipped PC, new demands are being placed on disk drive manufacturers. For disk drives with the highest production levels, the most important technical specification is cost. For that reason, low manufacturing cost has become the prime product development objective for the majority of 2-3 gigabyte drives, a design objective at least as important as performance and reliability. The major product development emphasis has been placed on devel-

opment of 3.5" and 2.5" drives which can be manufactured efficiently at high production rates, utilizing designs with a low parts count.

Areal density improvements are the largest influence on designers' ability to reduce drive costs. The well publicized 60% annual rate of improvement in areal density has not been consistently achieved, but remains a reasonable overall expectation for the balance of the current decade. The disk drive industry started its transition to high production levels for single platter 3.5" desktop drives with 2.1 gigabyte disks in the 4th quarter of 1997. In 1998, 2.5" drives with 2 gigabytes per platter are already in production in higher capacity ranges, and single platter 2.5" drives in the 2-3 gigabyte range are to be expected, to provide the most competitive drives possible to the notebook computer market.

Most of the technology development needed for future drives in the 2-3 gigabyte capacity range will not be specifically targeted to this product group. Development of semiconductors with the very high data rates required will be undertaken for all disk drives. Miniaturization of heads and head assemblies will be applicable to most disk drives in the second half of the 1990's. The movement to advanced magnetoresistive head designs and improvement in disk substrates and disk surfaces will also find general application.

Forecasting assumptions

1. Low cost 5.25" drives will stay in production until 1999, but sales growth will be held down by competitive action and declining markets.
2. 3.5" drive shipments peaked in 1997, and will drop rapidly as personal computer markets move to higher disk drive capacities.
3. 2.5" drives will peak in 1998, then decline through 2001, as notebook computer markets transition to drives with higher capacities.

TABLE 39

FIXED DISK DRIVES, 2 - 3 GIGABYTES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1997 Revenues		Forecast							
			1998		1999		2000		2001	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Captive	875.1	1,371.4	174.6	289.3	6.5	10.8	--	--	--	--
Distributor	1,038.1	2,187.1	485.9	1,095.8	59.2	130.1	10.0	21.9	.5	1.9
OEM/Integrator	2,312.3	4,283.6	745.8	1,488.3	391.9	654.7	101.4	168.4	37.8	62.8
TOTAL U.S. REVENUES	4,225.5	7,842.1	1,406.3	2,873.4	457.6	795.6	111.4	190.3	38.3	64.7
Non-U.S. Manufacturers										
Captive	81.9	534.4	161.2	881.6	47.4	272.8	6.2	34.3	1.4	8.3
Distributor	245.3	447.6	60.8	230.5	8.9	37.0	2.1	10.3	--	.9
OEM/Integrator	523.4	1,284.2	391.6	1,097.0	119.4	329.9	35.7	109.5	13.8	43.4
TOTAL NON-U.S. REVENUES	850.6	2,266.2	613.6	2,209.1	175.7	639.7	44.0	154.1	15.2	52.6
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	5,076.1	10,108.3	2,019.9	5,082.5	633.3	1,435.3	155.4	344.4	53.5	117.3
OEM Average Price ($000)		.181		.137		.104		.098		.096

TABLE 40

FIXED DISK DRIVES, 2 - 3 GIGABYTES

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1997		Forecast							
	Shipments		1998		1999		2000		2001	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Captive	1,480.0	2,320.0	350.0	580.0	15.0	25.0	--	--	--	--
Distributor	5,654.0	12,820.0	3,741.0	8,591.0	590.0	1,310.0	105.0	230.0	5.0	20.0
OEM/Integrator	11,310.0	22,717.5	5,491.0	11,306.0	4,030.0	6,760.0	1,090.0	1,810.0	415.0	690.0
TOTAL U.S. SHIPMENTS	18,444.0	37,857.5	9,582.0	20,477.0	4,635.0	8,095.0	1,195.0	2,040.0	420.0	710.0
Non-U.S. Manufacturers										
Captive	130.0	877.4	310.0	1,780.7	120.0	715.0	20.0	110.0	5.0	30.0
Distributor	1,688.0	3,006.0	460.0	1,745.0	65.0	285.0	20.0	100.0	--	10.0
OEM/Integrator	3,305.9	8,015.5	2,740.3	7,487.3	1,030.0	2,710.0	340.0	1,000.0	135.0	410.0
TOTAL NON-U.S. SHIPMENTS	5,123.9	11,898.9	3,510.3	11,013.0	1,215.0	3,710.0	380.0	1,210.0	140.0	450.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	23,567.9	49,756.4	13,092.3	31,490.0	5,850.0	11,805.0	1,575.0	3,250.0	560.0	1,160.0
Total Capacity (Terabytes)		108,914.5		71,097.5		25,575.5		7,047.5		2,515.2
Cumulative Shipments (Units in millions)										
IBM	2.5	3.8	2.8	4.4	2.8	4.4	2.8	4.4	2.8	4.4
Non-IBM	37.7	71.4	50.5	102.4	56.3	114.1	57.9	117.4	58.4	118.5
WORLDWIDE TOTAL	40.2	75.3	53.3	106.8	59.2	118.6	60.8	121.8	61.3	123.0

