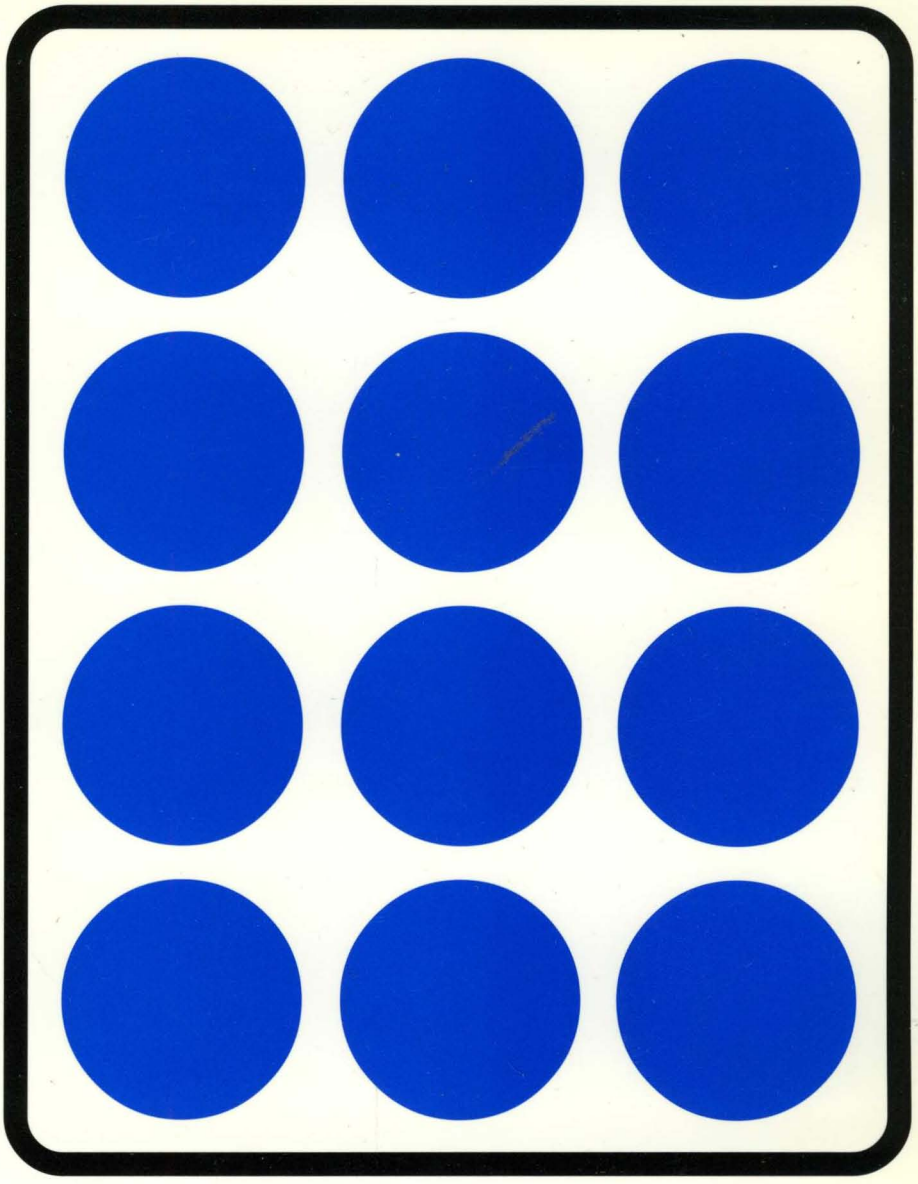
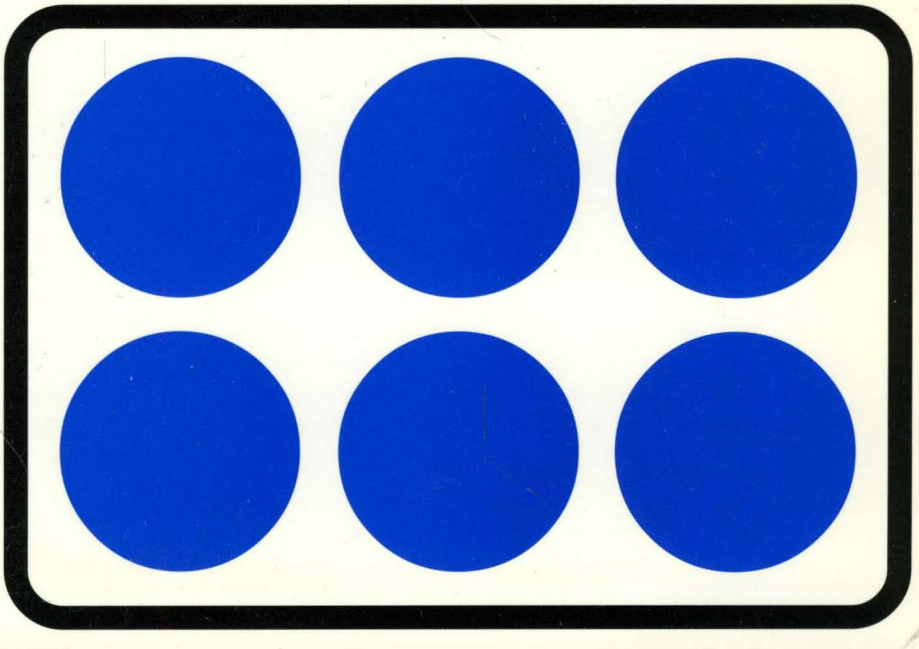


1999 DISK/TREND® REPORT

RIGID
DISK
DRIVES



1999 DISK/TREND® REPORT

RIGID DISK DRIVES

June, 1999

DISK/TREND, Inc.
1925 Landings Drive
Mountain View, California 94043

Telephone: 650-961-6209
Facsimile: 650-969-2560
E-mail: dtinfo@disktrend.com
Web: www.disktrend.com

© Copyright 1999 by DISK/TREND, Inc. All rights reserved. No portion of this report may be reproduced in whole or in part without written permission, including translation into another language or redistribution by any means or in any form. All information included is believed to be reliable but cannot be guaranteed to be complete or correct. DISK/TREND is a trademark registered in the United States Patent and Trademark Office.

FOREWORD

It's always surprising that an industry which holds net profits to such a low level (in the years when there are profits) can advance its basic technology and the value of its products so rapidly. The last year or two have been typical: Increased product shipments, loss of market share by industry leaders, dramatic increases in drive capacities for all product segments, sharp reductions in average price per megabyte, initial shipments to new consumer electronic markets, losses by several drive manufacturers, bankruptcies of marginal drive producers. It appears that severe competition is the most effective way to generate rapid development of technology.

The DISK/TREND Report on rigid disk drives is now in its 23rd year, and the organization of the report continues to evolve, as the disk drive industry does. The other annual editions of the DISK/TREND Report also change from time to time, and this year two reports previously published separately are being combined, as the Optical and Removable Disk Drive report, which will be available in July. The report on Disk Drive Arrays will again be published in October.

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 now included in the DISK/TREND web site. Incidentally, if you are not already familiar with the web site, we suggest a visit to www.disktrend.com, where you'll find information on current industry events and links to every known web site in the disk drive industry.

We are always willing to help you at any time by providing additional information on the industry which we may have available. Your suggestions for improvements in the DISK/TREND Report are always welcome and are sincerely appreciated.

James N. Porter
Robert H. Katzive

TABLE OF CONTENTS

	Page
INTRODUCTION	SUM-1
SUMMARY	SUM-2
Industry size	SUM-2
Marketing channels	SUM-4
Product mix	SUM-6
Platform trends	SUM-14
Price per megabyte	SUM-18
Noncaptive market	SUM-22
TECHNICAL REVIEW	SUM-29
Competing technologies	SUM-29
Disk drive enhancements	SUM-41
DEFINITIONS	SUM-57
DISK CARTRIDGE DRIVES	DT1-1
FIXED DISK DRIVES, LESS THAN 2 GIGABYTES	DT2-1
FIXED DISK DRIVES, 2-3 GIGABYTES	DT3-1
FIXED DISK DRIVES, 3-5 GIGABYTES	DT4-1
FIXED DISK DRIVES, 5-10 GIGABYTES	DT5-1
FIXED DISK DRIVES, 10-20 GIGABYTES	DT6-1
FIXED DISK DRIVES, 20-40 GIGABYTES	DT7-1
FIXED DISK DRIVES, 40-80 GIGABYTES	DT8-1
FIXED DISK DRIVES, MORE THAN 80 GIGABYTES	DT9-1
RIGID DISK DRIVE SPECIFICATIONS	RSPEC-1
MANUFACTURER PROFILES	MFGR-1
DISK/TREND ON DISK	DTDISK-1

LIST OF TABLES

Table		Page
1	CONSOLIDATED WORLDWIDE REVENUES, All Rigid Magnetic Disk Drive Groups	SUM-3
2	CONSOLIDATED WORLDWIDE REVENUES, Market Class Review	SUM-5
3	CONSOLIDATED WORLDWIDE REVENUES, Product Category Review, Revenue Summary	SUM-9
4	CONSOLIDATED WORLDWIDE SHIPMENTS, Product Category Review, Unit Shipment Summary	SUM-11
5	CONSOLIDATED WORLDWIDE SHIPMENTS, Summary by Disk Diameter	SUM-13
6	CONSOLIDATED WORLDWIDE SHIPMENTS, Summary by Platform	SUM-15
7	CONSOLIDATED WORLDWIDE SHIPMENTS, Product Category Review, Capacity Shipment Summary	SUM-17
8	NONCAPTIVE WORLDWIDE Product Category Review, Price per Megabyte Summary	SUM-20
9	CAPTIVE WORLDWIDE SHIPMENTS, Product Category Review, Price per Megabyte Summary	SUM-21
10	NONCAPTIVE WORLDWIDE REVENUES, Product Category Review, Revenue Summary	SUM-23
11	NONCAPTIVE WORLDWIDE SHIPMENTS, Product Category Review, Unit Shipment Summary	SUM-24
12	NONCAPTIVE WORLDWIDE SHIPMENTS, Product Category Review, Capacity Shipment Summary	SUM-25

LIST OF TABLES (Continued)

Table		Page
13	1998 MARKET SHARES, Manufacturers of Rigid Magnetic Disk Drives	SUM-27
14	CURRENT PRODUCT LINES, Manufacturers of Rigid Magnetic Disk Drives	SUM-28
15	DISK CARTRIDGE DRIVES, Revenue Summary	DT1-7
16	DISK CARTRIDGE DRIVES, Unit Shipment Summary	DT1-8
17	DISK CARTRIDGE DRIVES, Revenue Breakdown by Disk Diameter	DT1-9
18	DISK CARTRIDGE DRIVES, Shipment Breakdown by Disk Diameter	DT1-10
19	DISK CARTRIDGE DRIVES, Shipment Breakdown by Platform	DT1-11
20	DISK CARTRIDGE DRIVES, Applications Summary	DT1-12
21	DISK CARTRIDGE DRIVES, Worldwide Price per Megabyte	DT1-13
22	DISK CARTRIDGE DRIVES, Market Share Summary, Noncaptive Drives	DT1-14
23	FIXED DISK DRIVES, LESS THAN 2 GIGABYTES, Revenue Summary	DT2-7
24	FIXED DISK DRIVES, LESS THAN 2 GIGABYTES, Unit Shipment Summary	DT2-8
25	FIXED DISK DRIVES, LESS THAN 2 GIGABYTES, Revenue Breakdown by Disk Diameter	DT2-9
26	FIXED DISK DRIVES, LESS THAN 2 GIGABYTES, Shipment Breakdown by Disk Diameter	DT2-10
27	FIXED DISK DRIVES, LESS THAN 2 GIGABYTES, Shipment Breakdown by Platform	DT2-11

LIST OF TABLES (Continued)

Table		Page
28	FIXED DISK DRIVES, LESS THAN 2 GIGABYTES, Applications Summary	DT2-12
29	FIXED DISK DRIVES, LESS THAN 2 GIGABYTES, Worldwide Price per Megabyte	DT2-13
30	FIXED DISK DRIVES, LESS THAN 2 GIGABYTES, Market Share Summary, Noncaptive Drives	DT2-14
31	FIXED DISK DRIVES, 2-3 GIGABYTES, Revenue Summary	DT3-7
32	FIXED DISK DRIVES, 2-3 GIGABYTES, Unit Shipment Summary	DT3-8
33	FIXED DISK DRIVES, 2-3 GIGABYTES, Revenue Breakdown by Disk Diameter	DT3-9
34	FIXED DISK DRIVES, 2-3 GIGABYTES, Shipment Breakdown by Disk Diameter	DT3-10
35	FIXED DISK DRIVES, 2-3 GIGABYTES, Shipment Breakdown by Platform	DT3-11
36	FIXED DISK DRIVES, 2-3 GIGABYTES, Application Summary	DT3-12
37	FIXED DISK DRIVES, 2-3 GIGABYTES, Worldwide Price per Megabyte	DT3-13
38	FIXED DISK DRIVES, 2-3 GIGABYTES, Market Share Summary, Noncaptive Drives	DT3-14
39	FIXED DISK DRIVES, 3-5 GIGABYTES, Revenue Summary	DT4-7
40	FIXED DISK DRIVES, 3-5 GIGABYTES, Unit Shipment Summary	DT4-8
41	FIXED DISK DRIVES, 3-5 GIGABYTES, Revenue Breakdown by Disk Diameter	DT4-9
42	FIXED DISK DRIVES, 3-5 GIGABYTES, Shipment Breakdown by Disk Diameter	DT4-10

LIST OF TABLES (Continued)

Table		Page
43	FIXED DISK DRIVES, 3-5 GIGABYTES, Shipment Breakdown by Platform	DT4-11
44	FIXED DISK DRIVES, 3-5 GIGABYTES, Application Summary	DT4-12
45	FIXED DISK DRIVES, 3-5 GIGABYTES, Worldwide Price per Megabyte	DT4-13
46	FIXED DISK DRIVES, 3-5 GIGABYTES, Market Share Summary, Noncaptive Drives	DT4-14
47	FIXED DISK DRIVES, 5-10 GIGABYTES, Revenue Summary	DT5-7
48	FIXED DISK DRIVES, 5-10 GIGABYTES, Unit Shipment Summary	DT5-8
49	FIXED DISK DRIVES, 5-10 GIGABYTES, Revenue Breakdown by Disk Diameter	DT5-9
50	FIXED DISK DRIVES, 5-10 GIGABYTES, Shipment Breakdown by Disk Diameter	DT5-10
51	FIXED DISK DRIVES, 5-10 GIGABYTES, Shipment Breakdown by Platform	DT5-11
52	FIXED DISK DRIVES, 5-10 GIGABYTES, Application Summary	DT5-12
53	FIXED DISK DRIVES, 5-10 GIGABYTES, Worldwide Price per Megabyte	DT5-13
54	FIXED DISK DRIVES, 5-10 GIGABYTES, Market Share Summary, Noncaptive Drives	DT5-14
55	FIXED DISK DRIVES, 10-20 GIGABYTES, Revenue Summary	DT6-7
56	FIXED DISK DRIVES, 10-20 GIGABYTES, Unit Shipment Summary	DT6-8
57	FIXED DISK DRIVES, 10-20 GIGABYTES, Revenue Breakdown by Disk Diameter	DT6-9

LIST OF TABLES (Continued)

Table		Page
58	FIXED DISK DRIVES, 10-20 GIGABYTES, Shipment Breakdown by Disk Diameter	DT6-10
59	FIXED DISK DRIVES, 10-20 GIGABYTES, Shipment Breakdown by Platform	DT6-11
60	FIXED DISK DRIVES, 10-20 GIGABYTES, Application Summary	DT6-12
61	FIXED DISK DRIVES, 10-20 GIGABYTES, Worldwide Price per Megabyte	DT6-13
62	FIXED DISK DRIVES, 10-20 GIGABYTES, Market Share Summary, Noncaptive Drives	DT6-14
63	FIXED DISK DRIVES, 20-40 GIGABYTES, Revenue Summary	DT7-5
64	FIXED DISK DRIVES, 20-40 GIGABYTES, Unit Shipment Summary	DT7-6
65	FIXED DISK DRIVES, 20-40 GIGABYTES, Revenue Breakdown by Disk Diameter	DT7-7
66	FIXED DISK DRIVES, 20-40 GIGABYTES, Shipment Breakdown by Disk Diameter	DT7-8
67	FIXED DISK DRIVES, 20-40 GIGABYTES, Shipment Breakdown by Platform	DT7-9
68	FIXED DISK DRIVES, 20-40 GIGABYTES, Application Summary	DT7-10
69	FIXED DISK DRIVES, 20-40 GIGABYTES, Worldwide Price per Megabyte	DT7-11
70	FIXED DISK DRIVES, 40-80 GIGABYTES, Revenue Summary	DT8-5
71	FIXED DISK DRIVES, 40-80 GIGABYTES, Unit Shipment Summary	DT8-6

LIST OF TABLES (Continued)

Table		Page
72	FIXED DISK DRIVES, 40-80 GIGABYTES, Revenue Breakdown by Disk Diameter	DT8-7
73	FIXED DISK DRIVES, 40-80 GIGABYTES, Revenue Breakdown by Disk Diameter	DT8-8
74	FIXED DISK DRIVES, 40-80 GIGABYTES, Shipment Breakdown by Platform	DT8-9
75	FIXED DISK DRIVES, 40-80 GIGABYTES, Application Summary	DT8-10
76	FIXED DISK DRIVES, 40-80 GIGABYTES, Worldwide Price per Megabyte	DT8-11
77	FIXED DISK DRIVES, MORE THAN 80 GIGABYTES, Revenue Summary	DT9-5
78	FIXED DISK DRIVES, MORE THAN 80 GIGABYTES, Unit Shipment Summary	DT9-6
79	FIXED DISK DRIVES, MORE THAN 80 GIGABYTES, Revenue Breakdown by Disk Diameter	DT9-7
80	FIXED DISK DRIVES, MORE THAN 80 GIGABYTES, Shipment Breakdown by Disk Diameter	DT9-8
81	FIXED DISK DRIVES, MORE THAN 80 GIGABYTES, Shipment Breakdown by Platform	DT9-9
82	FIXED DISK DRIVES, MORE THAN 80 GIGABYTES, Application Summary	DT9-10
83	FIXED DISK DRIVES, MORE THAN 80 GIGABYTES, Worldwide Price per Megabyte	DT9-11

LIST OF FIGURES

Figure		Page
1	CHANGING PRODUCT MIX, Consolidated Rigid Disk Drive Revenue	SUM-8
2	UNIT SHIPMENT SUMMARY, Worldwide Shipments in Millions of Units	SUM-10
3	DISK DIAMETER SUMMARY, Worldwide Shipments in Millions of Units	SUM-12
4	CAPACITY SHIPMENT SUMMARY, Worldwide Shipments in Terabytes	SUM-16
5	PRICE PER MEGABYTE SUMMARY, Noncaptive Worldwide Shipments	SUM-19
6	1998 ESTIMATED MARKET SHARE, Percentage of Worldwide Revenues	SUM-26

INTRODUCTION

Product groups move up another step

This year we again found it necessary to revise the lowest and highest product groups used for fixed disk drives, which we are always hesitant to do because we know that many companies organize their industry data accordingly. However, it was necessary due to the disappearance of lower capacity disk drives from almost every manufacturer's product lines and the rapid upward movement of high end drives. The new product group lineup uses a single product group for "less than 2 gigabytes" and splits the previous top capacity product group into two new groups: "40-80 gigabytes" and "more than 80 gigabytes".

DISK/TREND ON DISK instructions on web site

For many years, the statistical and specification tables included in each edition of the DISK/TREND Report have been available in diskette form as a separately purchased option to buyers of each report, and instructions for using the diskettes were included in the last section of the printed reports. However, user instructions are now contained in the diskettes and are also available on the DISK/TREND web site. Information on how to access the web site are included at the end of this report.

Removable data storage is on the move again

For the last four years, the data on disk cartridge drives and removable card format disk drives included in the DISK/TREND Report on rigid disk drives has also been included in a separate report on removable data storage. Starting this year, the separate report on removable data storage will be combined with our report covering optical disk drives in a single report to be published in July, identified as the DISK/TREND Report on "Optical and Removable Disk Drives." In the new report, the section on disk cartridge drives will be substantially the same as the product group in this report on disk cartridge drives, and the data on drives in removable card formats is extracted from the product group in this report covering drives with less than 2 gigabyte capacities.

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

The last year has been good for buyers of disk drives, but it's been a difficult period for most disk drive manufacturers. Worldwide unit shipments increased 11.1% in 1998, with 144.9 million drives, and are projected to reach 168.3 million in 1999, up another 16.1%. However, 1998 sales revenues declined 5.2% to $30.0 billion, and the forecasted $32.4 billion sales revenue total in 1999 is a modest increase of only 7.7%. It's clear that several disk drive manufacturers have placed a higher priority on market share than on profits.

Several factors have contributed to the relatively rapid decline in average unit prices during the past year. Competition has become more intense as Fujitsu, Samsung Electronics, Maxtor, IBM and Hitachi have expedited development of new drives, expanded production facilities and added sales coverage. Although losing market share, industry shipment leaders Seagate Technology, Quantum and Western Digital have fought back with their own aggressive product development and pricing strategies. Despite the leaders' competitive counterattacks, their collective share of the industry's worldwide shipments fell from 61.3% in 1997 to 51.0% in 1998. The competitive environment has also been significantly affected by the rapid growth of the low end personal computer market. As it has grown, that market segment has demanded lower and lower prices for one and two platter desktop drives, and many drive manufacturers have been scrambling to accommodate the demand.

Industry participants frequently argue about whether the market's demand for more disk storage capacity is increasing at the same rate as the areal density curve. Many factors affect both trends, but nevertheless the shipment leadership keeps moving up to higher DISK/TREND Report product groups each year. In 1998 the leader was the 3-5 gigabyte group, in 1999 it's the 5-10 gigabyte group, and by 2002 the 40-80 gigabyte group looks like the winner.

Because of strong performances by several drive manufacturers which also happen to be system manufacturers, the ratio of captive sales revenues has been slightly higher than previously forecast, at 21.4% this year, and the revenue level for OEM/Integrator sales is lower, due to growing shipments to the low end PC market and increased price competition.

TABLE 1

CONSOLIDATED WORLDWIDE REVENUES

RIGID MAGNETIC DISK DRIVES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1998		Forecast							
	Revenues		1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Captive	3,330.5	5,019.9	3,531.3	5,297.0	3,595.3	5,373.1	4,100.1	6,020.9	4,716.3	6,893.9
Distributor	3,299.4	6,495.8	3,862.5	6,418.1	4,629.4	6,993.3	5,346.7	7,581.9	5,335.5	7,593.6
OEM/Integrator	6,569.0	11,895.8	8,360.3	13,340.9	10,709.6	16,000.2	13,464.4	19,555.4	16,308.2	23,586.4
TOTAL U.S. REVENUES	13,198.9	23,411.5	15,754.1	25,056.0	18,934.3	28,366.6	22,911.2	33,158.2	26,360.0	38,073.9
Non-U.S. Manufacturers										
Captive	324.1	2,061.7	228.1	1,642.7	136.8	1,167.0	107.8	1,182.1	127.0	1,321.8
Distributor	572.1	1,360.0	464.7	1,161.7	610.9	1,081.1	817.2	1,303.1	1,018.7	1,651.6
OEM/Integrator	1,040.8	3,243.6	2,216.2	4,539.8	2,866.6	5,670.2	3,898.7	7,316.8	4,937.5	9,271.0
TOTAL NON-U.S. REVENUES	1,937.0	6,665.3	2,909.0	7,344.2	3,614.3	7,918.3	4,823.7	9,802.0	6,083.2	12,244.4
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	15,135.9	30,076.8	18,663.1	32,400.2	22,548.6	36,284.9	27,734.9	42,960.2	32,443.2	50,318.3

Marketing channels

The DISK/TREND list of rigid disk drive manufacturers is now down to 18 companies, the current survivors in one of the world's most competitive industries. The United States still dominates the list, with 12 companies headquartered in the U.S. Five are headquartered in Asia, and only one disk drive manufacturer remains in Europe. Maxtor has been reclassified as a U.S. company, after Hyundai relinquished ownership last year in the sale of its shares in the U.S. stock market.

JTS succumbed to aggressive competitive product development and falling prices with a 1998 bankruptcy. Integral Peripherals' assets were sold in bankruptcy proceedings after the 1.8" drive market stayed too small and it took too long to establish a 3" drive market. SyQuest also went into bankruptcy when sales didn't generate enough cash to cover production and marketing costs. Avatar closed its doors when the 2.5" disk cartridge drive business turned out to be more of a theory than a reality. And Nomai departed from the 3.5" disk cartridge drive business after Iomega purchased control of the company, with other objectives in mind. The newcomers are Conner Technology, populated with industry old pros who hope to penetrate the low end desktop drive segment, Halo Data Devices, with a plan to enter the market for 1" disk drives, and PCS, an established supplier of disk drive service and limited manufacturing programs, which provides end of life manufacturing of drive models originated by companies which are now inactive.

Captive sales revenues currently are slightly higher than previously expected, because the strong product development programs by IBM and several Asian drive manufacturers, which also happen to be system manufacturers, have also helped to strengthen captive sales of drives by those firms. Nevertheless, the long term expectation is that the ratio of captive sales revenues to the overall total will decline to 16.3% in 2002. The ratio of OEM/Integrator revenues is destined to increase, reaching a projected 65.3% in 2002. A variety of influences will help boost OEM sales more rapidly, including growing sales of low end personal computers, development of new consumer electronic markets, and continuing strength in mobile and server drive applications -- all markets in which most of the drives are sold on an OEM basis directly to system manufacturers.

TABLE 2

CONSOLIDATED WORLDWIDE REVENUES
RIGID MAGNETIC DISK DRIVES
MARKET CLASS REVIEW

REVENUE SUMMARY

WORLDWIDE REVENUES BY MANUFACTURER TYPE	1998 Revenues $M	1998 Revenues %	Forecast 1999 $M	Forecast 1999 %	Forecast 2000 $M	Forecast 2000 %	Forecast 2001 $M	Forecast 2001 %	Forecast 2002 $M	Forecast 2002 %
U.S. Manufacturers										
Captive	5,019.9 --	16.6%	5,297.0 +5.5%	16.3%	5,373.1 +1.4%	14.8%	6,020.9 +12.1%	14.0%	6,893.9 +14.5%	13.7%
Distributor	6,495.8 -.2%	21.5%	6,418.1 -1.2%	19.8%	6,993.3 +9.0%	19.2%	7,581.9 +8.4%	17.6%	7,593.6 +.2%	15.0%
OEM/Integrator	11,895.8 -12.7%	39.5%	13,340.9 +12.1%	41.1%	16,000.2 +19.9%	44.0%	19,555.4 +22.2%	45.5%	23,586.4 +20.6%	46.8%
Total U.S. Manufacturers	23,411.5 -4.7%	77.6%	25,056.0 +7.0%	77.2%	28,366.6 +13.2%	78.0%	33,158.2 +16.9%	77.1%	38,073.9 +14.8%	75.5%
Non-U.S. Manufacturers										
Captive	2,061.7 +9.7%	6.8%	1,642.7 -20.3%	5.0%	1,167.0 -29.0%	3.2%	1,182.1 +1.3%	2.7%	1,321.8 +11.8%	2.6%
Distributor	1,360.0 +1.7%	4.5%	1,161.7 -14.6%	3.5%	1,081.1 -6.9%	2.9%	1,303.1 +20.5%	3.0%	1,651.6 +26.7%	3.2%
OEM/Integrator	3,243.6 -17.9%	11.1%	4,539.8 +40.0%	14.3%	5,670.2 +24.9%	15.9%	7,316.8 +29.0%	17.2%	9,271.0 +26.7%	18.7%
Total Non-U.S. Manufacturers	6,665.3 -7.0%	22.4%	7,344.2 +10.2%	22.8%	7,918.3 +7.8%	22.0%	9,802.0 +23.8%	22.9%	12,244.4 +24.9%	24.5%
Worldwide Recap										
Captive	7,081.6 +12.1%	23.5%	6,939.7 -2.0%	21.4%	6,540.1 -5.8%	18.0%	7,203.0 +10.1%	16.8%	8,215.7 +14.1%	16.3%
Distributor	7,855.8 +.2%	26.1%	7,579.8 -3.5%	23.4%	8,074.4 +6.5%	22.3%	8,885.0 +10.0%	20.7%	9,245.2 +4.1%	18.4%
OEM/Integrator	15,139.4 -13.9%	50.4%	17,880.7 +18.1%	55.2%	21,670.4 +21.2%	59.7%	26,872.2 +24.0%	62.5%	32,857.4 +22.3%	65.3%
Total All Manufacturers	30,076.8 -5.2%	100.0%	32,400.2 +7.7%	100.0%	36,284.9 +12.0%	100.0%	42,960.2 +18.4%	100.0%	50,318.3 +17.1%	100.0%

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

Product mix

The disk drive industry's strategists will continue to watch the market's reaction very closely as each new drive with incremental increases in capacity goes on sale. They generally agree that the rigid disk drive areal density curve will move upward by at least 60% per year for several years, but they have a variety of hypotheses as to the market's receptiveness. The pessimists claim that most users will neither need or want to buy disk drives at many of the capacity levels expected to be offered during the next few years. The optimists expect the new generations of drives to be sold with a minimum of problems, as today's applications expand, new ones are developed, and the price per drive goes down regardless of increased capacity.

DISK/TREND forecasts assume that relentless demand for higher disk drive capacities for all of the industry's major application areas will 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.

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, and shipments of the remaining 5.25" models are forecasted to be phased out during the next few years. After initially dominating the desktop personal computer market, 3.5" drives benefited from the disk drive industry's 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.

3.5" disk drives, in separate desktop and server configurations, have become the dominant drive standards for both desktop personal computer and server

markets. Usually, each year's highest capacity server drives have been packaged in the standard 3.5" drive form factor with 1.625" height, and both desktop and low end server drives have used the 1" high form factor. Until recently, there has been a clear differentiation between the 1" high server drives and the desktop models, with the server drives using 7,200 RPM motors and the desktop drives operating at 5,400 RPM or less. But the separation between low end server and high end desktop drives is now starting to become blurred, as most desktop drive manufacturers introduce IDE interface models operating at 7,200 RPM, and several drive manufacturers start to utilize a single drive design family for both types of drives, differentiated only by separate controller electronics.

An interesting development is the appearance of 3" drives in most of the 10,000 RPM server drives which have appeared in the last year. This technique helps to reduce heat and vibration problems and minimizes power consumption in 10,000 RPM drives, and is becoming a standard in the industry.

A few years ago, it appeared that 3" disks would become widely used in mobile drives designed for notebook computer markets, as an economical method to increase drive capacities while reducing the number of disks which would be required for a given capacity if 2.5" disks were used. However, the 3" surge for this market has disappeared as each of the three drive manufacturers with announced products stopped production for various reasons. Integral Peripherals was the last remaining advocate of 3" drives, but weak sales brought financial problems and bankruptcy. Integral's assets were purchased and a new company named Mobile Storage was formed in 1998 to continue development of drives for the mobile market using 3" disks, so there still may be 3" competition for the 2.5" standard in the mobile drive market.

After a period of intense competitive activity during 1998, the market for removable disk cartridge drives now has only two surviving manufacturers, with current drives in the 1 to 2 gigabyte range. The market available for these drives consists of a wide variety of graphics, prepress and security markets, which have been joined by a range of applications for video and multimedia editing, plus an assortment of personal computer applications. The availability of drives in the CompactFlash card format, expected in 1999, will also open a wide assortment of consumer electronics and other specialized applications to potential growth.

Figure 1

CHANGING PRODUCT MIX
Worldwide Rigid Disk Drive Revenue

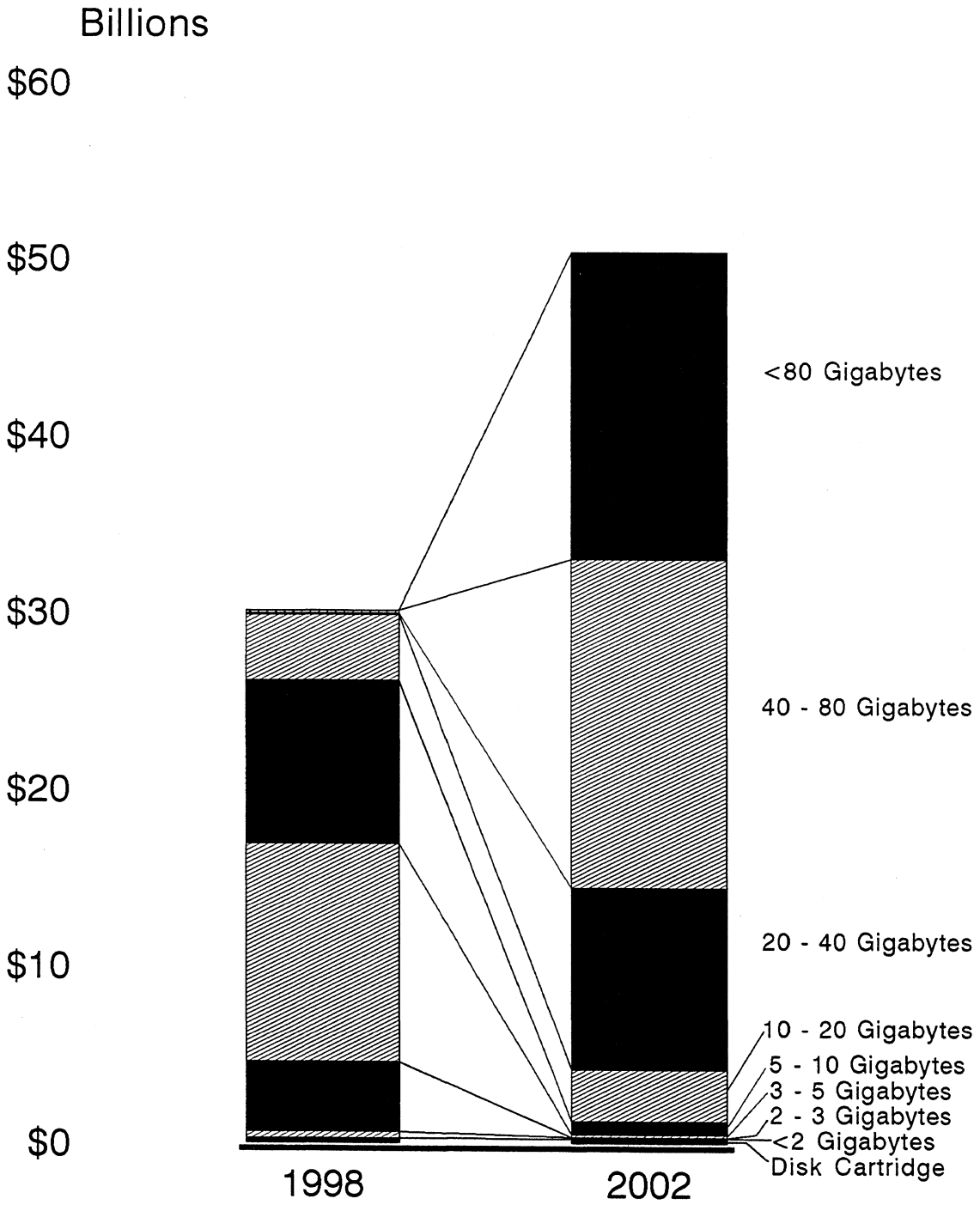


TABLE 3

CONSOLIDATED WORLDWIDE REVENUES
RIGID DISK DRIVES
PRODUCT GROUP REVIEW

REVENUE SUMMARY

WORLDWIDE REVENUES ALL MANUFACTURERS	1998 Revenues $M	 %	Forecast 1999 $M	 %	 2000 $M	 %	 2001 $M	 %	 2002 $M	 %
DISK CARTRIDGE DRIVES	271.1 -21.7%	.9%	180.6 -33.4%	.6%	187.9 +4.0%	.5%	210.5 +12.0%	.5%	242.5 +15.2%	.5%
FIXED DISK DRIVES less than 2 Gigabytes	372.1 -94.8%	1.2%	84.7 -77.2%	.3%	58.1 -31.4%	.2%	80.2 +38.0%	.2%	96.7 +20.6%	.2%
FIXED DISK DRIVES 2 - 3 Gigabytes	3,906.5 -61.4%	13.0%	1,237.2 -68.3%	3.8%	338.6 -72.6%	.9%	106.2 -68.6%	.2%	-- --	--
FIXED DISK DRIVES 3 - 5 Gigabytes	12,339.6 +41.8%	41.0%	6,116.3 -50.4%	18.9%	1,568.5 -74.4%	4.3%	470.0 -70.0%	1.1%	148.6 -68.4%	.3%
FIXED DISK DRIVES 5 - 10 Gigabytes	9,229.5 +86.2%	30.7%	12,149.4 +31.6%	37.5%	7,691.6 -36.7%	21.2%	2,253.4 -70.7%	5.2%	737.5 -67.3%	1.5%
FIXED DISK DRIVES 10 - 20 Gigabytes	3,736.5 --	12.4%	10,604.7 +183.8%	32.7%	14,171.7 +33.6%	39.1%	8,771.1 -38.1%	20.4%	2,926.3 -66.6%	5.8%
FIXED DISK DRIVES 20 - 40 Gigabytes	62.4 -72.6%	.2%	1,757.7 --	5.4%	10,053.5 +472.0%	27.7%	15,968.7 +58.8%	37.2%	10,247.6 -35.8%	20.4%
FIXED DISK DRIVES 40 - 80 Gigabytes	159.1 --	.5%	269.6 +69.5%	.8%	2,044.8 +658.5%	5.6%	11,681.1 +471.3%	27.2%	18,577.2 +59.0%	36.9%
FIXED DISK DRIVES more than 80 Gigabytes	-- --	--	-- --	--	170.2 --	.5%	3,419.0 --	8.0%	17,341.9 +407.2%	34.4%
Total Worldwide Revenue	30,076.8 -5.2%	100.0%	32,400.2 +7.7%	100.0%	36,284.9 +12.0%	100.0%	42,960.2 +18.4%	100.0%	50,318.3 +17.1%	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

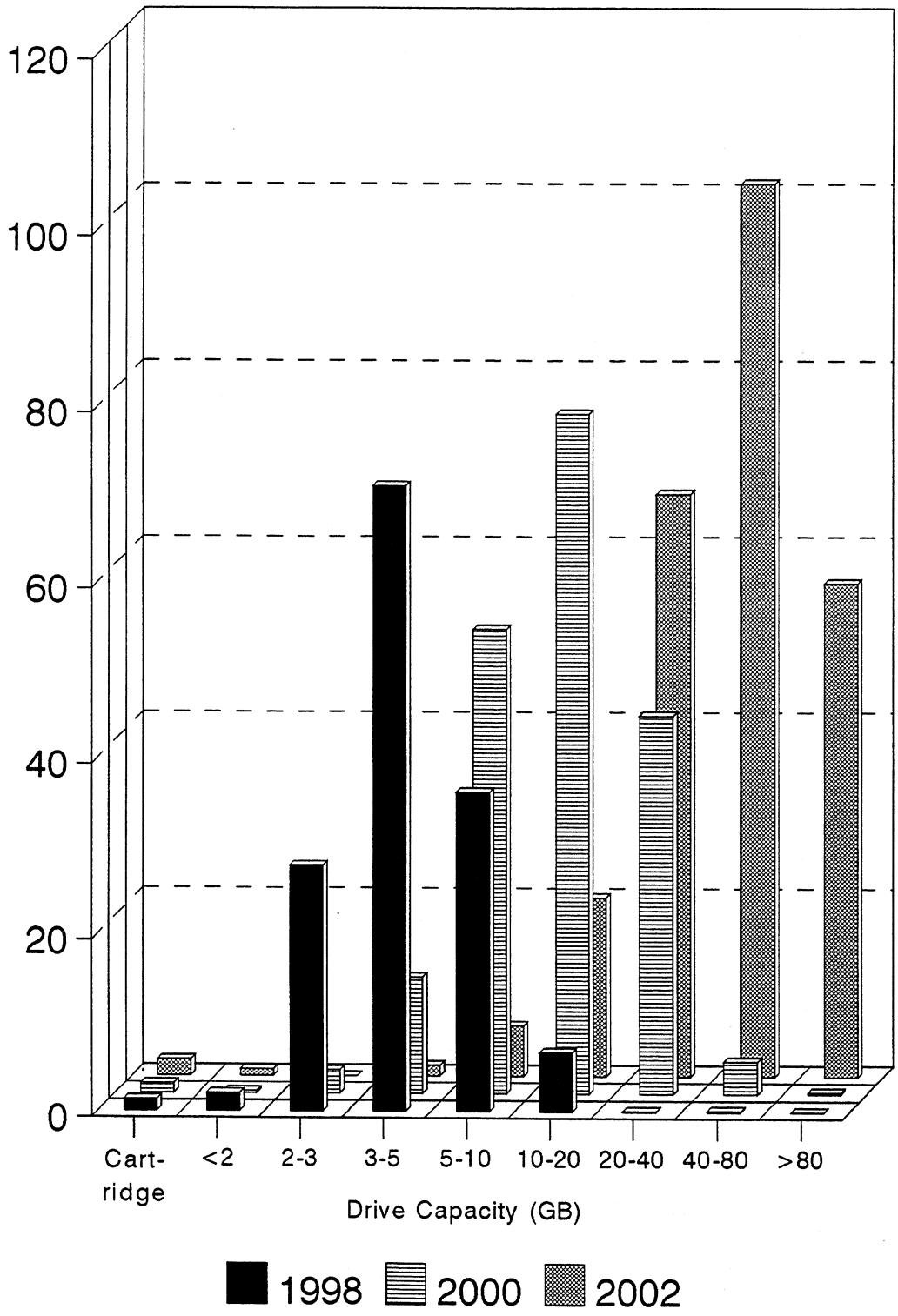


TABLE 4

CONSOLIDATED WORLDWIDE SHIPMENTS
RIGID DISK DRIVES
PRODUCT GROUP REVIEW

UNIT SHIPMENT SUMMARY

UNIT SHIPMENTS IN THOUSANDS	1998 Shipments Units	1998 Shipments %	1999 Units	1999 %	2000 Forecast Units	2000 Forecast %	2001 Forecast Units	2001 Forecast %	2002 Forecast Units	2002 Forecast %
DISK CARTRIDGE DRIVES	1,289.7	.9%	970.0	.6%	1,120.0	.6%	1,410.0	.6%	1,820.0	.7%
	-10.4%		-24.8%		+15.5%		+25.9%		+29.1%	
FIXED DISK DRIVES less than 2 Gigabytes	2,014.1	1.4%	375.5	.2%	250.0	.1%	475.0	.2%	750.0	.3%
	-95.2%		-81.4%		-33.4%		+90.0%		+57.9%	
FIXED DISK DRIVES 2 - 3 Gigabytes	27,730.4	19.1%	8,813.1	5.2%	2,645.0	1.4%	580.0	.3%	--	--
	-44.3%		-68.2%		-70.0%		-78.1%		--	
FIXED DISK DRIVES 3 - 5 Gigabytes	70,968.1	49.0%	48,772.2	29.0%	13,140.0	6.8%	4,225.0	1.9%	1,195.0	.5%
	+143.9%		-31.3%		-73.1%		-67.8%		-71.7%	
FIXED DISK DRIVES 5 - 10 Gigabytes	36,108.7	24.9%	67,033.5	39.8%	52,695.0	27.2%	16,280.0	7.3%	5,685.0	2.2%
	+374.9%		+85.6%		-21.4%		-69.1%		-65.1%	
FIXED DISK DRIVES 10 - 20 Gigabytes	6,688.8	4.6%	39,467.5	23.4%	77,205.0	39.8%	57,600.0	26.0%	20,190.0	8.0%
	--		+490.1%		+95.6%		-25.4%		-64.9%	
FIXED DISK DRIVES 20 - 40 Gigabytes	57.5	--	2,733.0	1.6%	42,830.0	22.1%	88,390.0	39.8%	66,060.0	26.1%
	-62.9%		+4,653.0%		+1,467.1%		+106.4%		-25.3%	
FIXED DISK DRIVES 40 - 80 Gigabytes	109.5	--	189.0	.1%	3,705.0	1.9%	46,970.0	21.2%	101,260.0	40.0%
	--		+72.6%		+1,860.3%		+1,167.8%		+115.6%	
FIXED DISK DRIVES more than 80 Gigabytes	--	--	--	--	230.0	.1%	6,015.0	2.7%	55,970.0	22.1%
	--		--		--		+2,515.2%		+830.5%	
Total Worldwide Shipments	144,966.8	100.0%	168,353.8	100.0%	193,820.0	100.0%	221,945.0	100.0%	252,930.0	100.0%
	+11.1%		+16.1%		+15.1%		+14.5%		+14.0%	
% U.S. Manufacturers	76.5%		74.7%		77.3%		77.1%		76.0%	
Total Capacity (Terabytes)	694,339.5		1,393,435.3		2,888,531.9		7,352,898.6		16,600,653.8	