TABLE 41

FIXED DISK DRIVES, 2 - 3 GIGABYTES

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1997 Revenues				Forecast									
					1998			1999			2000		2001	
	>5.25"	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"	3.5"	2.5"	3.5"	2.5"
U.S. MANUFACTURERS														
Captive	--	--	885.4	486.0	--	19.0	270.3	--	--	10.8	--	--	--	--
Distributor	--	127.7	2,041.1	18.3	48.8	1,040.6	6.4	8.8	121.3	--	21.9	--	1.9	--
OEM/Integrator	--	258.1	3,491.5	534.0	97.8	1,292.0	98.5	16.9	632.4	5.4	168.4	--	62.8	--
TOTAL U.S. REVENUES	--	385.8	6,418.0	1,038.3	146.6	2,351.6	375.2	25.7	753.7	16.2	190.3	--	64.7	--
NON-U.S. MANUFACTURERS														
Captive	13.1	--	211.1	310.2	--	137.8	743.8	--	33.8	239.0	--	34.3	--	8.3
Distributor	--	--	421.7	25.9	--	174.0	56.5	--	14.8	22.2	7.4	2.9	.9	--
OEM/Integrator	6.7	--	1,015.2	262.3	--	509.6	587.4	--	138.3	191.6	53.5	56.0	20.9	22.5
TOTAL NON-U.S. REVENUES	19.8	--	1,648.0	598.4	--	821.4	1,387.7	--	186.9	452.8	60.9	93.2	21.8	30.8
WORLDWIDE RECAP														
Captive	13.1	--	1,096.5	796.2	--	156.8	1,014.1	--	33.8	249.8	--	34.3	--	8.3
	-85.6%	--	+162.5%	+340.6%	--	-85.7%	+27.4%	--	-78.4%	-75.4%	--	-86.3%	--	-75.8%
Distributor	--	127.7	2,462.8	44.2	48.8	1,214.6	62.9	8.8	136.1	22.2	29.3	2.9	2.8	--
	--	--	+86.7%	+74.0%	-61.8%	-50.7%	+42.3%	-82.0%	-88.8%	-64.7%	-78.5%	-86.9%	-90.4%	--
OEM/Integrator	6.7	258.1	4,506.7	796.3	97.8	1,801.6	685.9	16.9	770.7	197.0	221.9	56.0	83.7	22.5
	+644.4%	--	+53.4%	+345.1%	-62.1%	-60.0%	-13.9%	-82.7%	-57.2%	-71.3%	-71.2%	-71.6%	-62.3%	-59.8%
Total Revenues	19.8	385.8	8,066.0	1,636.7	146.6	3,173.0	1,762.9	25.7	940.6	469.0	251.2	93.2	86.5	30.8
	-78.8%	--	+72.5%	+325.1%	-62.0%	-60.7%	+7.7%	-82.5%	-70.4%	-73.4%	-73.3%	-80.1%	-65.6%	-67.0%
ANNUAL SHARE, BY DIAMETER	.2%	3.8%	79.9%	16.1%	2.9%	62.5%	34.6%	1.8%	65.6%	32.6%	73.0%	27.0%	73.8%	26.2%

TABLE 43

FIXED DISK DRIVES, 2 - 3 GIGABYTES

SUMMARY BY PLATFORM

UNIT SHIPMENTS IN THOUSANDS	1997 Shipments Units	1997 Shipments %	1998 Forecast Units	1998 Forecast %	1999 Forecast Units	1999 Forecast %	2000 Forecast Units	2000 Forecast %	2001 Forecast Units	2001 Forecast %
MOBILE SYSTEM DRIVES	4,917.4	9.8%	6,007.8	19.0%	2,050.0	17.3%	560.0	17.2%	210.0	18.1%
	--		+22.1%		-65.8%		-72.6%		-62.5%	
2.5 INCH	4,917.4		6,007.8		2,050.0		560.0		210.0	
DESKTOP SYSTEM DRIVES	40,569.8	81.5%	24,967.2	79.2%	9,665.0	81.8%	2,685.0	82.6%	950.0	81.9%
	--		-38.4%		-61.2%		-72.2%		-64.6%	
5.25 INCH	2,660.0		1,215.0		270.0		--		--	
3.5 INCH	37,909.8		23,752.2		9,395.0		2,685.0		950.0	
SERVER SYSTEM DRIVES	4,269.2	8.5%	515.0	1.6%	90.0	.7%	5.0	.1%	--	--
	--		-87.9%		-82.5%		-94.4%		--	
>5.25 INCH	1.5		--		--		--		--	
3.5 INCH	4,267.7		515.0		90.0		5.0		--	
Total Shipments	49,756.4	100.0%	31,490.0	100.0%	11,805.0	100.0%	3,250.0	100.0%	1,160.0	100.0%
	--		-36.7%		-62.5%		-72.4%		-64.3%	

Notes: Percentage figures with plus/minus signs refer to year-to-year growth rates.

TABLE 42

FIXED DISK DRIVES, 2 - 3 GIGABYTES

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DISK DIAMETER

	1997 Shipments				Forecast									
					1998			1999			2000		2001	
	>5.25"	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"	3.5"	2.5"	3.5"	2.5"
U.S. MANUFACTURERS														
Captive	--	--	1,510.0	810.0	--	50.0	530.0	--	--	25.0	--	--	--	--
Distributor	--	880.0	11,855.0	85.0	400.0	8,156.0	35.0	90.0	1,220.0	--	230.0	--	20.0	--
OEM/Integrator	--	1,780.0	18,771.0	2,166.5	815.0	10,002.0	489.0	180.0	6,550.0	30.0	1,810.0	--	690.0	--
TOTAL U.S. SHIPMENTS	--	2,660.0	32,136.0	3,061.5	1,215.0	18,208.0	1,054.0	270.0	7,770.0	55.0	2,040.0	--	710.0	--
NON-U.S. MANUFACTURERS														
Captive	1.0	--	382.8	493.6	--	342.2	1,438.5	--	110.0	605.0	--	110.0	--	30.0
Distributor	--	--	2,896.0	110.0	--	1,460.0	285.0	--	155.0	130.0	80.0	20.0	10.0	--
OEM/Integrator	.5	--	6,762.7	1,252.3	--	4,257.0	3,230.3	--	1,450.0	1,260.0	570.0	430.0	230.0	180.0
TOTAL NON-U.S. SHIPMENTS	1.5	--	10,041.5	1,855.9	--	6,059.2	4,953.8	--	1,715.0	1,995.0	650.0	560.0	240.0	210.0
WORLDWIDE RECAP														
Captive	1.0	--	1,892.8	1,303.6	--	392.2	1,968.5	--	110.0	630.0	--	110.0	--	30.0
	-85.7%	--	+176.1%	+421.4%	--	-79.3%	+51.0%	--	-72.0%	-68.0%	--	-82.5%	--	-72.7%
Distributor	--	880.0	14,751.0	195.0	400.0	9,616.0	320.0	90.0	1,375.0	130.0	310.0	20.0	30.0	--
	--	--	+219.8%	+160.0%	-54.5%	-34.8%	+64.1%	-77.5%	-85.7%	-59.4%	-77.5%	-84.6%	-90.3%	--
OEM/Integrator	.5	1,780.0	25,533.7	3,418.8	815.0	14,259.0	3,719.3	180.0	8,000.0	1,290.0	2,380.0	430.0	920.0	180.0
	-50.0%	--	+164.4%	+505.1%	-54.2%	-44.2%	+8.8%	-77.9%	-43.9%	-65.3%	-70.2%	-66.7%	-61.3%	-58.1%
Total Shipments	1.5	2,660.0	42,177.5	4,917.4	1,215.0	24,267.2	6,007.8	270.0	9,485.0	2,050.0	2,690.0	560.0	950.0	210.0
	-83.3%	--	+182.0%	+452.5%	-54.3%	-42.5%	+22.2%	-77.8%	-60.9%	-65.9%	-71.6%	-72.7%	-64.7%	-62.5%
ANNUAL SHARE, BY DIAMETER	--	5.3%	84.9%	9.8%	3.9%	77.2%	18.9%	2.3%	80.4%	17.3%	82.9%	17.1%	82.0%	18.0%