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

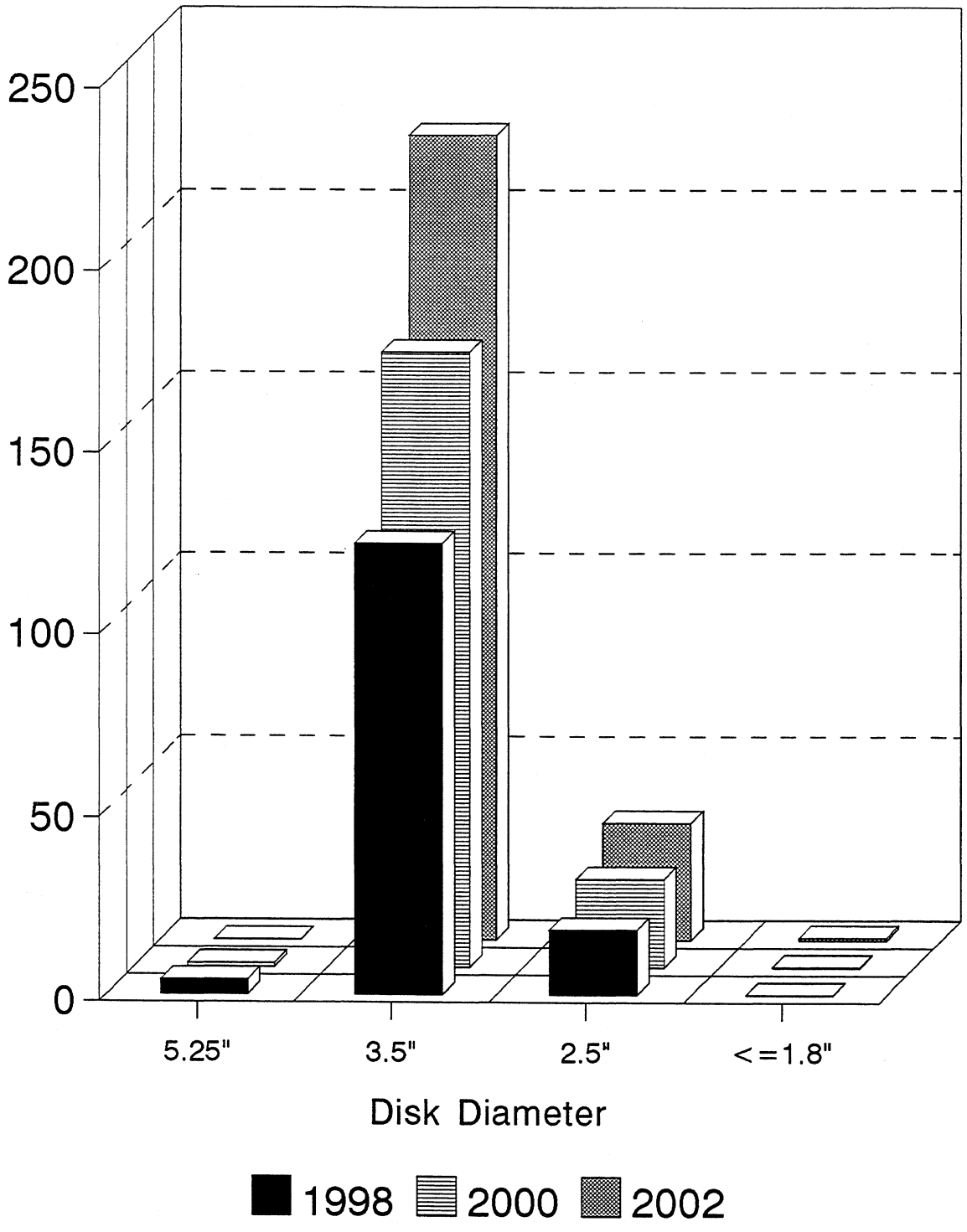


TABLE 5

CONSOLIDATED WORLDWIDE SHIPMENTS
RIGID DISK DRIVES
SUMMARY BY DISK DIAMETER

UNIT SHIPMENTS IN THOUSANDS	1998 Shipments Units	%	1999 Forecast Units	%	2000 Forecast Units	%	2001 Forecast Units	%	2002 Forecast Units	%
5.25 INCH	4,073.9	2.8%	2,175.0	1.3%	1,095.0	.6%	400.0	.2%	--	--
	-27.6%		-46.6%		-49.7%		-63.5%		--	
3.5 INCH	123,047.1	84.9%	145,188.8	86.2%	168,385.0	86.9%	193,330.0	87.1%	220,330.0	87.1%
	+12.2%		+18.0%		+16.0%		+14.8%		+14.0%	
2.5 INCH	17,729.9	12.2%	20,817.0	12.4%	24,090.0	12.4%	27,740.0	12.5%	31,850.0	12.6%
	+18.3%		+17.4%		+15.7%		+15.2%		+14.8%	
<= 1.8 INCH	115.9	.1%	173.0	.1%	250.0	.1%	475.0	.2%	750.0	.3%
	-42.9%		+49.3%		+44.5%		+90.0%		+57.9%	
Total Worldwide Shipments	144,966.8	100.0%	168,353.8	100.0%	193,820.0	100.0%	221,945.0	100.0%	252,930.0	100.0%
	+11.1%		+16.1%		+15.1%		+14.5%		+14.0%	

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

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

2.5 inch totals include mobile platform 3 inch drives.

1.8 inch totals include 1.0 inch drives.

Platform trends

The data in summary Table 6, and in each of the platform summary tables included in the nine individual product groups, provides an overview of the industry's shipments of desktop, mobile and server drives. Please note that 3" disk drives 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 12,000 RPM server drives manufactured by Hitachi have also been combined with 3.5" server drive data.

With reference to worldwide unit shipments, the individual shares held by the desktop, server and mobile platforms are not forecasted to change significantly during the forecast period covered by this report. The product mix within each platform is clearly destined to see changes, however, with the disappearance of 5.25" drives from the server platform group after this year and from the desktop platform group after 2001.

Continuous growth is expected for drives intended for desktop personal computers, by far the industry's largest market, in terms of unit shipments. There are significant changes underway in the desktop drive market, affecting most drive manufacturers. The rapid growth of the very low cost personal computer market has forced drive manufacturers to design ultra low cost drives, and the efforts by manufacturers of midrange and high end PCs to establish product differentiation has stimulated the development of higher capacity and higher performance desktop disk drive families. Both upper and lower ends of the desktop drive product range also have the potential to develop interesting future markets as disk storage requirements for consumer electronic applications start to develop.

2.5" drives are expected to continue to dominate the mobile platform, but the industry will also be watching to see how rapidly the new 1" drives in CompactFlash card formats can develop significant markets. Server drives also appear to have several years of attractive growth, driven by a transition to higher performance, improving price per megabyte, and the growth of applications such as storage area networks.

TABLE 6

CONSOLIDATED WORLDWIDE SHIPMENTS
RIGID DISK DRIVES
SUMMARY BY PLATFORM

UNIT SHIPMENTS IN THOUSANDS	1998 Shipments Units	%	1999 Units	%	2000 Units	%	2001 Units	%	2002 Units	%
MOBILE SYSTEM DRIVES	17,845.8	12.3%	20,990.0	12.4%	24,340.0	12.5%	28,215.0	12.7%	32,600.0	12.8%
	+17.2%		+17.6%		+15.9%		+15.9%		+15.5%	
2.5 INCH	17,729.9		20,817.0		24,090.0		27,740.0		31,850.0	
<=1.8 INCH	115.9		173.0		250.0		475.0		750.0	
DESKTOP SYSTEM DRIVES	108,627.9	74.9%	125,645.7	74.6%	143,780.0	74.1%	163,180.0	73.5%	184,200.0	72.8%
	+9.9%		+15.6%		+14.4%		+13.4%		+12.8%	
5.25 INCH	3,947.1		2,141.0		1,095.0		400.0		--	
3.5 INCH	104,680.8		123,504.7		142,685.0		162,780.0		184,200.0	
SERVER SYSTEM DRIVES	18,493.1	12.7%	21,718.1	12.9%	25,700.0	13.2%	30,550.0	13.7%	36,130.0	14.2%
	+12.1%		+17.4%		+18.3%		+18.8%		+18.2%	
5.25 INCH	126.8		34.0		--		--		--	
3.5 INCH	18,366.3		21,684.1		25,700.0		30,550.0		36,130.0	
Total Shipments	144,966.8	100.0%	168,353.8	100.0%	193,820.0	100.0%	221,945.0	100.0%	252,930.0	100.0%
	+11.0%		+16.1%		+15.1%		+14.5%		+13.9%	

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

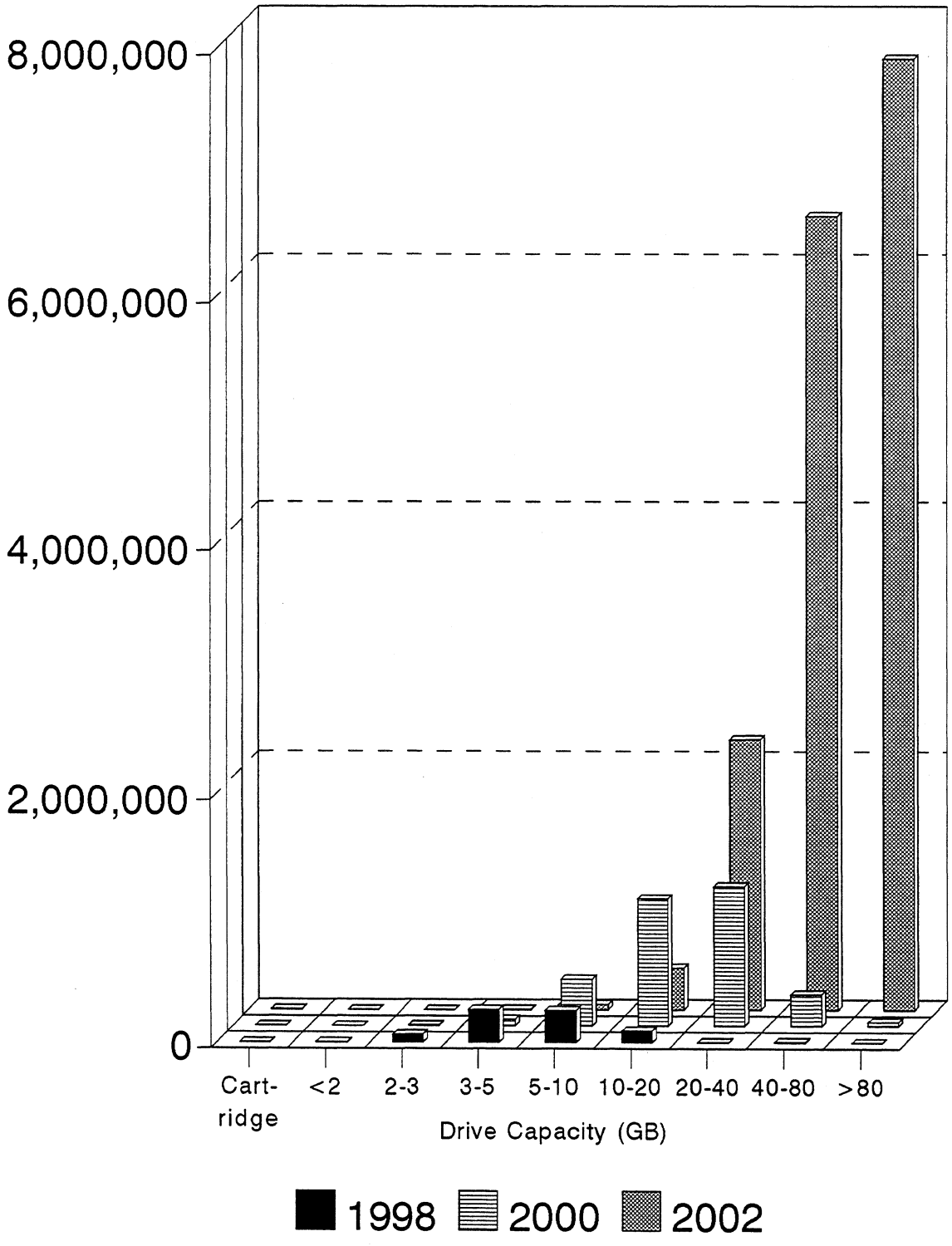


TABLE 7

CONSOLIDATED WORLDWIDE SHIPMENTS
RIGID DISK DRIVES
PRODUCT GROUP REVIEW

CAPACITY SHIPMENT SUMMARY

CAPACITY SHIPMENTS IN TERABYTES	1998 Shipments Tbytes	1998 Shipments %	1999 Forecast Tbytes	1999 Forecast %	2000 Forecast Tbytes	2000 Forecast %	2001 Forecast Tbytes	2001 Forecast %	2002 Forecast Tbytes	2002 Forecast %
DISK CARTRIDGE DRIVES	1,669.8	.2%	1,802.0	.1%	2,016.0	.1%	2,820.0	--	4,550.0	--
	+49.9%		+7.9%		+11.9%		+39.9%		+61.3%	
FIXED DISK DRIVES less than 2 Gigabytes	2,966.4	.4%	373.2	--	130.5	--	273.5	--	586.2	--
	-94.4%		-87.4%		-65.0%		+109.6%		+114.4%	
FIXED DISK DRIVES 2 - 3 Gigabytes	63,293.5	9.1%	19,782.1	1.4%	5,927.4	.2%	1,252.8	--	--	--
	-41.7%		-68.7%		-70.0%		-78.9%		--	
FIXED DISK DRIVES 3 - 5 Gigabytes	267,306.0	38.5%	205,397.0	14.7%	54,701.0	1.9%	17,528.5	.2%	4,859.0	--
	+148.2%		-23.2%		-73.4%		-68.0%		-72.3%	
FIXED DISK DRIVES 5 - 10 Gigabytes	259,863.7	37.4%	511,659.2	36.7%	378,100.0	13.1%	118,959.8	1.6%	42,950.7	.3%
	+334.9%		+96.9%		-26.1%		-68.5%		-63.9%	
FIXED DISK DRIVES 10 - 20 Gigabytes	92,372.8	13.3%	569,904.3	40.9%	1,029,267.0	35.6%	861,198.0	11.7%	336,655.0	2.0%
	--		+517.0%		+80.6%		-16.3%		-60.9%	
FIXED DISK DRIVES 20 - 40 Gigabytes	1,714.5	.2%	73,336.4	5.3%	1,126,439.0	39.0%	2,596,362.0	35.3%	2,162,140.0	13.0%
	-52.7%		--		--		+130.5%		-16.7%	
FIXED DISK DRIVES 40 - 80 Gigabytes	5,152.8	.7%	11,181.1	.8%	258,463.0	8.9%	2,690,452.0	36.6%	6,389,163.0	38.5%
	--		+117.0%		--		+940.9%		+137.5%	
FIXED DISK DRIVES more than 80 Gigabytes	--	--	--	--	33,488.0	1.2%	1,064,052.0	14.5%	7,659,749.9	46.1%
	--		--		--		--		+619.9%	
Total Capacity (Terabytes)	694,339.5		1,393,435.3		2,888,531.9		7,352,898.6		16,600,653.8	
	+105.6%		+100.7%		+107.3%		+154.6%		+125.8%	
% U.S. Manufacturers	81.8%		79.3%		81.2%		82.3%		79.6%	

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

Price per megabyte

The disk drive industry's improvements over the years in price per megabyte have been dramatic, and much more is expected. The major factors underlying the rate of improvement include the upward areal density curve, the lower manufacturing costs made possible by constant refinement and larger quantities, and the continuing growth of the personal computer market. The PC market has caused fundamental changes in the disk drive industry's product mix during the last two decades. The rapid migration to higher disk 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.

In the lower capacity DISK/TREND product groups, the noncaptive price per megabyte annual averages do not decline at rates similar to the higher capacity product groups due to product mix considerations. In the less than 2 gigabyte group, for example, desktop drives, with relatively low prices, will be gone in 2000, leaving only relatively expensive 1.8" and 1" drives -- which will drop in price per megabyte in subsequent years as shipments increase. In the case of the 2-3 and 3-5 gigabyte groups, the price per megabyte figures go up in the forecast periods because of the departure of low price desktop drives, leaving only more expensive 2.5" mobile drives.

Price per megabyte for captive drives also will fall rapidly, as captive drive producers respond to prices in the noncaptive market, holding prices down to stay competitive with other system manufacturers which buy OEM disk drives at low cost. IBM is the largest captive disk drive producer and has aggressively lowered its pricing to stay competitive, as it has moved to newer, smaller, lower cost drives.

Please note that data for desktop, mobile and server drives is combined in the price per megabyte tables, and that the data shown in the tables represents the estimated total sales revenues for each product type divided by the total capacity of all drives of that type.

Figure 5

PRICE PER MEGABYTE SUMMARY

Noncaptive Worldwide Shipments ($/MB)

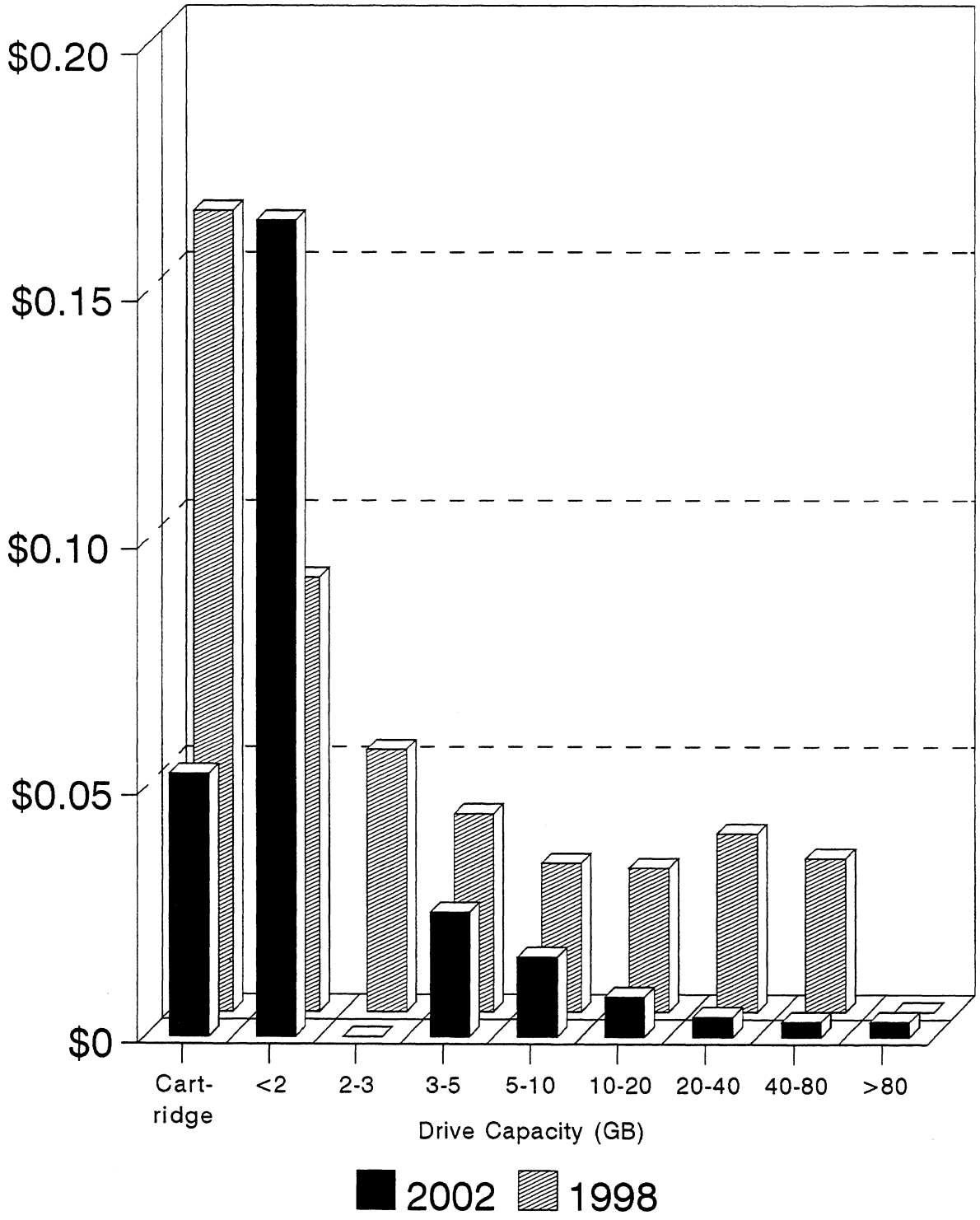


TABLE 8

NONCAPTIVE WORLDWIDE SHIPMENTS
RIGID DISK DRIVES
PRODUCT GROUP REVIEW

PRICE PER MEGABYTE SUMMARY ($/MB)

		Forecast			
	1998	1999	2000	2001	2002
DISK CARTRIDGE DRIVES	.162 -47.7%	.100 -38.3%	.093 -7.0%	.075 -19.9%	.053 -28.6%
FIXED DISK DRIVES less than 2 Gigabytes	.088 -22.4%	.200 +125.9%	.445 +122.7%	.293 -34.1%	.165 -43.7%
FIXED DISK DRIVES 2 - 3 Gigabytes	.053 -34.5%	.043 -18.1%	.041 -5.1%	.056 +36.7%	-- --
FIXED DISK DRIVES 3 - 5 Gigabytes	.040 -43.5%	.026 -35.9%	.025 -3.5%	.023 -6.7%	.025 +9.6%
FIXED DISK DRIVES 5 - 10 Gigabytes	.030 -57.6%	.021 -30.6%	.019 -9.4%	.017 -7.1%	.016 -8.1%
FIXED DISK DRIVES 10 - 20 Gigabytes	.029 -51.9%	.016 -46.1%	.012 -24.7%	.009 -24.2%	.008 -14.6%
FIXED DISK DRIVES 20 - 40 Gigabytes	.037 -40.8%	.019 -49.3%	.008 -59.5%	.005 -28.6%	.004 -24.0%
FIXED DISK DRIVES 40 - 80 Gigabytes	.031 --	.023 -25.7%	.007 -67.3%	.004 -49.0%	.003 -31.4%
FIXED DISK DRIVES more than 80 Gigabytes	-- --	-- --	.005 --	.003 -34.4%	.002 -32.6%

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			
	1998	1999	2000	2001	2002
DISK CARTRIDGE DRIVES	-- --	-- --	-- --	-- --	-- --
FIXED DISK DRIVES less than 2 Gigabytes	.337 -29.8%	.361 +7.0%	-- --	-- --	-- --
FIXED DISK DRIVES 2 - 3 Gigabytes	.200 -25.8%	.178 -10.9%	.128 -28.1%	.118 -8.3%	-- --
FIXED DISK DRIVES 3 - 5 Gigabytes	.145 -25.2%	.106 -26.9%	.086 -18.9%	.081 -5.9%	.081 -.2%
FIXED DISK DRIVES 5 - 10 Gigabytes	.083 -51.8%	.065 -21.7%	.043 -34.1%	.041 -4.0%	.037 -10.6%
FIXED DISK DRIVES 10 - 20 Gigabytes	.085 -43.4%	.054 -37.0%	.041 -23.1%	.028 -32.0%	.025 -12.5%
FIXED DISK DRIVES 20 - 40 Gigabytes	.025 --	.042 +69.0%	.026 -37.7%	.016 -38.1%	.014 -14.2%
FIXED DISK DRIVES 40 - 80 Gigabytes	-- --	.041 --	.015 -64.6%	.011 -23.5%	.007 -36.6%
FIXED DISK DRIVES more than 80 Gigabytes	-- --	-- --	.009 --	.005 -46.8%	.004 -10.8%

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.

Noncaptive market

During recent decades, the disk drive industry's structure has evolved, with a decline in the number of computer system manufacturers which also produce disk drives and an increase in the proportion of the total drives produced by independent manufacturers. 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 it's created healthy growth in the share for noncaptive drives. The growth in overall noncaptive share is expected to continue during the forecast period of this report, with the Distributor portion declining slightly while the OEM segment picks up the growth.

The emergence of the personal computer market for disk drives has enabled independent disk drive manufacturers to quickly exploit technology advances during the last decade which have enabled them to respond with competitive drives for some of the computer industry's fastest growth sectors: Desktop 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". OEM drives in each of these form factors arrived in the market well before captive drives and set the patterns for the entire industry.

The extent of the importance of noncaptive shipments to the disk drive industry is apparent, with noncaptive drives providing 92.7% of the 1998 worldwide shipment total for all disk drives. The 2002 noncaptive share is projected to grow to 93.8% of the total. The noncaptive share of worldwide sales revenues is expected to increase at a slightly faster rate, influenced by changes in both product mix and selling prices, with the noncaptive share of revenues advancing from 76.5% of the 1998 total to 83.7% in 2002.

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	1998 Revenues $M	 %	Forecast 1999 $M	 %	 2000 $M	 %	 2001 $M	 %	 2002 $M	 %
DISK CARTRIDGE DRIVES	271.1 -21.7%	1.2%	180.6 -33.4%	.7%	187.9 +4.0%	.6%	210.5 +12.0%	.6%	242.5 +15.2%	.6%
FIXED DISK DRIVES less than 2 Gigabytes	223.6 -96.1%	1.0%	62.1 -72.2%	.3%	58.1 -6.4%	.2%	80.2 +38.0%	.2%	96.7 +20.6%	.2%
FIXED DISK DRIVES 2 - 3 Gigabytes	3,147.5 -61.6%	13.7%	734.8 -76.7%	2.8%	198.7 -73.0%	.7%	37.6 -81.1%	.1%	-- --	--
FIXED DISK DRIVES 3 - 5 Gigabytes	10,107.3 +43.6%	44.0%	5,019.9 -50.3%	19.9%	1,273.5 -74.6%	4.3%	380.8 -70.1%	1.1%	111.9 -70.6%	.3%
FIXED DISK DRIVES 5 - 10 Gigabytes	6,844.7 +87.9%	29.8%	9,759.7 +42.6%	38.3%	6,534.0 -33.1%	22.0%	1,915.3 -70.7%	5.3%	641.0 -66.5%	1.5%
FIXED DISK DRIVES 10 - 20 Gigabytes	2,182.2 +917.3%	9.4%	8,393.8 +284.6%	33.0%	11,538.4 +37.5%	38.8%	7,345.9 -36.3%	20.7%	2,458.8 -66.5%	5.8%
FIXED DISK DRIVES 20 - 40 Gigabytes	59.7 -73.8%	.3%	1,069.8 --	4.2%	7,991.2 +647.0%	26.9%	13,223.6 +65.5%	37.0%	8,398.4 -36.5%	20.1%
FIXED DISK DRIVES 40 - 80 Gigabytes	159.1 --	.6%	239.8 +50.7%	.8%	1,820.0 +659.0%	6.1%	9,549.1 +424.7%	26.7%	15,650.6 +63.9%	37.2%
FIXED DISK DRIVES more than 80 Gigabytes	-- --	--	-- --	--	143.0 --	.4%	3,014.2 --	8.3%	14,502.7 +381.1%	34.3%
Total Worldwide Revenues	22,995.2 -9.5%		25,460.5 +10.7%		29,744.8 +16.8%		35,757.2 +20.2%		42,102.6 +17.7%	

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	1998 Shipments Units	1998 Shipments %	1999 Units	1999 %	2000 Units	2000 %	2001 Units	2001 %	2002 Units	2002 %
DISK CARTRIDGE DRIVES	1,289.7 -10.4%	1.0%	970.0 -24.8%	.6%	1,120.0 +15.5%	.6%	1,410.0 +25.9%	.7%	1,820.0 +29.1%	.8%
FIXED DISK DRIVES less than 2 Gigabytes	1,694.2 -95.7%	1.2%	324.7 -80.8%	.2%	250.0 -23.0%	.2%	475.0 +90.0%	.2%	750.0 +57.9%	.3%
FIXED DISK DRIVES 2 - 3 Gigabytes	25,999.8 -44.2%	19.5%	7,516.5 -71.1%	4.8%	2,140.0 -71.5%	1.1%	310.0 -85.5%	.2%	-- --	--
FIXED DISK DRIVES 3 - 5 Gigabytes	66,972.5 +148.9%	49.8%	46,286.2 -30.9%	29.6%	12,280.0 -73.5%	6.8%	3,945.0 -67.9%	1.8%	1,075.0 -72.8%	.4%
FIXED DISK DRIVES 5 - 10 Gigabytes	32,644.8 +387.4%	24.3%	62,534.5 +91.6%	39.9%	49,055.0 -21.6%	27.1%	15,150.0 -69.1%	7.3%	5,330.0 -64.8%	2.3%
FIXED DISK DRIVES 10 - 20 Gigabytes	5,600.3 --	4.2%	36,950.0 +559.8%	23.5%	73,065.0 +97.7%	40.1%	54,475.0 -25.4%	26.3%	19,080.0 -65.0%	8.0%
FIXED DISK DRIVES 20 - 40 Gigabytes	52.5 -66.1%	--	2,148.0 --	1.4%	40,255.0 --	22.2%	82,990.0 +106.2%	39.8%	62,015.0 -25.3%	26.3%
FIXED DISK DRIVES 40 - 80 Gigabytes	109.5 --	--	179.0 +63.5%	--	3,475.0 --	1.9%	43,995.0 --	21.1%	94,800.0 +115.5%	40.0%
FIXED DISK DRIVES more than 80 Gigabytes	-- --	--	-- --	--	210.0 --	--	5,620.0 --	2.6%	52,255.0 +829.8%	21.9%
Total Worldwide Shipments	134,363.3 +10.5%		156,908.9 +16.8%		181,850.0 +15.9%		208,370.0 +14.6%		237,125.0 +13.8%	
% U.S. Manufacturers	77.7%		75.2%		77.5%		77.0%		75.6%	
Total Capacity (Terabytes)	627,535.9		1,284,828.2		2,694,854.2		6,846,778.8		15,386,572.4	

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

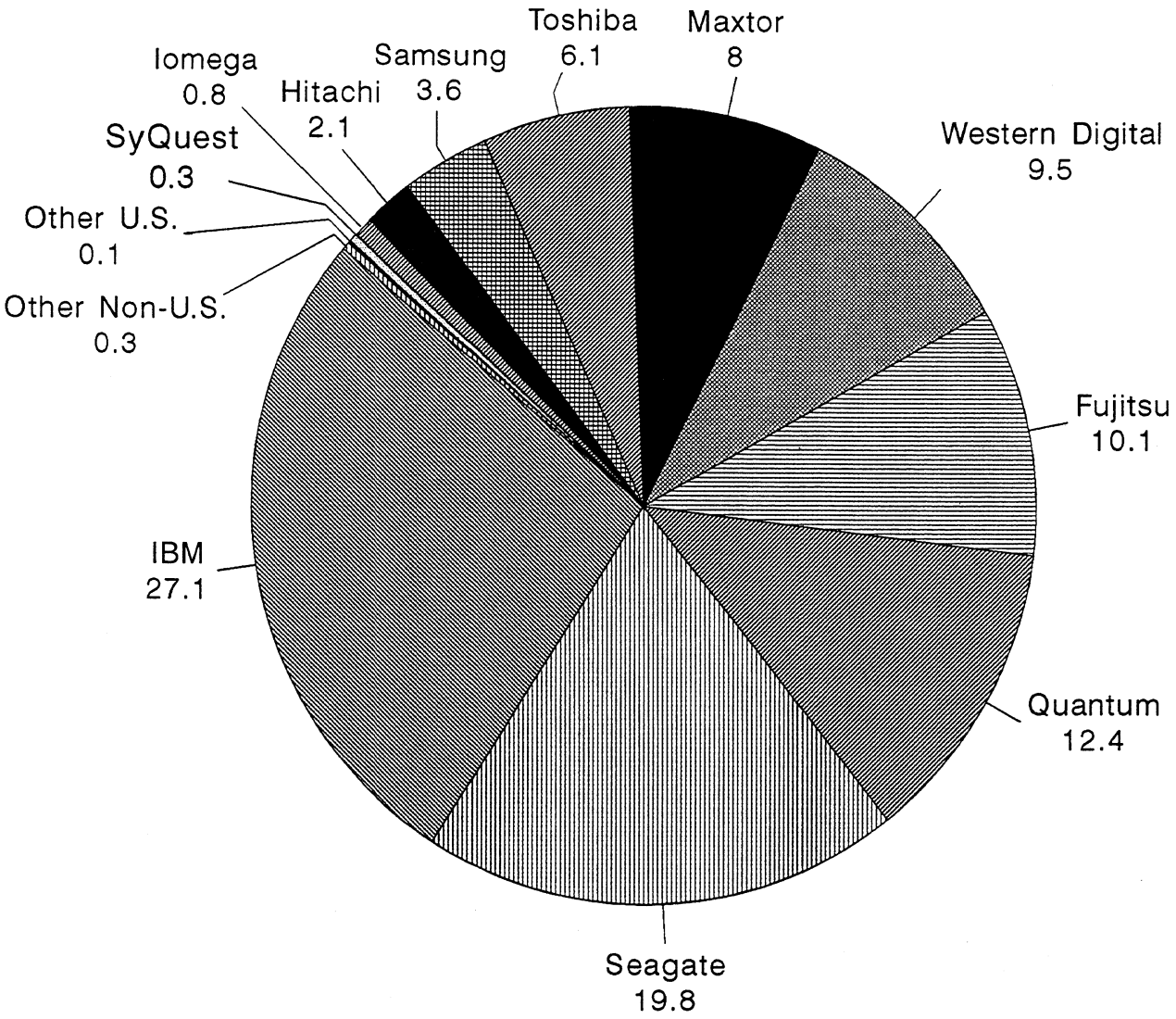
CAPACITY SHIPPED IN TERABYTES	1998 Capacity Tbytes	1998 Capacity %	1999 Tbytes	1999 %	2000 Tbytes	2000 %	Forecast 2001 Tbytes	Forecast 2001 %	Forecast 2002 Tbytes	Forecast 2002 %
DISK CARTRIDGE DRIVES	1,669.8	.3%	1,802.0	.1%	2,016.0	.1%	2,820.0	--	4,550.0	--
	+49.9%		+7.9%		+11.9%		+39.9%		+61.3%	
FIXED DISK DRIVES less than 2 Gigabytes	2,526.1	.4%	310.6	.1%	130.5	--	273.5	--	586.2	--
	-95.0%		-87.7%		-58.0%		+109.6%		+114.4%	
FIXED DISK DRIVES 2 - 3 Gigabytes	59,503.4	9.5%	16,967.3	1.3%	4,836.6	.2%	669.6	.1%	--	--
	-41.4%		-71.5%		-71.5%		-86.2%		--	
FIXED DISK DRIVES 3 - 5 Gigabytes	251,870.5	40.2%	195,028.5	15.3%	51,260.0	1.9%	16,422.5	.2%	4,403.0	.1%
	+154.2%		-22.6%		-73.7%		-68.0%		-73.2%	
FIXED DISK DRIVES 5 - 10 Gigabytes	231,066.7	36.8%	474,791.3	36.9%	351,002.1	13.1%	110,717.2	1.6%	40,318.2	.2%
	+343.4%		+105.5%		-26.1%		-68.5%		-63.6%	
FIXED DISK DRIVES 10 - 20 Gigabytes	74,142.1	11.8%	528,725.0	41.2%	965,459.0	35.8%	810,398.0	11.9%	317,603.0	2.1%
	--		+613.1%		+82.6%		-16.1%		-60.8%	
FIXED DISK DRIVES 20 - 40 Gigabytes	1,604.5	.3%	56,750.4	4.4%	1,046,604.0	38.8%	2,424,670.0	35.5%	2,027,284.0	13.3%
	-55.8%		--		--		+131.7%		-16.4%	
FIXED DISK DRIVES 40 - 80 Gigabytes	5,152.8	.7%	10,453.1	.7%	242,970.0	9.1%	2,498,256.0	36.4%	5,973,033.0	38.8%
	--		+102.9%		--		+928.2%		+139.1%	
FIXED DISK DRIVES more than 80 Gigabytes	--	--	--	--	30,576.0	1.0%	982,552.0	14.3%	7,018,795.0	45.5%
	--		--		--		--		+614.3%	
Total Capacity (Terabytes)	627,535.9		1,284,828.2		2,694,854.2		6,846,778.8		15,386,572.4	
	+101.5%		+104.7%		+109.7%		+154.1%		+124.7%	
% U.S. Manufacturers	81.9%		79.1%		81.0%		82.0%		79.0%	

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

Figure 6

1998 ESTIMATED MARKET SHARE

Worldwide Percentage Revenues



1998 Revenues: $30,075,700,000

TABLE 13

1998 ESTIMATED MARKET SHARES

WORLDWIDE REVENUES OF ALL RIGID MAGNETIC DISK DRIVES
(Value of non-U.S. currencies estimated at average 1998 rates)

	CAPTIVE		DISTRIBUTOR		OEM/INTEGRATOR		TOTAL INDUSTRY	
	$M	%	$M	%	$M	%	$M	%
U.S. MANUFACTURERS								
IBM	5,019.7	70.9	751.4	9.6	2,390.8	15.8	8,161.9	27.1
Iomega	--	--	150.0	1.9	25.9	.2	175.9	.6
Maxtor	--	--	531.8	6.8	1,876.4	12.4	2,408.2	8.0
Quantum	--	--	1,530.8	19.5	2,186.4	14.4	3,717.2	12.4
Seagate Technology	--	--	2,042.6	26.0	3,900.3	25.8	5,942.9	19.8
SyQuest	--	--	86.1	1.1	1.2	--	87.3	.3
Western Digital	--	--	1,362.8	17.3	1,509.1	10.0	2,871.9	9.5
Other U.S.	.2	--	40.3	.5	4.6	--	45.1	.1
U.S. Total	5,019.9	70.9	6,495.8	82.7	11,894.7	78.6	23,410.4	77.8
NON-U.S. MANUFACTURERS								
Fujitsu	449.4	6.3	696.0	8.9	1,876.5	12.4	3,021.9	10.1
Hitachi	129.6	1.8	5.2	.1	494.6	3.2	629.4	2.1
Samsung Electronics	138.7	2.0	588.7	7.5	350.4	2.3	1,077.8	3.6
Toshiba	1,296.1	18.3	43.4	.5	509.2	3.4	1,848.7	6.1
Other Non-U.S.	47.9	.7	26.7	.3	12.9	.1	87.5	.3
Non-U.S. Total	2,061.7	29.1	1,360.0	17.3	3,243.6	21.4	6,665.3	22.2
WORLDWIDE TOTAL	7,081.6	100.0	7,855.8	100.0	15,138.3	100.0	30,075.7	100.0

Note: 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 = 1" C = Captive
1.8 = 1.8" D = Distributor
2 = 2.5" O = OEM
3 = 3.5"
5 = 5.25"

TABLE 14

CURRENT PRODUCT LINES
MANUFACTURERS OF RIGID MAGNETIC DISK DRIVES

U.S. Manufacturers (13)	DISK/TREND PRODUCT GROUP Type	1 Disk Cartridge Drives	2 Fixed Disk Drives <2 GB	3 Fixed Disk Drives 2 GB-3 GB	4 Fixed Disk Drives 3 GB-5 GB	5 Fixed Disk Drives 5 GB-10 GB	6 Fixed Disk Drives 10 GB-20 GB	7 Fixed Disk Drives 20 GB-40 GB	8 Fixed Disk Drives 40 GB-80 GB	9 Fixed Disk Drives >80 GB
Belfort Memory International	D,O				5	5				
Castlewood Systems	D,O	3								
Conner Technology	D,O				3	3				
IBM	C,D,O		1	2,3	2,3	2,3	2,3	3		
Iomega	D,O	3								
Halo Data Devices	D,O		1							
Maxtor	D,O				3	3	3	3		
Quantum	D,O			3	3	3,5	3,5	3		
PCS, Inc.	O		1,8							
Raymond Engineering	O		3							
Seagate Technology	D,O				3	3	3	3	3	
SyQuest Technology	D,O	3,5								
Western Digital	D,O				3	3	3	3		
Asian Manufacturers (5)										
Fujitsu	C,D,O		2,3	2,3	2,3	2,3	2,3	3		
Hitachi	C,D,O			2	2,3	2,3	2,3	3		
NEC	C			3	3	3	3			
Samsung Electronics	C,D,O				3	3	3	3		
Toshiba	C,D,O		2	2	2	2	2			
European Manufacturers (1)										
Calluna Technology	D,O		1,8							

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 industry's drive towards ever-higher areal density and ever-lower price per gigabyte continues, again confirming rigid disk drives in their position as the leading storage technology. Serious competition from hybrid optical and rigid disk drive designs has not yet developed, and the continuing rapid increases in areal density and performance simply continue to reinforce the nearly impregnable position of the rigid magnetic disk drive industry against all challengers. Ongoing improvements in rigid disk drive performance further add to the problems facing any competing storage technology. Except in a few niche applications, rigid disk drives reign securely as 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. Although the annual rate of areal density increase dipped to 45% at mid-decade as manufacturers focussed upon mechanical issues, it has surpassed the 60% average since 1997. It appears likely that areal densities will continue to improve at a 60% or more annual average rate through 2002, the end of this report's forecast period.

With increasing areal density have come tougher challenges to designers trying to increase drive performance, leading to the appearance of drive families optimized for either maximum aerial density or maximum performance, but not both simultaneously.

Disk drive designs must evolve as increasing areal densities invoke the superparamagnetic effect (somewhere between 20 and 100 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 is expected to cause intractable stability problems that require the disk drive industry to switch from longitudinal recording to perpendicular recording and new forms of media (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 well above 100 gigabits per square inch.

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 that 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 continuous 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 3.2 gigabytes in a full height 5.25" disk drive form factor and up to 1.6 gigabytes 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 has been a major factor in promoting the acceptance of plug-in semiconductor memory as a disk drive alternative. In addition, 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 interchangeable.

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 672 megabytes are packaged to fit within the physical envelope of the 2.5" disk drive and over 220 megabytes in a 1.8" format.

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 64 megabit configurations, which are now the largest production capacity category.

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 that 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 128 megabit chips are currently in production, manufactured by Intel, AMD, SanDisk, Samsung, Atmel, Seeq Technology, Toshiba and other firms. Most flash memory cards have capacities under 10 megabytes, but average capacities are increasing rapidly as flash card-using

digital cameras with megapixel resolutions enter the market. Digital cameras are also creating pressure for improved write performance, even at the expense of cost. Digital audio players now incorporate flash cards with 32 megabytes of capacity.

Flash disk cards, some with capacities in excess of 440 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.

1999 flash memory OEM prices have declined to the range of 2 to10 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. Sub-microsecond 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 ranging from 4 to 256 kilobits. The chips are being sold for a variety of applications, including electronic games and smart cards. Chips up to 16 megabits are planned for future years.

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.

Yet another contender, magnetic RAM (MRAM), is under development. In this form of non-volatile storage semiconductor storage, data is retained on very small magnetic films deposited in cells on the chip. Several design approaches are being investigated, including a modified spin valve design employing giant magnetoresistance (GMR), a switched Hall effect cell, and a tunnel junction approach (tunnel magnetoresistance, or TMR), currently being researched at IBM and in Japan. Products are not expected soon, as the devices require manufacturing of extremely thin films, fabrication temperatures that degrade device stability, or cell densities that generate too much heat in operation. But the capability of magnetic RAM to achieve high bit density, high speed, and infinite rewritability make this class of device likely to inspire continuing development efforts. In addition to IBM, Motorola, Honeywell, Hewlett-Packard, Toshiba and several other companies are pursuing magnetic RAM development.

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 only the reference beam, 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, including DEC, NCR, Eastman Kodak, General Dynamics and E-Systems. 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. MCC demonstrated working prototypes of write-once holographic memories in 1992 and established a subsidiary corporation, Tamarack Storage Devices, to commercialize the technology.

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 supported 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 den-

sity is under 50 megabytes per cubic centimeter, but the target is storage media with 10 gigabytes per cubic centimeter capability.

Among the organizations participating in the HDSS consortium are IBM, Siros (previously named 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, Siros, 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 after 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. Siros is currently concentrating its efforts on a disk format capable of recording on multiple layers using holographic principles for layer and bit addressing.

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 96,000 bits per inch or more, optical disk drives don't match the higher areal densities magnetic disk drives now provide. Not yet announced magnetic disk drives exceeding 7 gigabits per square inch areal density are expected to expand the gap. Also, 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, Maxoptix and other firms developing very high capacity magneto-optic drives introduce expected products in 1999 and thereafter. 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 im-

mersion 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. Much of this work and its follow-on efforts are being made available to Siros Technology through its strategic alliance with Lucent Technologies. Siros anticipates achieving areal density as high as 200 gigabits per square inch using near field recording techniques.

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 3.5" magneto-optical drives, offering better performance, lower price and higher capacity. Magnetic disk cartridge products such as the 2 gigabyte Iomega "Jaz" compare well against 3.5" optical drives. The 4.7 gigabyte removable disk cartridge drive expected from Castlewood will put further pressure on optical drives if successful. In the short term, 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. The 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 will eventually 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 that 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 Maxoptix 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 Sony has announced future availability of 9.1 gigabyte 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 1999 time frame and after, including anticipated MO drives using 120 millimeter media.

3.5" drives now offer over 1.3 gigabytes per surface, and are expected to move beyond the 1.3 gigabyte per surface mark after 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 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. While unlikely to displace

rigid disk drives because of limitations in performance and reliability, they have largely displaced write-once CD-R drives and PD drives.

DVD writable drives, while offering capacity up to 4.7 gigabytes, are too slow to seriously challenge rigid disk drives and too expensive to challenge CD-RW drives. Disputes over formats and some incompatibilities with DVD-ROM drives limit their appeal.

Individual firms working on other proposed reversible optical recording technologies have yet to overcome technical problems. These 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 50X, 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 1999 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 the 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 and 250 megabyte "Zip" drives, and this technology is potentially extendible beyond 250 megabytes.

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 Mitsubishi Electric. Like the 20 megabyte version, these drives are backward compatible with 1.44 megabyte floppy disks. 130 megabyte floppy drives, also backward compatible, expected from Swan Instruments and Mitsumi Electric, were not placed in volume production. Caleb Technology and Samsung Electro-Mechanics also currently have high capacity floppy drive development programs, but neither has yet placed a product into volume production. Sony's 200 megabyte floppy, also backward compatible with the 1.44 MB floppy, may challenge all of the high density floppy drives currently announced once production problems are resolved.

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 standard 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 22 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

Continuous and rapid improvement in product technology has been the hallmark of the magnetic disk drive industry throughout its 43 year history. Disk drive product development leadership, maintained by IBM until the late 1970s, was captured 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 ever since.

IBM's capability to implement major advances in magnetic disk recording technology has sustained the company's leading position in the industry, and has also provided a technology role model for competitors. During the 1990's, most of the industry followed IBM's early transition to magneto-resistive heads (which

IBM first utilized in production drives in 1991) and PRML encoding. These and other refinements have enabled IBM's average annual improvement in areal density to exceed 60%. Other manufacturers followed as closely behind as possible, but have been restrained 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. Hitachi subsequently regained leadership with 6.3 gigabit per square inch drive shipments. With IBM's shipment of the first drives using giant magnetoresistive heads in early 1998, competitors are racing to secure availability of GMR heads and implement the next wave of areal density advances. Seagate has demonstrated 16.3 gigabits per square inch in the laboratory, but IBM remains the areal density leader in the laboratory, having announced recording at over 20 gigabits per square inch in May, 1999.