TABLE 44

FIXED DISK DRIVES, 2 - 3 GIGABYTES

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1997 Estimate Units (000)	1997 Estimate %	2001 Projection Units (000)	2001 Projection %
SPECIALIZED HIGH PERFORMANCE Supercomputers, video and high end imaging	--	--	--	--
MAINFRAME SYSTEMS General purpose	--	--	--	--
NETWORK/MIDRANGE SYSTEMS Midrange systems, network servers and workstations	4,224.3	8.5	--	--
DESKTOP PERSONAL COMPUTERS Business and professional, single user	35,645.5	71.6	729.6	62.9
CONSUMER COMPUTERS Desktop PCs, game, and hobby computers	4,970.7	10.0	220.4	19.0
PORTABLE COMPUTERS Notebook and smaller mobile computers	4,915.9	9.9	210.0	18.1
OTHER APPLICATIONS	--	--	--	--
Total	49,756.4	100.0	1,160.0	100.0

TABLE 45

FIXED DISK DRIVES, 2 - 3 GIGABYTES

WORLDWIDE PRICE PER MEGABYTE ($/MB)

DISK DIAMETER		Forecast			
	1997	1998	1999	2000	2001
Captive					
>5.25"	4.517	--	--	--	--
3.5"	.265	.176	.139	--	--
2.5"	.272	.234	.183	.144	.127
Captive Average	.270	.224	.176	.144	.127
Distributor					
5.25"	.069	.058	.046	--	--
3.5"	.077	.056	.046	.044	.043
2.5"	.103	.091	.079	.069	--
Distributor Average	.077	.057	.048	.045	.043
OEM/Integrator					
>5.25"	4.433	--	--	--	--
5.25"	.069	.057	.045	--	--
3.5"	.080	.055	.044	.043	.042
2.5"	.104	.084	.071	.060	.058
OEM/Integrator Average	.082	.061	.048	.046	.045

Note: Price per megabyte calculations represent estimated total sales revenues for each product type divided by the total yearly shipped capacity of all drives of that type.

TABLE 46

FIXED DISK DRIVES, 2 - 3 GIGABYTES

MARKET SHARE SUMMARY
Worldwide Shipments of Noncaptive Disk Drives

	1997 Net Shipments									
	To United States Destinations					Worldwide				
	Units (000)				%	Units (000)				%
Drive Manufacturers	5.25"	3.5"	2.5"	Total		5.25"	3.5"	2.5"	Total	
Western Digital	--	5615.0	--	5615.0	25.6	--	10991.0	--	10991.0	23.6
Seagate Technology	--	4980.0	34.0	5014.0	22.8	--	10690.0	135.0	10825.0	23.3
Quantum	1060.0	3275.0	--	4335.0	19.7	2660.0	8075.0	--	10735.0	23.1
Maxtor	--	1939.0	--	1939.0	8.8	--	3678.0	--	3678.0	7.9
Fujitsu	--	1198.4	11.5	1209.9	5.5	--	3229.7	82.3	3312.0	7.1
IBM	--	340.0	1470.0	1810.0	8.2	--	490.0	2090.0	2580.0	5.5
Samsung	--	1169.0	--	1169.0	5.3	--	2449.0	--	2449.0	5.3
Other U.S.	--	190.0	--	190.0	.9	--	380.0	26.5	406.5	.9
Other Non-U.S.	--	200.0	476.0	676.0	3.2	.5	302.0	1280.0	1582.5	3.3
TOTAL	1060.0	18906.4	1991.5	21957.9	100.0	2660.5	40284.7	3613.8	46559.0	100.0

FIXED DISK DRIVES, 3 - 5 GIGABYTES

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