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

Areal density: Areal density has increased more 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. 3 gigabits per square inch was attained in 1997, followed by drives exhibiting 4.1 gigabits per square inch in early 1998. Areal density exceeded 5.69 gigabits per square inch by year end, and drives with 6.3 gigabits per square inch became available in early 1999. 30-40 gigabits per square inch is expected before the end of 2002.

TPI in excess of 8,000 is common and some of the newest small drives operate at or over 19,000 TPI. IBM's "Biscayne" 2.5" drive operates at 19,900 TPI, while the 3.5" "Janus" operates at 16,000 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. 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, and was exceeded slightly by

Hitachi at 165,000 BPI. IBM's new 2.5" "Biscayne" operates at 286,100 BPI, a slight increase from the previous generation, while Hitachi is shipping a drive with 323,000 BPI, suggesting that TPI is growing faster than BPI, at least for the present. Many of today's small drives operate with bit densities above 200,000 BPI, and an increasing number have BPI in excess of 240,000 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.

Seagate laboratory demonstrations have shown TPI as high as 43,000 with BPI of 380,000, or 16.3 gigabits per square inch, while Read-Rite claimed 400,000 BPI in a 1998 lab demo. IBM's 1999 announcement claimed 490,000 BPI and 41,400 TPI.

Limits to areal density: Today's conventional magnetic 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 inter-domain interference until it reaches the superparamagnetic limit (described by various authorities as somewhere between 20 to 100 gigabits per square inch), at which time further increases in longitudinal recording density are not possible.

Theoretically, recording heads and media could support higher linear densities 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. Using a bit cell geometry that is more nearly symmetrical, 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. However, 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 is one of the major factors that determines the achievable areal density, reductions are of critical importance. Head flying height is in the two microinch range for an increasing number of drives, and several firms are designing drives in which there is no measurable flying height. Laboratory demonstrations of advanced recording techniques have shown flying heights in the half microinch range.

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 was normally in contact with the disk. While wear did occur, the rate of wear of the critical parts of the head was low enough to permit head lifetimes to exceed expected drive lifetimes. The head area and loading was small enough to control stiction effects, and the in-contact thin film head was 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 inductive thin film, magnetoresistive, and 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 were 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" magneto-resistance, (GMR), also known as spin valve heads, is well under way as areal density approaches 10 gigabits per square inch. Some head suppliers are expected to shift entirely to GMR head production in 1999.

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) was 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 head overcoat, first employed by IBM, is now used by other manufacturers to improve head life and to reduce stiction.

Head suspensions have become a challenging design area as slider form factors continue to shrink and magnetoresistive heads, which require more wires, have 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 and GMR heads are now available from multiple vendors, with many also produced by drive manufacturers such as IBM, MKE, 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 more disk drive manufacturers introduced drives with MR heads in 1994, and others have since 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. IBM's laboratory demonstration of recording at 11.6 gigabits per square inch has been upstaged by Seagate, which used GMR heads to demonstrate 16.3 gigabits per square inch in the laboratory. The flying height was 0.6 microinches.

There appear to be several possible methods of constructing multilayer heads that exhibit 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. The first drives with GMR heads, introduced by IBM, appeared 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 microinches. 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 destined to be replaced by finer geometric patterns that minimize interference with low flying heads.

Some drives (typically used in mobile systems, and some high RPM server drives) use ramp loaded heads to avoid the need for textured surfaces. Ramp loading also permits a faster disk spinup, with less power, due to the absence of heads 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, if used, 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 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 toward the 10 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 areal density increases cause the superparamagnetic effect to become a significant factor.

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. Glass disks are also starting to appear in some of the newer 3" 10,000 RPM server drives (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. They also 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. 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 substrates still cost more than aluminum substrates and industry production capacity is limited at present. With IBM's 1999 announcement of drives using ramp loaded heads and glass media for server class drives, aluminum is being challenged as the substrate of choice for 3.0" media. But 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.

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 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 3.5" 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. Designers are expected to adopt 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 eventually appear, as companies begin acquiring manufacturing experience with the technique. Suspension mounted micro-actuators 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 inductance/capacitance/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 used peak detection during the 1980s and had bandwidths under 100 megabits per second, most current drives employ PRML (Probable Response, Maximum Likelihood) channels and have moved past 100 megahertz in read channel bandwidth. 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 read-back 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. 3" drives for use in notebook computers were briefly in production during the last 2 years, before being withdrawn for various reasons. They were expected by many notebook producers to be a good compromise between size, capacity and power drain. 2.5" drives are already available in the 6.5 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 and the 5 millimeter Type II height requirements are in production, although their limited capacity and higher price per megabyte has confined them to a narrow market niche. Calluna introduced the Type II drive in 1999.

The 340 megabyte, 1" diameter IBM microfile, which was formally unveiled (but unpriced) in 1998, is the current hands down winner for disk drive miniaturization. Future advances in areal density are expected to evolve this design to gigabyte capacities within a few years. IBM expects it to be employed in various types of mobile electronic systems.

Despite the move to smaller form factors, 5.25" drives are not quite dead yet. In 1995 Belfort Memory International announced a single platter 1.1 gigabyte 5.25" drive, followed by Quantum's announcement of "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). These drives take advantage of minimal parts count and the larger surface area of the disk to

obtain a lower cost per megabyte. These drives were shipped in significant numbers, but interest in them is winding down as 3.5" drives with 1 or 2 disks begin to overtake them in capacity.

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 many drive designs, a major effort is made to reduce chip count to the practical minimum in order to reduce manufacturing cost.

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 adapter. 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 in volume production, and Ultra 2 SCSI (LVDS) drives are also shipping in quantity. The 160 megabyte per second Ultra 3 SCSI drives are expected to ship in significant quantities beginning in 2000, delayed by the market's need to first absorb the Ultra 2 SCSI technology. Beyond Ultra 3, plans for defining Ultra 4 (320 megabytes per second) and Ultra 5 (640 megabytes per second) versions of SCSI are being put in place.

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. It provides 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 initiated.

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.

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. They 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 serial interface used will be chosen 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 manufacturers, and an increasing amount of support from chip and controller producers has materialized. FC-AL drives have now been announced by Seagate, Quantum, Hitachi, IBM, Western Digital and Fujitsu, and are desired by many integrators of storage 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 1999, acceptance is broadening, and

competition should lower prices. 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 was little chip support for P1394 until interface chips became available from Symbios (now LSI Logic) 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 interface 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 the buffer's 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, has become more widely used. It is now well understood by the rest of the industry and appropriate chips are 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 proposed (but generally rejected) SPX design, which interfaced to CD-ROM drives and provided 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.

Other functions to be incorporated now or in the future include status reporting, on-line configuration, firmware updates, and, possibly, the incorporation of network attachment capabilities.

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 controlling 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 subsystems, it can provide fault tolerance, very high data transfer rates, or 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 rapidly, 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 that specific 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 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 that resell them as part of complete computer systems. Also includes sales to system integrators that 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 1999 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 applications.

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 uses such as video set-top boxes, intelligent fax machines, copiers, scanners, intelligent personal communication devices, automotive navigation systems, digital cameras, factory data collection equipment, etc.

DISK CARTRIDGE DRIVES

1999 DISK/TREND REPORT

DISK CARTRIDGE DRIVES

Coverage

Examples of disk drives in this group include:

3.5" disk diameter

Castlewood Systems	ORB2
Iomega	Jaz 1, Jaz 2

The range of disk drives available in this product group, which includes all types of disk drives using removable media in the form of rigid disk cartridges, has seen major changes in the last year. Until 1995, 5.25" disk drives provided the majority of shipments in the disk cartridge drive product group. However, SyQuest's 3.5" drives became available in 1992, 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, followed in the first quarter of 1998 by Iomega's Jaz 2, with 2 gigabytes.

Competitors in the rigid disk cartridge field have struggled to find the optimum product type for the market. Iomega's products introduced to date have used two 3.5" disks in each cartridge, in an attempt to offer the highest available capacities, despite the additional cost of using a second disk. SyQuest attempted to capture market share with the 3.5" SparQ 1 gigabyte single disk cartridge drive, designed for low manufacturing cost. Castlewood Systems has also used a single 3.5" disk in the 2 gigabyte ORB2, with shipments initiated in the first quarter of 1999. The Avatar 2.5" disk cartridge drives, in a series of models with various capacities up to 250 megabytes, were first shipped in 1993, with volume production at the company's Thailand plant. Demand for the Avatar 2.5" drives never reached the expected levels, and Avatar ceased operations in 1998.

Market status

1998 was a year of significant changes in the rigid disk cartridge drive business. By the end of the year, the most aggressive advertising and sales promotion campaigns in the history of disk cartridge drives had been undertaken, all manufacturers produced sales at disappointing levels, and three companies were no longer making drives. 1998 worldwide unit shipments were down 10.3% from the previous year, at 1,289,700 drives, and the DISK/TREND forecast for 1999 shipments is down another 24.7%, at 970,000 units. 1998 sales revenues for the product group were $271.1 million, a decline of 21.7%, with 1999 projected at $180.6, a drop of 33.4%.

The product group's major casualty in 1998 was SyQuest, which stopped operations in early November, followed by Chapter 11 bankruptcy. SyQuest's turnaround management initiated production of the company's 1 gigabyte SparQ in late 1997, and emphasized increasing production, intense market development programs and aggressive pricing during 1998. The firm shipped 530.7 thousand drives during 1998, but sales at that level, combined with low prices and high sales and promotion expenses, proved to be a losing business. During the bankruptcy proceedings, Iomega arranged to purchase all of SyQuest's intellectual property, U.S. fixed assets and inventory for $9.1 million. The remaining service and warranty business, and some limited sales activity, is continuing under the name SYQT, Inc. It is expected that Iomega will probably license a company specializing in disk drive service and limited production programs to manufacture current SyQuest drive models to satisfy existing demand.

Since its founding in 1991, Avatar had gradually increased the capacity of its 2.5" disk cartridge drive from the initial 85 megabytes to 250 megabytes, while searching for a market of significant size. After shipping almost 200,000 drives in 1997, Avatar's attempt to develop a distribution market had apparently peaked, with declining sales in 1998. The company ceased operations at midyear. The French firm Nomai S.A. also left the disk drive manufacturing field during 1998. Nomai entered the disk cartridge drive field in late 1995, after making disk cartridge media products for several years, with drive production in the U.K. on a contract basis by Xyratex. Nomai attracted lawsuits in several countries by

Iomega by offering a Zip compatible floppy disk cartridge, a problem which Iomega solved by buying control of Nomai in mid-1998 for $42 million. One of the results of that purchase was the withdrawal of Nomai's rigid disk cartridge drives from the market.

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 were only 3,100 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 later with 230 megabytes, was intended for many of the same markets as Iomega's successful Zip high capacity floppy drive. 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 cartridge drives were able to address a broader range of applications, resulting in increased sales levels through 1997.

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 functional 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.

Although it is clear that the market for the remaining 3.5" disk cartridge drives is softer in 1999 than in the last few years, it is not clear which of the apparent reasons are contributing the greatest impact. It is possible that 1998's intense sales promotion by SyQuest and Iomega confused as many potential buyers as it convinced, as they tried to decide which to buy. Rapid growth of the market for CD-RW rewritable optical drives may have diverted potential customers to that format. And, of course, it may merely be the case that the current market for rigid disk cartridge drives is a limited business and professional market which has become saturated.

Iomega was again the leader in worldwide unit shipments in 1998, with 712,000 drives for 55.2% of the overall total, but that figure was below the company's 818,000 Jaz drive total in 1997. SyQuest's 530,700 drives, all 3.5" except for 3,100 5.25" models, were 41.2% of the industry total. In 1998, all disk cartridge drives were shipped in noncaptive market channels, predominantly in the Distributor channel.

Marketing trends

Despite the softer 1999 market for rigid disk cartridge drives, a pattern of increasing shipments is expected in future years, but with somewhat lower expectations than in previous years. The current DISK/TREND forecast indicates an average annual increase in the 2000-2002 period of 23.4%, with unit shipments of 1.8 million drives in 2002. Sales revenues are expected to achieve a more modest average annual increase of 10.4%, yielding 2002 revenues of $242.5 million, limited by falling average unit prices.

With SyQuest no longer in the game, the only current competitor to Iomega's Jaz product line is Castlewood Systems, founded in 1996 by Syed Iftikar, an industry veteran who originally founded SyQuest. Castlewood is using contract manufacturers in Southeast Asia to manufacture its drive, a single disk design with potentially lower cost than the two platter Iomega Jaz series. Iomega is expected to introduce a single disk 3.5" cartridge drive, but the timetable is uncertain. If Castlewood is able to obtain significant quantities of drives, with

appropriate cost and quality, the firm clearly can gain a sizable share of the market. It has been demonstrated that the market for disk cartridge drives in the over 1 gigabyte range is greater than a million drives per year. The eventual market size will depend upon how many potential users doing sophisticated projects will find this recording medium to be convenient and cost effective -- and whether the drive manufacturers provide solutions they can live with.

Technical trends

The basic recording technologies now in use for products in this group will continue to predominate for years. The disk drives now 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. Disk cartridge drives 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. Each Jaz 2 cartridge uses two 1 gigabyte disks, the type used in the highest volume fixed disk drives in 1996. Castlewood's drive uses a single 2 gigabyte disk, the type which peaked in shipments in 1998. 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.

Forecasting assumptions

1. Shipments of 3.5" disk cartridge drives will increase, primarily due to demand in specialized business and professional markets, with further increases in drive capacity available, and with sales predominantly in the aftermarket.
2. There will be no further production of 2.5" or 5.25" disk cartridge drives.

TABLE 15

DISK CARTRIDGE DRIVES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1998 Revenues		Forecast							
	1999		2000		2001		2002			
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Captive	--	--	--	--	--	--	--	--	--	--
Distributor	189.3	239.5	107.8	157.1	96.3	160.2	114.0	175.4	129.4	199.4
OEM/Integrator	17.9	27.1	13.8	23.5	15.2	27.7	20.3	35.1	25.7	43.1
TOTAL U.S. REVENUES	207.2	266.6	121.6	180.6	111.5	187.9	134.3	210.5	155.1	242.5
Non-U.S. Manufacturers										
Captive	--	--	--	--	--	--	--	--	--	--
Distributor	.9	4.5	--	--	--	--	--	--	--	--
OEM/Integrator	--	--	--	--	--	--	--	--	--	--
TOTAL NON-U.S. REVENUES	.9	4.5	--	--	--	--	--	--	--	--
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	208.1	271.1	121.6	180.6	111.5	187.9	134.3	210.5	155.1	242.5
OEM Average Price ($000)		.238		.195		.178		.156		.139

TABLE 16

DISK CARTRIDGE DRIVES

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1998		Forecast							
	Shipments		1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Captive	--	--	--	--	--	--	--	--	--	--
Distributor	921.8	1,151.2	555.0	850.0	580.0	965.0	770.0	1,185.0	980.0	1,510.0
OEM/Integrator	75.3	113.5	65.0	120.0	85.0	155.0	130.0	225.0	185.0	310.0
TOTAL U.S. SHIPMENTS	997.1	1,264.7	620.0	970.0	665.0	1,120.0	900.0	1,410.0	1,165.0	1,820.0
Non-U.S. Manufacturers										
Captive	--	--	--	--	--	--	--	--	--	--
Distributor	5.0	25.0	--	--	--	--	--	--	--	--
OEM/Integrator	--	--	--	--	--	--	--	--	--	--
TOTAL NON-U.S. SHIPMENTS	5.0	25.0	--	--	--	--	--	--	--	--
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	1,002.1	1,289.7	620.0	970.0	665.0	1,120.0	900.0	1,410.0	1,165.0	1,820.0
Total Capacity (Terabytes)		1,669.8		1,802.0		2,016.0		2,820.0		4,550.0
Cumulative Shipments (Units in millions)										
WORLDWIDE TOTAL	5.3	7.9	6.0	8.8	6.6	10.0	7.5	11.4	8.7	13.2

TABLE 17

DISK CARTRIDGE DRIVES

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1998 Revenues			Forecast			
	5.25"	3.5"	2.5"	1999 3.5"	2000 3.5"	2001 3.5"	2002 3.5"
U.S. MANUFACTURERS							
Distributor	.6	235.6	3.3	157.1	160.2	175.4	199.4
OEM/Integrator	.3	26.8	--	23.5	27.7	35.1	43.1
TOTAL U.S. REVENUES	.9	262.4	3.3	180.6	187.9	210.5	242.5
NON-U.S. MANUFACTURERS							
Distributor	--	4.5	--	--	--	--	--
TOTAL NON-U.S. REVENUES	--	4.5	--	--	--	--	--
WORLDWIDE RECAP							
Distributor	.6 -95.8%	240.1 -3.9%	3.3 -91.6%	157.1 -34.6%	160.2 +2.0%	175.4 +9.5%	199.4 +13.7%
OEM/Integrator	.3 -93.9%	26.8 -26.2%	-- --	23.5 -12.3%	27.7 +17.9%	35.1 +26.7%	43.1 +22.8%
Total Revenues	.9 -95.3%	266.9 -6.7%	3.3 -91.9%	180.6 -32.3%	187.9 +4.0%	210.5 +12.0%	242.5 +15.2%
ANNUAL SHARE, BY DIAMETER	.3%	98.6%	1.1%	100.0%	100.0%	100.0%	100.0%

TABLE 18

DISK CARTRIDGE DRIVES

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DISK DIAMETER

	1998 Shipments			Forecast			
	5.25"	3.5"	2.5"	1999 3.5"	2000 3.5"	2001 3.5"	2002 3.5"
U.S. MANUFACTURERS							
Distributor	2.1	1,127.1	22.0	850.0	965.0	1,185.0	1,510.0
OEM/Integrator	1.0	112.5	--	120.0	155.0	225.0	310.0
TOTAL U.S. SHIPMENTS	3.1	1,239.6	22.0	970.0	1,120.0	1,410.0	1,820.0
NON-U.S. MANUFACTURERS							
Distributor	--	25.0	--	--	--	--	--
TOTAL NON-U.S. SHIPMENTS	--	25.0	--	--	--	--	--
WORLDWIDE RECAP							
Distributor	2.1	1,152.1	22.0	850.0	965.0	1,185.0	1,510.0
	-94.6%	+11.5%	-88.6%	-26.2%	+13.5%	+22.8%	+27.4%
OEM/Integrator	1.0	112.5	--	120.0	155.0	225.0	310.0
	-94.0%	-25.5%	--	+6.7%	+29.2%	+45.2%	+37.8%
Total Shipments	3.1	1,264.6	22.0	970.0	1,120.0	1,410.0	1,820.0
	-94.4%	+6.8%	-89.0%	-23.3%	+15.5%	+25.9%	+29.1%
ANNUAL SHARE, BY DIAMETER	.2%	98.2%	1.6%	100.0%	100.0%	100.0%	100.0%
TOTAL CAPACITY (Terabytes)	.9	1,663.4	5.5	1,802.0	2,016.0	2,820.0	4,550.0

TABLE 19

DISK CARTRIDGE DRIVES

SUMMARY BY PLATFORM

UNIT SHIPMENTS IN THOUSANDS	1998 Shipments Units	1998 Shipments %	1999 Forecast Units	1999 Forecast %	2000 Forecast Units	2000 Forecast %	2001 Forecast Units	2001 Forecast %	2002 Forecast Units	2002 Forecast %
MOBILE SYSTEM DRIVES	22.0	1.7%	--	--	--	--	--	--	--	--
	-88.9%		--		--		--		--	
2.5 INCH	22.0		--		--		--		--	
DESKTOP SYSTEM DRIVES	1,267.7	98.2%	970.0	100.0%	1,120.0	100.0%	1,410.0	100.0%	1,820.0	100.0%
	+2.3%		-23.4%		+15.4%		+25.8%		+29.0%	
5.25 INCH	3.1		--		--		--		--	
3.5 INCH	1,264.6		970.0		1,120.0		1,410.0		1,820.0	
Total Shipments	1,289.7	100.0%	970.0	100.0%	1,120.0	100.0%	1,410.0	100.0%	1,820.0	100.0%
	-10.4%		-24.8%		+15.5%		+25.9%		+29.1%	

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	1998 Estimate Units (000)	1998 Estimate %	2002 Projection Units (000)	2002 Projection %
SPECIALIZED HIGH PERFORMANCE Supercomputers, video and high end imaging	24.4	1.9	41.9	2.3
MAINFRAME SYSTEMS General purpose	--	--	--	--
NETWORK/MIDRANGE SYSTEMS Midrange systems, network servers and workstations	206.4	16.0	96.5	5.3
DESKTOP PERSONAL COMPUTERS Business and professional, single user	892.5	69.2	1,577.9	86.7
CONSUMER COMPUTERS Desktop PCs, game, and hobby computers	109.6	8.5	69.2	3.8
PORTABLE COMPUTERS Notebook and smaller mobile computers	29.7	2.3	21.8	1.2
OTHER APPLICATIONS	27.1	2.1	12.7	.7
Total	1,289.7	100.0	1,820.0	100.0

TABLE 21

DISK CARTRIDGE DRIVES

WORLDWIDE PRICE PER MEGABYTE ($/MB)

DISK DIAMETER	1998	Forecast 1999	2000	2001	2002
Distributor					
5.25"	.875	--	--	--	--
3.5"	.160	.100	.092	.074	.053
2.5"	.600	--	--	--	--
Distributor Average	.162	.100	.092	.074	.053
OEM/Integrator					
5.25"	.833	--	--	--	--
3.5"	.161	.102	.099	.078	.056
2.5"	--	--	--	--	--
OEM/Integrator Average	.162	.102	.099	.078	.056

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

	1998 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	--	525.0	--	525.0	52.4	--	712.0	--	712.0	55.2
SyQuest	2.6	449.5	--	452.1	45.1	3.1	527.6	--	530.7	41.2
Other U.S.	--	--	20.0	20.0	2.0	--	--	22.0	22.0	1.7
Other Non-U.S.	--	5.0	--	5.0	.5	--	25.0	--	25.0	1.9
TOTAL	2.6	979.5	20.0	1002.1	100.0	3.1	1264.6	22.0	1289.7	100.0

FIXED DISK DRIVES, LESS THAN 2 GIGABYTES

1999 DISK/TREND REPORT

FIXED DISK DRIVES, LESS THAN 2 GIGABYTES

Coverage

Examples of disk drives in this group include:

3.5" disk diameter

Fujitsu	MPA3017AT*
Raymond Engineering	8440, 84300

2.5" disk diameter

Fujitsu	M2724TAM**, M2722**
Toshiba	MK-1403MAV**, MK-1608MAT***

1.8" disk diameter

Calluna Technology	CT-1040RM****, CT-260T2*****
PCS, Inc.	Integral 8170E****, 8340PA****

1" disk diameter

Halo Data Devices	Halo Ultra******
IBM	Microdrive*****

*Maximum 25.4 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).
*****PC Card Type II/CompactFlash Card Type II (5 mm height).
******CompactFlash Card Type I (3.3 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 2 gigabytes, due to the current demand for the higher disk capacities required for most applications, and the continually dropping prices for disk drives with higher capacities. 1998 was the last year of significant shipments for 3.5" and 2.5" disk drives in this product group.

Several disk drive manufacturers introduced 1.8" drives in the PC Card format, starting with Integral Peripheral's 20 megabyte model, first produced in 1991. In the early 1990's, 1.8" drives appeared to have a significant market potential, but the PC Card format was too large to be conveniently used with

most handheld mobile devices and 1.8" drives couldn't compete against the price per megabyte available with the 2.5" drives used in notebook computers. Most of the announced 1.8" drive manufacturers gradually dropped out, and Integral Peripheral's 1.8" program was phased out in early 1998, leaving Calluna Technology as the only current manufacturer of 1.8" drives. Calluna has increased the capacity of its 10.5 millimeter thick PC Card Type III drives to 1 gigabyte and is starting production of a 260 megabyte Type II model, with a height of only 5 millimeters.

The potential role in computer and consumer electronics applications of drives with 1" disk diameters is open to speculation. IBM has announced plans to start production in mid-1999 for its "microdrive", in the CompactFlash Type II format, with 5 millimeter height. It will have a capacity of 340 megabytes in the version using two heads, or 170 megabytes using one head. IBM's published development roadmaps indicate an expected capacity for the format of over 1 gigabyte within a few years. Halo Data Devices is planning to produce, on an unannounced timetable, a 265 megabyte drive in the CompactFlash standard 3.3 millimeter Type I format, using a single head. For the first time, disk drives this small will make it possible to greatly increase the features offered by handheld computers, mobile GPS systems, digital cameras and other mobile devices. For example, it will be possible to add voice recognition capability to handheld computers, which could offer complete word processing systems and other features. Assuming that the promised 1" disk drives become available on schedule, the time required to develop the new mobile devices which will utilize them is the pacing element which will control development of the market.

Market status

The industry's movement to higher areal densities rapidly obsoletes yesterday's shipment leaders, and 1997 was the last year of major shipments for drives in the less than 2 gigabyte capacity range. After leading the industry in shipments in 1996, the product group's 1998 worldwide total was only 2.0 million drives, and 1999 is expected to drop further, to only 375,500 units. 1998 sales revenues for the product group declined 94.8% from the previous year, down to $372.1 million. 1999 sales revenues are projected at only $84.7 million, off another 77.2%.

Incessant growth in the personal computer market's craving for more disk storage capacity generated the rapid growth of shipments in this capacity range. 3.5" drives were the primary beneficiaries of storage demand for desktop personal computers, with 44.3 million drives shipped in 1996. The notebook computer market also saw a similar upward swing in demand for disk storage, with the result that shipments of 2.5" drives continued an upward ramp, but peaked in 1997, with 7.1 million units. Faster PC processors, improved operating systems and application programs, data downloaded from the Internet, and wider personal computer usage all contributed to the notable increase in drive shipments in the less than 2 gigabytes range. Just in time to exploit the new demand, the industry's continuing increases in areal density made possible 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.

But the growth period for both 3.5" and 2.5" drives in the less than 2 gigabytes range came to an end, 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, with drives in the leading capacity range now available for a fraction of the prices charged for less than 2 gigabyte models.

Desktop personal computers utilized half of the drives in this product group in 1998, and about a third were used with portable computers of various types. However, as shipments of drives used for desktop and notebook personal computers continue to decline, the mix of applications for which the product group is utilized will continue to evolve. That ratio is expected to change radically by 2002, when 87.1% of the drives produced in that year are forecasted for use with portable computers. 1999 is expected to be the last year of shipments for 3.5" and 2.5" drives in this capacity range, with only 1.8" and smaller drives remaining in the product group through 2002.

Seagate held the lead in noncaptive unit shipments for 1998, with 47.5% of the worldwide total, mostly 3.5" drives. Toshiba advanced to second with 11.8%, all 2.5" drives, with Fujitsu close behind with 11.6%, shipping a combination of 3.5" and 2.5" drives.

Marketing trends

Although shipments in this product group have been declining sharply during the last few years, the obsolete 3.5" and 2.5" drive models are expected to be out of production by the end of 1999, leaving only 1.8" and smaller drives in the group. Emerging applications with mobile devices are forecasted to generate increasing shipments. Although the growth rate to be expected with completely new applications is somewhat speculative, DISK/TREND shipment forecasts for 1.8" and smaller drives are conservatively projected at a 2000-2002 average annual increase of 64.1%, reaching 750,000 units in 2002. The average annual increase in sales revenues during the same period is estimated at only 28.3%, as average unit prices fall rapidly with early growth in shipment levels.

The actual growth rate to be achieved through 2002 by 1.8" and smaller drives will depend on how rapidly new applications are developed to take advantage of the storage capacity made available by these drives. Cost effective storage devices offering hundreds of megabytes of capacity have never before been available in form factors as small as the CompactFlash card. Software developers and system designers will be able to explore completely new applications, but such activities occur on uncertain timetables. A prudent forecast must assume that actual shipment demand for the new drives during the first few years of availability will be modest.

To some extent, the energy level expended in developing new applications for 1" drives will depend upon the computer industry's perception of how serious IBM is in developing manufacturing capability and in further enhancements to the drive series, including increased capacity. If IBM follows through on the initial strong market introduction, it is expected that application development will follow. In addition, 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 the next few years, 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 those of this product group. During the last few years, developing disk drives for the low capacity ranges 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.

The technical challenges for the miniaturized disk drives to be developed in this capacity range during the next few years will have to exploit the low cost production techniques utilized for the earlier drive designs, compressed into an amazingly small form factor. Designers will be challenged to combine extreme reduction in parts count, mechanical engineering akin to a watchmaker's, new techniques for automated assembly, the latest technology in areal density, and extremely low cost targets. Some of the industry's most interesting products could result from these efforts.

Forecasting assumptions

1. Shipments of 3.5" and 2.5" drives will end in 1999, displaced by higher capacity models available for both desktop and notebook computer markets.
2. 1.8" drive shipments will continue through 2002, with a base of specialized applications and limited usage with notebook computers.
3. The first shipments of 1" disk drives will occur in 1999, with gradual development of applications through 2002.

TABLE 23

FIXED DISK DRIVES, LESS THAN 2 GIGABYTES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1998 Revenues		Forecast							
			1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Captive	26.3	40.5	--	--	--	--	--	--	--	--
Distributor	30.7	51.1	2.4	6.0	.6	1.0	1.3	1.7	2.8	4.0
OEM/Integrator	46.0	64.9	1.5	5.0	1.9	4.7	7.5	15.3	12.7	24.2
TOTAL U.S. REVENUES	103.0	156.5	3.9	11.0	2.5	5.7	8.8	17.0	15.5	28.2
Non-U.S. Manufacturers										
Captive	19.6	108.0	4.5	22.6	--	--	--	--	--	--
Distributor	17.2	44.8	15.2	28.6	18.8	33.3	23.5	40.1	26.1	43.1
OEM/Integrator	15.7	62.8	10.2	22.5	10.2	19.1	13.4	23.1	15.0	25.4
TOTAL NON-U.S. REVENUES	52.5	215.6	29.9	73.7	29.0	52.4	36.9	63.2	41.1	68.5
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	155.5	372.1	33.8	84.7	31.5	58.1	45.7	80.2	56.6	96.7
OEM Average Price ($000)		.133		.174		.183		.123		.095

TABLE 24

FIXED DISK DRIVES, LESS THAN 2 GIGABYTES

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1998		Forecast							
	Shipments		1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Captive	65.0	100.0	--	--	--	--	--	--	--	--
Distributor	273.5	457.5	22.0	58.0	3.0	5.0	15.0	20.0	45.0	65.0
OEM/Integrator	402.5	577.0	17.0	55.0	22.0	55.0	105.0	215.0	215.0	410.0
TOTAL U.S. SHIPMENTS	741.0	1,134.5	39.0	113.0	25.0	60.0	120.0	235.0	260.0	475.0
Non-U.S. Manufacturers										
Captive	37.7	219.9	9.0	50.8	--	--	--	--	--	--
Distributor	85.0	279.6	54.0	109.0	65.0	115.0	85.0	145.0	100.0	165.0
OEM/Integrator	77.4	380.1	42.0	102.7	40.0	75.0	55.0	95.0	65.0	110.0
TOTAL NON-U.S. SHIPMENTS	200.1	879.6	105.0	262.5	105.0	190.0	140.0	240.0	165.0	275.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	941.1	2,014.1	144.0	375.5	130.0	250.0	260.0	475.0	425.0	750.0
Total Capacity (Terabytes)		2,966.4		373.2		130.5		273.5		586.2
Cumulative Shipments (Units in millions)										
WORLDWIDE TOTAL	255.6	496.7	255.7	497.0	255.9	497.3	256.1	497.8	256.5	498.5

TABLE 25

FIXED DISK DRIVES, LESS THAN 2 GIGABYTES

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1998 Revenues			Forecast					
				1999			2000	2001	2002
	3.5"	2.5"	<=1.8"	3.5"	2.5"	<=1.8"	<=1.8"	<=1.8"	<=1.8"
U.S. MANUFACTURERS									
Captive	--	40.5	--	--	--	--	--	--	--
Distributor	40.7	8.7	1.7	4.2	--	1.8	1.0	1.7	4.0
OEM/Integrator	51.3	13.6	--	2.9	--	2.1	4.7	15.3	24.2
TOTAL U.S. REVENUES	92.0	62.8	1.7	7.1	--	3.9	5.7	17.0	28.2
NON-U.S. MANUFACTURERS									
Captive	14.8	93.2	--	4.6	18.0	--	--	--	--
Distributor	20.8	2.2	21.8	1.7	.4	26.5	33.3	40.1	43.1
OEM/Integrator	8.8	41.1	12.9	.3	6.6	15.6	19.1	23.1	25.4
TOTAL NON-U.S. REVENUES	44.4	136.5	34.7	6.6	25.0	42.1	52.4	63.2	68.5
WORLDWIDE RECAP									
Captive	14.8 -94.2%	133.7 -88.6%	-- --	4.6 -68.9%	18.0 -86.5%	-- --	-- --	-- --	-- --
Distributor	61.5 -96.8%	10.9 -92.1%	23.5 -27.2%	5.9 -90.4%	.4 -96.3%	28.3 +20.4%	34.3 +21.2%	41.8 +21.9%	47.1 +12.7%
OEM/Integrator	60.1 -97.7%	54.7 -94.7%	12.9 -29.5%	3.2 -94.7%	6.6 -87.9%	17.7 +37.2%	23.8 +34.5%	38.4 +61.3%	49.6 +29.2%
Total Revenues	136.4 -97.1%	199.3 -91.5%	36.4 -28.1%	13.7 -90.0%	25.0 -87.5%	46.0 +26.4%	58.1 +26.3%	80.2 +38.0%	96.7 +20.6%
ANNUAL SHARE, BY DIAMETER	36.8%	53.6%	9.6%	16.2%	29.5%	54.3%	100.0%	100.0%	100.0%

Note: "<=" means "Less than or equal to".

TABLE 26

FIXED DISK DRIVES, LESS THAN 2 GIGABYTES

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DISK DIAMETER

	1998 Shipments			Forecast					
				1999			2000	2001	2002
	3.5"	2.5"	<=1.8"	3.5"	2.5"	<=1.8"	<=1.8"	<=1.8"	<=1.8"
U.S. MANUFACTURERS									
Captive	--	100.0	--	--	--	--	--	--	--
Distributor	394.0	56.0	7.5	50.0	--	8.0	5.0	20.0	65.0
OEM/Integrator	489.5	87.5	--	35.0	--	20.0	55.0	215.0	410.0
TOTAL U.S. SHIPMENTS	883.5	243.5	7.5	85.0	--	28.0	60.0	235.0	475.0
NON-U.S. MANUFACTURERS									
Captive	40.3	179.6	--	14.8	36.0	--	--	--	--
Distributor	201.5	13.0	65.1	20.0	2.0	87.0	115.0	145.0	165.0
OEM/Integrator	80.4	256.4	43.3	2.7	42.0	58.0	75.0	95.0	110.0
TOTAL NON-U.S. SHIPMENTS	322.2	449.0	108.4	37.5	80.0	145.0	190.0	240.0	275.0
WORLDWIDE RECAP									
Captive	40.3	279.6	--	14.8	36.0	--	--	--	--
	-92.2%	-86.8%	--	-63.3%	-87.1%	--	--	--	--
Distributor	595.5	69.0	72.6	70.0	2.0	95.0	120.0	165.0	230.0
	-95.8%	-90.3%	-43.1%	-88.2%	-97.1%	+30.9%	+26.3%	+37.5%	+39.4%
OEM/Integrator	569.9	343.9	43.3	37.7	42.0	78.0	130.0	310.0	520.0
	-96.9%	-94.0%	-42.7%	-93.4%	-87.8%	+80.1%	+66.7%	+138.5%	+67.7%
Total Shipments	1,205.7	692.5	115.9	122.5	80.0	173.0	250.0	475.0	750.0
	-96.4%	-91.9%	-42.9%	-89.8%	-88.4%	+49.3%	+44.5%	+90.0%	+57.9%
ANNUAL SHARE, BY DIAMETER	60.0%	34.4%	5.6%	32.6%	21.3%	46.1%	100.0%	100.0%	100.0%
TOTAL CAPACITY (Terabytes)	2,012.7	895.0	58.7	208.4	80.0	84.8	130.5	273.5	586.3

Note: "<=" means "Less than or equal to".

TABLE 27

FIXED DISK DRIVES, LESS THAN 2 GIGABYTES

SUMMARY BY PLATFORM

UNIT SHIPMENTS IN THOUSANDS	1998 Shipments Units	1998 Shipments %	1999 Forecast Units	1999 Forecast %	2000 Forecast Units	2000 Forecast %	2001 Forecast Units	2001 Forecast %	2002 Forecast Units	2002 Forecast %
MOBILE SYSTEM DRIVES	808.4	40.1%	253.0	67.3%	250.0	100.0%	475.0	100.0%	750.0	100.0%
	-90.8%		-68.7%		-1.1%		+90.0%		+57.8%	
2.5 INCH	692.5		80.0		--		--		--	
<=1.8 INCH	115.9		173.0		250.0		475.0		750.0	
DESKTOP SYSTEM DRIVES	1,171.7	58.1%	122.5	32.6%	--	--	--	--	--	--
	-96.4%		-89.5%		--		--		--	
3.5 INCH	1,171.7		122.5		--		--		--	
SERVER SYSTEM DRIVES	34.0	1.6%	--	--	--	--	--	--	--	--
	-89.7%		--		--		--		--	
3.5 INCH	34.0		--		--		--		--	
Total Shipments	2,014.1	100.0%	375.5	100.0%	250.0	100.0%	475.0	100.0%	750.0	100.0%
	-95.2%		-81.4%		-33.4%		+90.0%		+57.9%	

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

TABLE 28

FIXED DISK DRIVES, LESS THAN 2 GIGABYTES

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1998 Estimate Units (000)	1998 Estimate %	2002 Projection Units (000)	2002 Projection %
SPECIALIZED HIGH PERFORMANCE				
Supercomputers, video and high end imaging	--	--	--	--
MAINFRAME SYSTEMS				
General purpose	--	--	--	--
NETWORK/MIDRANGE SYSTEMS				
Midrange systems, network servers and workstations	34.2	1.7	.8	.1
DESKTOP PERSONAL COMPUTERS				
Business and professional, single user	1,025.2	50.9	43.5	5.8
CONSUMER COMPUTERS				
Desktop PCs, game, and hobby computers	153.1	7.6	6.0	.8
PORTABLE COMPUTERS				
Notebook and smaller mobile computers	777.4	38.6	653.2	87.1
OTHER APPLICATIONS	24.2	1.2	46.5	6.2
Total	2,014.1	100.0	750.0	100.0

TABLE 29

FIXED DISK DRIVES, LESS THAN 2 GIGABYTES

WORLDWIDE PRICE PER MEGABYTE ($/MB)

DISK DIAMETER	1998	Forecast 1999	2000	2001	2002
Captive					
3.5"	.213	.172	--	--	--
2.5"	.360	.500	--	--	--
1.8" or less	--	--	--	--	--
Captive Average	.337	.361	--	--	--
Distributor					
3.5"	.062	.050	--	--	--
2.5"	.097	.160	--	--	--
1.8" or less	.651	.591	.504	.401	.268
Distributor Average	.084	.206	.504	.401	.268
OEM/Integrator					
3.5"	.063	.049	--	--	--
2.5"	.133	.155	--	--	--
1.8" or less	.575	.481	.384	.227	.121
OEM/Integrator Average	.092	.191	.384	.227	.121

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 2 GIGABYTES

MARKET SHARE SUMMARY
Worldwide Shipments of Noncaptive Disk Drives

	1998 Net Shipments									
	To United States Destinations					Worldwide				
	Units (000)				%	Units (000)				%
Drive Manufacturers	3.5"	2.5"	<=1.8"	Total		3.5"	2.5"	<=1.8"	Total	
Seagate Technology	480.0	80.5	--	560.5	66.8	707.5	97.5	--	805.0	47.5
Toshiba	--	51.2	--	51.2	6.1	--	200.7	--	200.7	11.8
Fujitsu	3.0	--	--	3.0	.4	156.9	39.2	--	196.1	11.6
Samsung Electronics	42.0	--	--	42.0	5.0	125.0	--	--	125.0	7.4
Other U.S.	86.0	26.0	3.5	115.5	13.8	176.0	46.0	7.5	229.5	13.6
Other Non-U.S.	--	6.5	59.7	66.2	7.9	--	29.5	108.4	137.9	8.1
TOTAL	611.0	164.2	63.2	838.4	100.0	1165.4	412.9	115.9	1694.2	100.0

Note: "<=" means "Less than or equal to".

FIXED DISK DRIVES, 2 - 3 GIGABYTES

1999 DISK/TREND REPORT

FIXED DISK DRIVES, 2 - 3 GIGABYTES

Coverage

Examples of disk drives in this group include:

3.5" disk diameter

Fujitsu	M2932*, MPB3021AT**
IBM	DCAS-32160**
NEC	DCAS-32160**
Quantum	Fireball EL**

2.5" disk diameter

Fujitsu	MHA2021****, MHD2021AT*****
Hitachi	DK226A-21U****
IBM	DKLA-22160*****
Toshiba	MK-2104MAV****, MK-2110MAF*****

*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. The early 5.25" drives offered in this capacity range were intended for midrange and mainframe systems. The 5.25" drives in this capacity range which stayed in production as recently as last year were 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 also 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. Only four disk drive manufacturers still participate in the remaining market among personal computer makers for 3.5" drives in this capacity range. Only four disk drive manufacturers also now offer 2.5" drives with 2-3 gigabyte capacities.

Market status

After reaching a 1997 peak of 49.8 million drives, shipments of 2-3 gigabyte drives have declined rapidly, 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 were down to 27.7 million in 1998 and are forecasted at only 8.8 million drives in 1999. Sales revenues for 1998 were down 61.4%, at $3.9 billion, with a further decline of 68.3% expected in 1999, to $1.2 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 faded in the mid-1990's, with final production in 1997. At the same time, many network server and midrange system requirements were 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 declined to 555,100 units, with 1999 shipments forecasted at only 62,900 drives.

During the 1997 peak, shipments of desktop drives dominated the product group, with 40.7 million units. A bloody battleground intensified during that year and the subsequent period, as the market leaders in the desktop drive market attempted to hold their individual market shares in the 2-3 gigabyte market as well as in higher capacity ranges, in the face of intense competition from several rapidly growing competitors. The OEM average unit price for 2-3 gigabyte desktop 3.5" drives fell from $158 in 1997 to $117 in 1998, with 1999 expected to

average $87. 1998's desktop 3.5" drive shipment total of 22.2 million drives is projected to drop to below six million in 1999. That decline would probably be higher without the emergency effort by some 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.

67.6% of the worldwide shipments of 2-3 gigabyte disk drives were used for desktop personal computers and 12.4% went to consumer computer applications. The share utilized for portable computers grew to 17.8%. No applications are forecasted for 2002, since it is expected that production of drives in the 2-3 gigabyte range will cease before 2002.

Although Seagate Technology has phased out production of 2-3 gigabyte drives, it held the leadership in 1998 shipments of noncaptive drives, with 22.3% of the worldwide unit total, mostly 3.5" models. Quantum held a 19.9% share, also mostly 3.5" models, but including some 5.25" drives, and Western Digital dropped to 14.1%, all 3.5" drives.

Marketing trends

The continuing increases in disk drive areal density are expected to cause shipments of 2-3 gigabyte drives to end by 2002. Single disk drives with capacities above 3 gigabytes are already available in both 3.5" and 2.5" formats, and drive models in both diameters with capacities below 3 gigabytes are inevitably approaching end of life. Worldwide shipments for the 2-3 gigabyte product group are projected to drop to 2.6 million units in 2000, and end with 580,000 drives in 2001. Sales revenues are forecasted to decline an average of 70.6% per year during 2000-2001, ending in 2001 with a nominal $106 million.

Although 3.5" drives for the desktop market lead the product group's current shipments, 2000 is expected to be the last year for 3.5" shipments. Few drive manufacturers are interested in producing 3.5" drives with less than 3 gigabytes per single disk, considering that 4.3 gigabyte per platter drives went into production in 1998, and 6.8 gigabyte per platter drives are being introduced in 1999.

Peak demand for disk capacities in the notebook computer market frequently lags a year behind the capacities used in desktop personal computers, and

shipments of 2-3 gigabyte 2.5" drives did not peak until 1998, at just under 5 million units. Movement to 2.5" drives with higher capacities for notebook computer applications is now well underway, and the last shipments of 2.5" drives are expected to occur in 2001. At this point, it is too early to project the appearance of smaller diameter drives in this product group by 2002, and any possibility of that happening will depend on the rate of development of the applications for 1.8" and 1" drives, with subsequent increases in the capacity levels offered.

Technical trends

As major personal computer manufacturers pursue their objective to lower the threshold price for a fully equipped PC, new demands have been placed on disk drive manufacturers. For disk drives with the highest production levels, the most important technical specification is price. For that reason, low manufacturing cost has become the prime product development objective for desktop drives in the most popular capacities, and the capacity per disk which can be produced at the lowest manufacturing cost has now moved above the range offered by this product group.

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 this forecast period. The disk drive industry continues to devote intense development activity to 3.5" drives for desktop computers and to 2.5" drives for notebook computers, but these efforts are now concentrated on capacity ranges above those of this product group.

Eventually, it is probable that drives using 1.8" and 1" disks will advance into the 2-3 gigabyte capacity range, requiring entirely new development programs utilizing sophisticated mechanical engineering, reduced semiconductor chip count and utilization of the highest areal densities. It is conceivable that such miniaturized drives could start production before the close of the current forecast period, but it is too early to predict how rapidly the markets for these drives will accelerate, and production in this forecast range is not included in the current forecast.

Forecasting assumptions

1. 3.5" drive shipments peaked in 1997, and will drop rapidly as personal computer markets move to higher disk drive capacities, with the last year of shipments in 2000.
2. 2.5" drives peaked in 1998, and will decline through 2001, as notebook computer markets transition to drives with higher capacities, with final production in 2001.
3. Shipments of 1.8" and 1" drives will not commence in the 2-3 gigabyte capacity range before the end of 2002.

TABLE 31

FIXED DISK DRIVES, 2 - 3 GIGABYTES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1998 Revenues		Forecast 1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Captive	41.5	62.3	6.9	10.3	--	--	--	--	--	--
Distributor	352.6	900.8	85.1	216.1	16.4	41.6	--	--	--	--
OEM/Integrator	599.7	1,270.3	108.3	240.8	19.9	49.2	--	--	--	--
TOTAL U.S. REVENUES	993.8	2,233.4	200.3	467.2	36.3	90.8	--	--	--	--
Non-U.S. Manufacturers										
Captive	129.0	696.7	114.9	492.1	34.6	139.9	16.5	68.6	--	--
Distributor	41.3	192.3	23.7	51.9	11.4	23.1	.6	2.5	--	--
OEM/Integrator	98.9	784.1	48.6	226.0	21.1	84.8	9.1	35.1	--	--
TOTAL NON-U.S. REVENUES	269.2	1,673.1	187.2	770.0	67.1	247.8	26.2	106.2	--	--
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	1,263.0	3,906.5	387.5	1,237.2	103.4	338.6	26.2	106.2	--	--
OEM Average Price ($000)		.125		.103		.098		.121		--

TABLE 32

FIXED DISK DRIVES, 2 - 3 GIGABYTES

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1998		Forecast							
	Shipments		1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Captive	100.0	150.0	20.0	30.0	--	--	--	--	--	--
Distributor	3,005.5	7,821.5	958.5	2,472.0	205.0	520.0	--	--	--	--
OEM/Integrator	4,633.2	10,217.6	1,139.5	2,668.0	255.0	630.0	--	--	--	--
TOTAL U.S. SHIPMENTS	7,738.7	18,189.1	2,118.0	5,170.0	460.0	1,150.0	--	--	--	--
Non-U.S. Manufacturers										
Captive	263.4	1,580.6	290.0	1,266.6	125.0	505.0	65.0	270.0	--	--
Distributor	365.9	1,743.2	260.5	545.0	130.0	255.0	5.0	20.0	--	--
OEM/Integrator	695.9	6,217.5	385.0	1,831.5	180.0	735.0	75.0	290.0	--	--
TOTAL NON-U.S. SHIPMENTS	1,325.2	9,541.3	935.5	3,643.1	435.0	1,495.0	145.0	580.0	--	--
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	9,063.9	27,730.4	3,053.5	8,813.1	895.0	2,645.0	145.0	580.0	--	--
Total Capacity (Terabytes)		63,293.5		19,782.1		5,927.4		1,252.8		--
Cumulative Shipments (Units in millions)										
WORLDWIDE TOTAL	49.3	103.0	52.4	111.8	53.2	114.5	53.4	115.1	53.4	115.1

TABLE 33

FIXED DISK DRIVES, 2 - 3 GIGABYTES

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1998 Revenues			Forecast					
				1999		2000		2001	2002
	5.25"	3.5"	2.5"	3.5"	2.5"	3.5"	2.5"	2.5"	All Dia.
U.S. MANUFACTURERS									
Captive	--	--	62.3	--	10.3	--	--	--	--
Distributor	4.9	885.4	10.5	214.7	1.4	41.6	--	--	--
OEM/Integrator	6.7	1,154.5	109.1	225.1	15.7	49.2	--	--	--
TOTAL U.S. REVENUES	11.6	2,039.9	181.9	439.8	27.4	90.8	--	--	--
NON-U.S. MANUFACTURERS									
Captive	2.9	113.6	580.2	24.8	467.3	--	139.9	68.6	--
Distributor	--	155.5	36.8	37.0	14.9	17.2	5.9	2.5	--
OEM/Integrator	--	380.3	403.8	25.7	200.3	13.6	71.2	35.1	--
TOTAL NON-U.S. REVENUES	2.9	649.4	1,020.8	87.5	682.5	30.8	217.0	106.2	--
WORLDWIDE RECAP									
Captive	2.9	113.6	642.5	24.8	477.6	--	139.9	68.6	--
	--	-89.6%	-19.3%	-78.2%	-25.7%	--	-70.7%	-51.0%	--
Distributor	4.9	1,040.9	47.3	251.7	16.3	58.8	5.9	2.5	--
	-96.2%	-57.7%	+7.0%	-75.8%	-65.5%	-76.6%	-63.8%	-57.6%	--
OEM/Integrator	6.7	1,534.8	512.9	250.8	216.0	62.8	71.2	35.1	--
	-97.4%	-65.9%	-35.3%	-83.7%	-57.9%	-75.0%	-67.0%	-50.7%	--
Total Revenues	14.5	2,689.3	1,202.7	527.3	709.9	121.6	217.0	106.2	--
	-96.2%	-66.7%	-26.3%	-80.4%	-41.0%	-76.9%	-69.4%	-51.1%	--
ANNUAL SHARE, BY DIAMETER	.4%	68.9%	30.7%	42.7%	57.3%	36.0%	64.0%	100.0%	--

TABLE 34

FIXED DISK DRIVES, 2 - 3 GIGABYTES

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DISK DIAMETER

	1998 Shipments			Forecast 1999		2000		2001	2002
	5.25"	3.5"	2.5"	3.5"	2.5"	3.5"	2.5"	2.5"	All Dia.
U.S. MANUFACTURERS									
Captive	--	--	150.0	--	30.0	--	--	--	--
Distributor	47.0	7,714.5	60.0	2,462.0	10.0	520.0	--	--	--
OEM/Integrator	65.0	9,522.6	630.0	2,558.0	110.0	630.0	--	--	--
TOTAL U.S. SHIPMENTS	112.0	17,237.1	840.0	5,020.0	150.0	1,150.0	--	--	--
NON-U.S. MANUFACTURERS									
Captive	.7	375.6	1,204.3	86.6	1,180.0	--	505.0	270.0	--
Distributor	--	1,510.5	232.7	435.0	110.0	210.0	45.0	20.0	--
OEM/Integrator	--	3,497.3	2,720.2	310.5	1,521.0	170.0	565.0	290.0	--
TOTAL NON-U.S. SHIPMENTS	.7	5,383.4	4,157.2	832.1	2,811.0	380.0	1,115.0	580.0	--
WORLDWIDE RECAP									
Captive	.7	375.6	1,354.3	86.6	1,210.0	--	505.0	270.0	--
	--	-80.2%	+3.9%	-76.9%	-10.7%	--	-58.3%	-46.5%	--
Distributor	47.0	9,225.0	292.7	2,897.0	120.0	730.0	45.0	20.0	--
	-94.7%	-37.5%	+50.1%	-68.6%	-59.0%	-74.8%	-62.5%	-55.6%	--
OEM/Integrator	65.0	13,019.9	3,350.2	2,868.5	1,631.0	800.0	565.0	290.0	--
	-96.3%	-49.0%	-1.2%	-78.0%	-51.3%	-72.1%	-65.4%	-48.7%	--
Total Shipments	112.7	22,620.5	4,997.2	5,852.1	2,961.0	1,530.0	1,115.0	580.0	--
	-95.8%	-46.4%	+2.2%	-74.1%	-40.7%	-73.9%	-62.3%	-48.0%	--
ANNUAL SHARE, BY DIAMETER	.4%	81.7%	17.9%	66.5%	33.5%	57.9%	42.1%	100.0%	--
TOTAL CAPACITY (Terabytes)	236.4	52,252.9	10,804.2	13,384.1	6,398.0	3,519.0	2,408.4	1,252.8	--

TABLE 35

FIXED DISK DRIVES, 2 - 3 GIGABYTES

SUMMARY BY PLATFORM

UNIT SHIPMENTS IN THOUSANDS	1998 Shipments Units	1998 Shipments %	Forecast 1999 Units	Forecast 1999 %	Forecast 2000 Units	Forecast 2000 %	Forecast 2001 Units	Forecast 2001 %	Forecast 2002 Units	Forecast 2002 %
MOBILE SYSTEM DRIVES	4,997.2	18.0%	2,961.0	33.6%	1,115.0	42.1%	580.0	100.0%	--	--
	+1.6%		-40.7%		-62.3%		-47.9%		--	
2.5 INCH	4,997.2		2,961.0		1,115.0		580.0		--	
DESKTOP SYSTEM DRIVES	22,177.4	79.9%	5,789.2	65.6%	1,530.0	57.8%	--	--	--	--
	-45.3%		-73.9%		-73.5%		--		--	
5.25 INCH	112.0		--		--		--		--	
3.5 INCH	22,065.4		5,789.2		1,530.0		--		--	
SERVER SYSTEM DRIVES	555.8	2.0%	62.9	.7%	--	--	--	--	--	--
	-86.9%		-88.6%		--		--		--	
5.25 INCH		.7		--		--		--		--
3.5 INCH	555.1		62.9		--		--		--	
Total Shipments	27,730.4	100.0%	8,813.1	100.0%	2,645.0	100.0%	580.0	100.0%	--	--
	-44.3%		-68.2%		-70.0%		-78.1%		--	

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

TABLE 36

FIXED DISK DRIVES, 2 - 3 GIGABYTES

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1998 Estimate Units (000)	1998 Estimate %	2002 Projection Units (000)	2002 Projection %
SPECIALIZED HIGH PERFORMANCE Supercomputers, video and high end imaging	--	--	--	--
MAINFRAME SYSTEMS General purpose	--	--	--	--
NETWORK/MIDRANGE SYSTEMS Midrange systems, network servers and workstations	554.6	2.0	--	--
DESKTOP PERSONAL COMPUTERS Business and professional, single user	18,745.7	67.6	--	--
CONSUMER COMPUTERS Desktop PCs, game, and hobby computers	3,438.6	12.4	--	--
PORTABLE COMPUTERS Notebook and smaller mobile computers	4,936.0	17.8	--	--
OTHER APPLICATIONS	55.5	.2	--	--
Total	27,730.4	100.0	--	--

TABLE 37

FIXED DISK DRIVES, 2 - 3 GIGABYTES

WORLDWIDE PRICE PER MEGABYTE ($/MB)

DISK DIAMETER		Forecast			
	1998	1999	2000	2001	2002
Captive					
5.25"	--	--	--	--	--
3.5"	.132	.124	--	--	--
2.5"	.219	.183	.128	.118	--
1.8"	--	--	--	--	--
Captive Average	.200	.178	.128	.118	--
Distributor					
5.25"	.050	--	--	--	--
3.5"	.049	.038	.035	--	--
2.5"	.074	.063	.060	.057	--
1.8"	--	--	--	--	--
Distributor Average	.050	.039	.036	.057	--
OEM/Integrator					
5.25"	.048	--	--	--	--
3.5"	.051	.038	.034	--	--
2.5"	.071	.061	.058	.056	--
1.8"	--	--	--	--	--
OEM/Integrator Average	.055	.046	.044	.056	--

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, 2 - 3 GIGABYTES

MARKET SHARE SUMMARY
Worldwide Shipments of Noncaptive Disk Drives

	1998 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	--	1586.5	15.5	1602.0	18.4	--	5704.0	90.0	5794.0	22.3
Quantum	48.0	2175.0	--	2223.0	25.5	112.0	5060.0	--	5172.0	19.9
Western Digital	--	2213.0	--	2213.0	25.4	--	3676.0	--	3676.0	14.1
Fujitsu	--	70.6	93.0	163.6	1.9	--	2446.8	848.3	3295.1	12.7
Maxtor	--	1125.7	--	1125.7	12.9	--	2642.1	--	2642.1	10.2
Samsung Electronics	--	450.0	--	450.0	5.2	--	2561.0	--	2561.0	9.8
Toshiba	--	--	327.0	327.0	3.8	--	--	1288.1	1288.1	5.0
Other U.S.	--	80.0	395.0	475.0	5.5	--	155.0	600.0	755.0	2.9
Other Non-U.S.	--	--	121.2	121.2	1.4	--	--	816.5	816.5	3.1
TOTAL	48.0	7700.8	951.7	8700.5	100.0	112.0	22244.9	3642.9	25999.8	100.0

FIXED DISK DRIVES, 3 - 5 GIGABYTES

1999 DISK/TREND REPORT

FIXED DISK DRIVES, 3 - 5 GIGABYTES

Coverage

Examples of disk drives in this group include:

5.25" disk diameter

Belfort Memory International	P53-1U**

3"-3.5" disk diameter (Desktop and server drives)

Conner Technology	CT-204**
Fujitsu	M2934*, MPA3043AT**
Hitachi	DK328H-43**
IBM	DTTA-350430**, DDRS-34560**
Maxtor	90432D2**
NEC	DTTA-350430**
Quantum	Fireball CR**, Atlas III**, Viking II**
Samsung Electronics	SV-0432A**
Seagate Technology	U4**, Medalist**, Barracuda**, Cheetah**
Western Digital	WDE4550**, WDAC14300**

2.5"-3" disk diameter (Mobile drives)

Fujitsu	MHE2043AT****, MHF2043AT*****
Hitachi	DK226A-32****, DK237A-32*****
IBM	DBCA-204860*****, DKLA-23240*****
Toshiba	MK-4006MAV****, MK-4310MAT*****

*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 first disk drive in the product group was IBM's 3,781 megabyte 3380K, with 14" disks, introduced in 1987, which in turn was made obsolete by IBM's 3390 series, using 10.8" disks, initially introduced in 1989. In 1991, the IBM 3390 series moved to capacities above 5 gigabytes. The various drives using 6.5"-10.5" disks manufactured in this capacity range since the late 1980's were intended mostly for mainframe and supermini applications similar to IBM's, and all are now out of production.

5.25" drives above 3 gigabytes appeared for the first time in 1992, and for a few years were offered by most manufacturers active in the markets for high-end disk drives. That product activity was short-lived, as some 5.25" drive manufac-

turers quickly moved to higher capacities and others developed 3.5" drives for this capacity range. Production of 5.25" disk drives in the 3-5 gigabyte range for high-end applications has been phased out, and the 5.25" models produced in volume during the last few years have been targeted at low cost desktop personal computers.

IBM utilized magnetoresistive heads and PRML encoding with the firm's Starfire 4.3 gigabyte 1.625" high drives announced in late 1993, the first 3.5" drives to pioneer over the 3 gigabyte level. After a difficult production start for these drives during 1994-95, IBM announced 4.5 gigabyte 1" high Scorpion 3.5" drives in late 1995. During 1995-96, IBM was joined by all of the other disk drive manufacturers active in the high capacity drive field in offering 3.5" drives with more than 3 gigabytes. The industry had a difficult start-up period with these drives, but production increased to significant levels in 1996. The pioneering high-end 3.5" drives intended for mainframe, midrange and network file server applications were joined in 1997 by a new generation of lower cost drives now manufactured in very large quantities for the desktop personal computer market.

Despite the initial high degree of technical difficulty, IBM shipped the first 2.5" drive in the 3-5 gigabyte range in late 1996. Hitachi was close behind, with a 2.5" drive in the first half of 1997 which was the first disk drive to utilize areal densities above the 2 gigabit per square inch level. Production of 2.5" drives for mobile applications is currently at high levels, with all models less than 12.7 millimeters in height. Several drives are 9.5 millimeters in height, and some Toshiba drives are only 8.5 millimeters high.

Market status

Worldwide shipments in the 3-5 gigabyte product group peaked in 1998, but competition in 1999 has been extremely intense as disk drive manufacturers struggle for market share in the rapidly growing low-end desktop personal computer market. Shipments totaled 70.9 million drives in 1998, up 143.9%, but 1999 shipments are forecasted at 48.7 million, down 31.3%. Extreme price competition held the 1998 sales revenue to $12.3 billion, up only 41.8%, and even more intense current pressure on prices will cut the 1999 sales revenue to an estimated $6.1 billion, down 50.4%.

Until 1996, mainframe and midrange system markets provided almost all of the growth for shipments in this product group, but that changed in 1996, with the advent of 3-5 gigabyte drives designed for personal computer applications. Led by strong shipments of 4.5 gigabyte 3.5" drives, the server drive market sustained a two year peak in 1997 with 7.3 million units, followed by 7.4 million drives in 1998. In 1999, server drive shipments in the 3-5 gigabyte group are expected to decline 31.2%, to 3.2 million units, as server drives with capacities above 5 gigabytes pick up sales momentum.

Although shipments of desktop drives in the 3-5 gigabyte product group peaked in 1998, the emerging market for low-end personal computers has held this year's decline to only 27.3%, a smaller reduction than typical after a product group's shipment peak. In 1999, a single platter 4.3 gigabyte desktop 3.5" drive can be produced at the lowest cost possible for any rigid disk drive, considering component cost and availability, manufacturing facilities and the size of the available market. Seagate's U4 drive, which went into production in March, 1999, was designed with minimum parts count and wide manufacturing tolerances in order to hold costs to the lowest possible level. The U4 has become the low cost design model others are working to match, and it has become the leader in forcing prices for desktop drives in the product group to levels lower than ever. Desktop 3.5" drives with 3-5 gigabyte capacities sold at an average of $123 in the OEM market in 1998, but the 1999 OEM price average is forecasted to drop to $89. Seagate's competitors have been reluctant to abandon business in the face of competition from the U4, and many have met the price regardless of the cost.

2.5" drive shipments for mobile applications increased to 13.9% of the product group's total in 1998, with 9.9 million disk drives. Although 1999 shipments are forecasted to decline by 34.2%, the total for the year will still reach an estimated 6.5 million units, with a majority of the shipments consisting of the newer thin drive designs, 9.5 millimeters or less in height.

Evolving changes in the nature of the drives in this product group are displayed in the breakdown of the group's applications. Desktop personal computers assumed leadership a few years ago and in 1998 continued the pattern with 66.0% of shipments, while portable computers jumped from very low utilization to 13.7% of the overall 1998 total. By 2002, the share for portable computers is

forecasted to increase to 45.7%, while business desktop computer markets and consumer computers are expected to have 26.1% and 24.3%, respectively.

Seagate Technology regained leadership in 1998 noncaptive shipments of 3-5 gigabyte drives, with 24.1% of the worldwide total, all 3.5" drives. Quantum's combination of 3.5" and 5.25" disk drives provided second place, with 16.5%, and Western Digital secured third position with 15.6%, all 3.5" models.

Marketing trends

Despite a relatively strong sales performance in 1998, time marches on, and by next year it will be possible to produce single platter desktop drives at costs just as low as 1999's 4.3 gigabyte models, but with significantly higher capacities. During the 2000-2002 period, the average annual decline in worldwide unit shipments of 3-5 gigabyte drives is forecasted at 70.9%, with the 2002 total down to 1.2 million units. Sales revenues for 2002 are projected at only $148.6 million, with the 2000-2002 revenue annual decline also set at 70.9%.

As shipments of 3.5" server drives fade away through 2001, sales activity for desktop 3.5" drives in the 3-5 gigabyte range will also drop rapidly as the industry emphasis on drive capacities moves upward, following the areal density curve and the market's appetite for increasing drive capacities. By 2002, the last of the 3.5" desktop drives are forecasted to sell to OEMs at an average of only $76.

1998 was the peak year for shipments of mobile, desktop and server drives. Although declining shipments are expected for all of these drive types, the rate of decline for 2.5" drives is projected to be less than for 3.5" drives, and by 2002 2.5" drives are projected to hold 46.4% of the product group's total shipments. Following the pattern of mobile 2.5" drives in lower capacity product groups, it has become normal for disk drive capacities utilized with notebook computers to lag behind those featured with desktop personal computers by a year or two. The last shipments of 3.5" server drives are expected to occur in 2001.

Technical trends

As the industry's attention moves to higher capacity product groups, it is expected that the technology improvements utilized in this product group will be

mostly the result of a "trickle down" effect from development activities undertaken for higher capacity drives. At the end of 1997, the first 3.5" desktop drives with only one disk became available in the 3-5 gigabyte capacity range, reducing parts count to a minimum. It is expected that major manufacturers of 3.5" desktop drives will utilize substantial development resources to cut overall manufacturing costs for such drives in all capacity ranges to a minimum during the coming year, to become competitive in the disk drive market for personal computers at minimum price levels. Such drives will be priced significantly lower than many of today's models, with higher reliability, and they may provide parts count reductions not yet realized in today's production drives. Although some of the cost efficiencies developed for desktop 3.5" drives may find their way into server drives, it is expected that most of the major changes in server drives in the 3-5 gigabyte range will also be derived from engineering projects targeted primarily at higher capacity drives.

The same type of product development effort will be devoted to the 2.5" mobile drives targeted at the notebook computer market. With low product cost as the overriding objective, these programs will stress attempts to achieve the lowest possible drive parts count consistent with areal densities which can be manufactured with high yields.

Forecasting assumptions

1. Production of 3.5" server drives in this capacity range will continue through 2001, but a high proportion of 3.5" drives will be designed for lower cost personal computer applications. 3-5 gigabyte 3.5" server drive shipments will end in 2001 and desktop drive shipments will end in 2002.
2. Shipments of low-cost 5.25" desktop drives intended to compete with 3.5" desktop drives for personal computer applications will end in 1999.
3. 2.5" mobile drive shipments in this product group will decline through 2002, but the share of the product group's overall shipments held by 2.5" drives will increase through 2002.

TABLE 39

FIXED DISK DRIVES, 3 - 5 GIGABYTES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1998		Forecast							
	Revenues		1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Captive	774.5	1,163.8	319.3	449.2	54.8	78.5	13.4	18.4	--	--
Distributor	1,151.6	2,520.7	443.9	828.3	55.2	103.0	9.4	17.1	.9	2.4
OEM/Integrator	2,768.0	5,118.0	1,413.3	2,462.3	418.0	718.3	149.0	251.1	39.7	56.5
TOTAL U.S. REVENUES	4,694.1	8,802.5	2,176.5	3,739.8	528.0	899.8	171.8	286.6	40.6	58.9
Non-U.S. Manufacturers										
Captive	158.7	1,068.5	79.1	647.2	35.7	216.5	14.2	70.8	9.2	36.7
Distributor	355.3	831.4	188.4	596.9	24.7	79.5	2.9	8.6	.7	2.3
OEM/Integrator	451.9	1,637.2	285.7	1,132.4	94.2	372.7	24.8	104.0	11.5	50.7
TOTAL NON-U.S. REVENUES	965.9	3,537.1	553.2	2,376.5	154.6	668.7	41.9	183.4	21.4	89.7
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	5,660.0	12,339.6	2,729.7	6,116.3	682.6	1,568.5	213.7	470.0	62.0	148.6
OEM Average Price ($000)		.157		.109		.103		.096		.104

TABLE 40

FIXED DISK DRIVES, 3 - 5 GIGABYTES

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1998 Shipments		Forecast 1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Captive	1,345.0	2,025.0	705.0	990.0	150.0	215.0	40.0	55.0	--	--
Distributor	7,778.4	18,037.0	3,886.0	7,636.0	480.0	960.0	80.0	160.0	8.0	25.0
OEM/Integrator	16,722.1	32,316.6	12,270.0	22,770.0	4,045.0	7,215.0	1,595.0	2,760.0	415.0	590.0
TOTAL U.S. SHIPMENTS	25,845.5	52,378.6	16,861.0	31,396.0	4,675.0	8,390.0	1,715.0	2,975.0	423.0	615.0
Non-U.S. Manufacturers										
Captive	267.5	1,970.6	155.0	1,496.0	90.0	645.0	40.0	225.0	30.0	120.0
Distributor	2,629.9	6,094.3	1,808.0	5,945.0	250.0	820.0	30.0	90.0	7.0	20.0
OEM/Integrator	2,992.1	10,524.6	2,610.1	9,935.2	870.0	3,285.0	235.0	935.0	105.0	440.0
TOTAL NON-U.S. SHIPMENTS	5,889.5	18,589.5	4,573.1	17,376.2	1,210.0	4,750.0	305.0	1,250.0	142.0	580.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	31,735.0	70,968.1	21,434.1	48,772.2	5,885.0	13,140.0	2,020.0	4,225.0	565.0	1,195.0
Total Capacity (Terabytes)		267,306.0		205,397.0		54,701.0		17,528.5		4,859.0
Cumulative Shipments (Units in millions)										
WORLDWIDE TOTAL	53.3	107.9	74.8	156.7	80.6	169.9	82.7	174.1	83.2	175.3

TABLE 41

FIXED DISK DRIVES, 3 - 5 GIGABYTES

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1998 Revenues			Forecast								
				1999			2000		2001		2002	
	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"	3.5"	2.5"	3.5"	2.5"	3.5"	2.5"
U.S. MANUFACTURERS												
Captive	--	736.7	427.1	--	218.2	231.0	--	78.5	--	18.4	--	--
Distributor	76.6	2,390.9	53.2	19.9	782.6	25.8	94.7	8.3	14.7	2.4	1.6	.8
OEM/Integrator	97.7	4,358.9	661.4	27.3	2,072.7	362.3	569.8	148.5	209.8	41.3	33.9	22.6
TOTAL U.S. REVENUES	174.3	7,486.5	1,141.7	47.2	3,073.5	619.1	664.5	235.3	224.5	62.1	35.5	23.4
NON-U.S. MANUFACTURERS												
Captive	--	226.8	841.7	--	174.9	472.3	43.1	173.4	8.7	62.1	--	36.7
Distributor	--	787.0	44.4	--	574.3	22.6	71.2	8.3	6.3	2.3	.8	1.5
OEM/Integrator	--	900.2	737.0	--	693.9	438.5	190.0	182.7	40.3	63.7	12.9	37.8
TOTAL NON-U.S. REVENUES	--	1,914.0	1,623.1	--	1,443.1	933.4	304.3	364.4	55.3	128.1	13.7	76.0
WORLDWIDE RECAP												
Captive	--	963.5	1,268.8	--	393.1	703.3	43.1	251.9	8.7	80.5	--	36.7
	--	-31.8%	+407.1%	--	-59.2%	-44.6%	-89.0%	-64.2%	-79.8%	-68.0%	--	-54.4%
Distributor	76.6	3,177.9	97.6	19.9	1,356.9	48.4	165.9	16.6	21.0	4.7	2.4	2.3
	-28.5%	+81.1%	+502.5%	-74.0%	-57.3%	-50.4%	-87.8%	-65.7%	-87.3%	-71.7%	-88.6%	-51.1%
OEM/Integrator	97.7	5,259.1	1,398.4	27.3	2,766.6	800.8	759.8	331.2	250.1	105.0	46.8	60.4
	-53.6%	+10.9%	+583.8%	-72.1%	-47.4%	-42.7%	-72.5%	-58.6%	-67.1%	-68.3%	-81.3%	-42.5%
Total Revenues	174.3	9,400.5	2,764.8	47.2	4,516.6	1,552.5	968.8	599.7	279.8	190.2	49.2	99.4
	-45.2%	+18.8%	+487.1%	-72.9%	-52.0%	-43.8%	-78.6%	-61.4%	-71.1%	-68.3%	-82.4%	-47.7%
ANNUAL SHARE, BY DIAMETER	1.4%	76.3%	22.3%	.8%	73.9%	25.3%	61.9%	38.1%	59.6%	40.4%	33.2%	66.8%

TABLE 42

FIXED DISK DRIVES, 3 - 5 GIGABYTES

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DISK DIAMETER

	1998 Shipments			Forecast 1999			2000		2001		2002	
	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"	3.5"	2.5"	3.5"	2.5"	3.5"	2.5"
U.S. MANUFACTURERS												
Captive	--	1,185.0	840.0	--	440.0	550.0	--	215.0	--	55.0	--	--
Distributor	657.0	17,140.0	240.0	221.0	7,275.0	140.0	910.0	50.0	145.0	15.0	20.0	5.0
OEM/Integrator	865.0	28,331.6	3,120.0	310.0	20,390.0	2,070.0	6,275.0	940.0	2,490.0	270.0	440.0	150.0
TOTAL U.S. SHIPMENTS	1,522.0	46,656.6	4,200.0	531.0	28,105.0	2,760.0	7,185.0	1,205.0	2,635.0	340.0	460.0	155.0
NON-U.S. MANUFACTURERS												
Captive	--	519.9	1,450.7	--	551.0	945.0	210.0	435.0	50.0	175.0	--	120.0
Distributor	--	5,877.4	216.9	--	5,820.0	125.0	770.0	50.0	75.0	15.0	10.0	10.0
OEM/Integrator	--	6,465.2	4,059.4	--	7,235.2	2,700.0	2,095.0	1,190.0	490.0	445.0	170.0	270.0
TOTAL NON-U.S. SHIPMENTS	--	12,862.5	5,727.0	--	13,606.2	3,770.0	3,075.0	1,675.0	615.0	635.0	180.0	400.0
WORLDWIDE RECAP												
Captive	--	1,704.9	2,290.7	--	991.0	1,495.0	210.0	650.0	50.0	230.0	--	120.0
	--	-4.5%	+462.3%	--	-41.9%	-34.7%	-78.8%	-56.5%	-76.2%	-64.6%	--	-47.8%
Distributor	657.0	23,017.4	456.9	221.0	13,095.0	265.0	1,680.0	100.0	220.0	30.0	30.0	15.0
	+7.7%	+219.8%	+730.7%	-66.4%	-43.1%	-42.0%	-87.2%	-62.3%	-86.9%	-70.0%	-86.4%	-50.0%
OEM/Integrator	865.0	34,796.8	7,179.4	310.0	27,625.2	4,770.0	8,370.0	2,130.0	2,980.0	715.0	610.0	420.0
	-27.3%	+103.4%	+858.9%	-64.2%	-20.6%	-33.6%	-69.7%	-55.3%	-64.4%	-66.4%	-79.5%	-41.3%
Total Shipments	1,522.0	59,519.1	9,927.0	531.0	41,711.2	6,530.0	10,260.0	2,880.0	3,250.0	975.0	640.0	555.0
	-15.4%	+128.1%	+719.7%	-65.1%	-29.9%	-34.2%	-75.4%	-55.9%	-68.3%	-66.1%	-80.3%	-43.1%
ANNUAL SHARE, BY DIAMETER	2.1%	84.0%	13.9%	1.1%	85.6%	13.3%	78.2%	21.8%	77.0%	23.0%	53.7%	46.3%
TOTAL CAPACITY (Terabytes)	6,082.9	226,083.8	35,139.3	2,127.9	177,267.1	26,002.0	43,275.0	11,426.0	13,687.5	3,841.0	2,688.0	2,171.0

TABLE 43

FIXED DISK DRIVES, 3 - 5 GIGABYTES

SUMMARY BY PLATFORM

UNIT SHIPMENTS IN THOUSANDS	1998 Shipments Units	1998 Shipments %	1999 Forecast Units	1999 Forecast %	2000 Forecast Units	2000 Forecast %	2001 Forecast Units	2001 Forecast %	2002 Forecast Units	2002 Forecast %
MOBILE SYSTEM DRIVES	9,927.0	13.9%	6,530.0	13.3%	2,880.0	21.9%	975.0	23.0%	555.0	46.4%
	+719.6%		-34.2%		-55.9%		-66.1%		-43.0%	
2.5 INCH	9,927.0		6,530.0		2,880.0		975.0		555.0	
DESKTOP SYSTEM DRIVES	53,604.3	75.5%	38,967.0	79.9%	9,650.0	73.4%	3,125.0	73.9%	640.0	53.5%
	+160.7%		-27.3%		-75.2%		-67.6%		-79.5%	
5.25 INCH	1,522.0		531.0		--		--		--	
3.5 INCH	52,082.3		38,436.0		9,650.0		3,125.0		640.0	
SERVER SYSTEM DRIVES	7,436.8	10.4%	3,275.2	6.7%	610.0	4.6%	125.0	2.9%	--	--
	+1.4%		-55.9%		-81.3%		-79.5%		--	
3.5 INCH	7,436.8		3,275.2		610.0		125.0		--	
Total Shipments	70,968.1	100.0%	48,772.2	100.0%	13,140.0	100.0%	4,225.0	100.0%	1,195.0	100.0%
	+143.9%		-31.3%		-73.1%		-67.8%		-71.7%	

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

TABLE 44

FIXED DISK DRIVES, 3 - 5 GIGABYTES

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1998 Estimate Units (000)	1998 Estimate %	2002 Projection Units (000)	2002 Projection %
SPECIALIZED HIGH PERFORMANCE Supercomputers, video and high end imaging	--	--	--	--
MAINFRAME SYSTEMS General purpose	283.9	.4	--	--
NETWORK/MIDRANGE SYSTEMS Midrange systems, network servers and workstations	7,167.8	10.1	38.2	3.2
DESKTOP PERSONAL COMPUTERS Business and professional, single user	46,838.9	66.0	311.9	26.1
CONSUMER COMPUTERS Desktop PCs, game, and hobby computers	6,742.0	9.5	290.4	24.3
PORTABLE COMPUTERS Notebook and smaller mobile computers	9,722.6	13.7	546.1	45.7
OTHER APPLICATIONS	212.9	.3	8.4	.7
Total	70,968.1	100.0	1,195.0	100.0

TABLE 45

FIXED DISK DRIVES, 3 - 5 GIGABYTES

WORLDWIDE PRICE PER MEGABYTE ($/MB)

DISK DIAMETER	1998	Forecast 1999	2000	2001	2002
Captive					
5.25"	--	--	--	--	--
3.5"	.131	.091	.049	.041	--
2.5"	.157	.116	.099	.090	.080
Captive Average	.145	.106	.086	.081	.080
Distributor					
5.25"	.029	.023	--	--	--
3.5"	.038	.025	.023	.022	.019
2.5"	.060	.045	.041	.039	.038
Distributor Average	.038	.025	.024	.024	.025
OEM/Integrator					
5.25"	.028	.022	--	--	--
3.5"	.039	.024	.022	.020	.018
2.5"	.055	.042	.039	.037	.036
OEM/Integrator Average	.041	.026	.025	.023	.025

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, 3 - 5 GIGABYTES

MARKET SHARE SUMMARY
Worldwide Shipments of Noncaptive Disk Drives

	1998 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	--	5636.5	--	5636.5	18.7	--	16156.5	--	16156.5	24.1
Quantum	640.0	4250.0	--	4890.0	16.2	1490.0	9564.0	--	11054.0	16.5
Western Digital	--	6695.0	--	6695.0	22.2	--	10436.0	--	10436.0	15.6
Fujitsu	--	2771.1	266.2	3037.3	10.1	--	8069.4	1504.6	9574.0	14.3
Maxtor	--	3959.0	--	3959.0	13.2	--	7921.1	--	7921.1	11.8
IBM	--	900.0	2385.0	3285.0	10.9	--	1334.0	3360.0	4694.0	7.0
Samsung Electronics	--	1828.0	--	1828.0	6.1	--	4269.0	--	4269.0	6.4
Other U.S.	5.0	30.0	--	35.0	.1	32.0	60.0	--	92.0	.1
Other Non-U.S.	--	--	756.7	756.7	2.5	--	4.2	2771.7	2775.9	4.2
TOTAL	645.0	26069.6	3407.9	30122.5	100.0	1522.0	57814.2	7636.3	66972.5	100.0

FIXED DISK DRIVES, 5 - 10 GIGABYTES

1999 DISK/TREND REPORT

FIXED DISK DRIVES, 5 - 10 GIGABYTES

Coverage

Examples of disk drives in this group include:

5.25" disk diameter

Belfort Memory International	P804U**
Quantum	Bigfoot TS**

3"-3.5" disk diameter (Desktop and server drives)

Conner Technology	CT-408**
Fujitsu	MPB3064AT**, MAG3091LV**
Hitachi	DK329H-91**, DK318H-91*
IBM	DTTA-350640**, DMVS-09D/V**
Maxtor	90650U2**, 90845U3**
NEC	DTTA-350840**
Quantum	Fireball CR**, Atlas IV**, Viking II**
Samsung Electronics	SV0642D**, SV0844D**
Seagate Technology	Medalist**, Barracuda**, Cheetah**
Western Digital	WDE9150**, WD64AA**

2.5" disk diameter (Mobile drives)

Fujitsu	MHE2064AT****, MHH2064AT*****
Hitachi	DK228A-65****, DK239A-65*****
IBM	DYLA-28100***, DBCA-206480*****
Toshiba	MK-6409MAV****, MK-6411MAT*****

2.5" disk diameter (Server drives)

Hitachi	DK3E1T-91*

*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 5-10 gigabyte capacity range didn't exist as a disk drive industry product area until IBM introduced the 3390-3 in 1991, using 10.8" disks, with 5,676 megabytes capacity. The 3390-3 stayed in production until 1995, and during most of that period it was IBM's primary disk drive for the mainframe computer systems market. IBM's introduction in Autumn, 1994, of the company's first disk array subsystem for mainframe applications under the recycled RAMAC name effectively replaced IBM's older large diameter drives with arrays of 3.5" drives.

A major share of the sales activity in this capacity range during 1995-96 was generated by 9 gigabyte 5.25" drives, led by the Seagate Elite 9. These drives appeared in mid-1994, and were widely used in arrays and other storage subsystems for mainframe, midrange and network file server applications, offering the most competitive price per megabyte available. IBM skipped 5.25" drives in this range and preannounced an 8.7 gigabyte 3.5" drive in late 1994, later changing the specification to 9.1 gigabytes when the drive went into production in late 1995. 3.5" 9.1 gigabyte drives now dominate the server drive market in this capacity range. 7,200 RPM models dominate the 3.5" server drive market, but the movement to 10,000 RPM initiated by Seagate in 1997 with the Cheetah series has also attracted other drive manufacturers, with most of the latest versions using 3" disks to reduce vibration and power problems. Hitachi has introduced 12,000 RPM server drive models, using 2.5" disks.

Starting in 1997, the increasing disk drive capacity appetite of the desktop personal computer market prompted several drive manufacturers to add drives intended for PC applications, at appropriate performance and price levels, with capacities ranging from 5 to 8.5 gigabytes. Nine drive manufacturers have now introduced 1" high 3.5" drives with IDE interfaces, and Quantum has expanded its Bigfoot 5.25" family to include 6.4 and 8.4 gigabyte models.

The 5-10 gigabyte product group currently includes drives from all four 2.5" drive manufacturers, with capacities ranging from 5 to 9.2 gigabytes. Led by IBM's mid-1997 introduction of the first 2.5" drives in this capacity range, most of the drives now offered are targeted at the growing mobile computer market, but Hitachi's 12,000 RPM models are designed for the specific high-performance requirements of sophisticated server applications.

Market status

1998 was a year of rapid sales expansion for 5-10 gigabyte disk drives, led by 3.5" desktop drives, and in 1999 the product group has become the largest in the industry. Worldwide shipments increased from 1997's 7.6 million to 36.1 million in 1998, up 374.9%, and the 1999 total is forecasted to reach 67.0 million, rising 85.6%. 1998 sales revenues reached $9.2 billion, an increase of 86.2%, and the forecasted $12.1 billion in 1999, is up 31.6%. The percentage increase

for sales revenues is much lower than that for shipments, due to falling average unit prices.

The predominant role of drives for desktop computer applications is a relatively recent development in this product group. 1996 shipments consisted entirely of server drives used primarily with mainframe and midrange computers, network file servers, and a variety of specialized applications requiring high-end disk drives. 55.3% of 1997 shipments were still server drives, but that year also saw the emergence of desktop drives in this capacity range, both 3.5" and 5.25" models, along with early shipments of 2.5" mobile drives. With the surge of growth in 1998 and 1999, shipments of server drives are expected to hold only a 15.1% share of 1999 shipments, with desktop drives at 72.0% and mobile drives at 12.8%.

The product mix within the server drive group is also evolving. About 40% of the server drives in this product group shipped in 1996 were 5.25" models, mostly Seagate's Elite 9. The server drive scene changed in 1997, with a sharp decline in shipments of 5.25" drives, impacted by Seagate's movement to the Elite 23 gigabyte version. 1998 was the last year for 5.25" server drive shipments, and the product mix within the 10.1 million 3.5" server drives forecasted for shipment in 1999 is also changing. The majority of the industry's server drives are currently 7,200 RPM models, following the standard established earlier in the decade. However, Seagate introduced the industry to 10,000 RPM drives in 1997 with the Cheetah series, originally produced with 3.5" disks. After an annoying period of heat, power and vibration problems, Seagate changed to 3" disks in 1998, solving the problems and setting a standard which most of the firm's competitors have emulated.

3.5" desktop drives have also received extensive development activity during the past year, with efforts targeted at both the low-end and high-end products. Most of the drive manufacturers struggling to design the single platter drive with the lowest possible cost this year have concentrated on 4.3 gigabyte models. But those development programs have usually also included a two disk version, and those drives will lower the pricing floor for desktop drives in the 5-10 gigabyte range. The 1998 OEM average unit price for desktop 3.5" drives was $154, but the equivalent price for 1999 is estimated at $115. Drive manufacturers are also attempting to expand the high end of the desktop drive market in this capac-

ity range by introducing higher performance models. During recent years, 5,400 RPM models have predominated, but most manufacturers have introduced 7,200 RPM desktop drives in 1998, hoping that the high end of the desktop market is large enough to justify the effort. The rate at which 7,200 RPM drives replace 5,400 RPM models will probably depend heavily on manufacturers' pricing policies, and most are expected to adopt aggressive programs.

The biggest changes in the mix of applications for disk drives in this product group has already occurred, with the current predominance of desktop computer applications. Server drive usage with mainframe systems is expected to disappear by 2002, and network/midrange system usage will drop from 1998's 19% to 8.1% in 2002. Business desktop PC and consumer computer usage combined will continue to use about 70% of total drive shipments. The largest growth in the share of drives shipped is expected in mobile applications, with portable computers increasing from 5.3% in 1998 to 22.1% in 2002.

Quantum moved up to first place in noncaptive unit shipments for this product group, with 23.12% of the 1998 worldwide total, including both 5.25" and 3.5" models. Seagate dropped to second position, at 18.3%, with mostly 3.5" drives, and IBM was third with 15.6%, including both 3.5" and 2.5" drives.

Marketing trends

After peaking in 1999, it will be a downhill path for shipments in this product group. Relentless increases in areal density and users' hunger for more disk drive capacity will continue to move the industry's average delivered drive capacity to higher levels. In 2002, total shipments of 5-10 gigabyte drives are projected at 5.6 million drives, an average annual decline during 2000-2002 of 51.9%. Since pricing levels will continue to fall, the product group's sales revenues will decline even more rapidly during the same period, dropping an average of 58.2%, to $737.5 million.

Succeeding generations of high capacity server drives will move the preponderance of shipments above this capacity range, but 5-10 gigabyte server drives are expected to remain in production throughout the forecast period for usage with PC servers and other applications.The industry will be closely observing the rate of movement from 7,200 RPM server drives to the 10,000 RPM models avail-

able from several manufacturers, most using 3" disks. Also receiving attention will be the rate at which 7,200 RPM desktop drives displace 5,400 RPM models. In both situations, a trend to higher speeds is expected. Hitachi's initiative in offering the first 12,000 RPM drives using 2.5" disks has alerted the firm's competitors in the server drive business to the possibility of even higher motor speeds in the server drive segment, and several manufacturers of both disk drives and motors are working on 15,000 RPM development programs.

Technical trends

As the industry moves up in recording density, it is always necessary to solve new technical problems involving the head/disk interface, track density/head positioning, semiconductor data rates, new encoding methods, magnetic/electrical interference, new interface requirements, and a myriad of other electronic and mechanical engineering considerations. In addition, there is the challenge of developing and securing reliable supplies of many new components, never previously in quantity production.

Most of the current challenges in developing and manufacturing 5-10 gigabyte drives are much more manageable, and the areas of great difficulty are now found with new development programs for drives in higher capacity ranges. Many of the new high performance drives for the 5-10 gigabyte range will be depopulated models derived from development programs for higher capacity ranges. The completely different development activities targeted at low cost 3.5" and 2.5" drives will also have a major impact on this product group in future years. The basic objective for such programs will be efficient manufacturing.

Forecasting assumptions

1. 5.25" desktop drive shipments will decline and will be halted in 2001, in the face of severe price competition from 3.5" desktop drives produced in larger quantities.
2. Shipments of 3.5" desktop drives with 5-10 gigabyte capacities will peak in 1999, dominated by shipments of low cost models for personal computer applications. 3.5" server drive shipments will also peak in 1999, as higher capacity drives divert sales growth.
3. 2.5" mobile drive shipments will peak in 1999, as sales momentum for mobile drives moves to higher capacity product groups.

TABLE 47

FIXED DISK DRIVES, 5 - 10 GIGABYTES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1998 Revenues		Forecast 1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Captive	1,479.8	2,231.5	1,419.3	2,144.3	614.4	933.7	161.4	242.8	37.4	57.5
Distributor	1,163.5	2,166.3	1,450.1	2,547.0	944.5	1,667.2	225.0	405.9	69.7	126.8
OEM/Integrator	2,128.5	3,872.2	3,086.4	5,155.5	1,846.9	3,107.8	485.6	816.5	141.2	238.8
TOTAL U.S. REVENUES	4,771.8	8,270.0	5,955.8	9,846.8	3,405.8	5,708.7	872.0	1,465.2	248.3	423.1
Non-U.S. Manufacturers										
Captive	16.8	153.3	24.3	245.4	37.0	223.9	18.4	95.3	7.9	39.0
Distributor	131.5	256.4	151.0	369.1	115.0	281.0	33.4	83.2	11.9	30.3
OEM/Integrator	307.8	549.8	787.8	1,688.1	583.0	1,478.0	215.4	609.7	85.4	245.1
TOTAL NON-U.S. REVENUES	456.1	959.5	963.1	2,302.6	735.0	1,982.9	267.2	788.2	105.2	314.4
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	5,227.9	9,229.5	6,918.9	12,149.4	4,140.8	7,691.6	1,139.2	2,253.4	353.5	737.5
OEM Average Price ($000)		.213		.158		.134		.130		.124

TABLE 48

FIXED DISK DRIVES, 5 - 10 GIGABYTES

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1998		Forecast							
	Shipments		1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Captive	2,135.0	3,215.0	2,560.0	3,870.0	1,970.0	2,990.0	567.0	855.0	158.0	240.0
Distributor	5,532.5	10,466.8	9,125.0	16,775.0	6,920.0	12,700.0	1,895.0	3,525.0	633.0	1,175.0
OEM/Integrator	10,040.0	17,938.5	19,370.0	32,565.0	14,275.0	24,325.0	4,050.0	6,900.0	1,300.0	2,215.0
TOTAL U.S. SHIPMENTS	17,707.5	31,620.3	31,055.0	53,210.0	23,165.0	40,015.0	6,512.0	11,280.0	2,091.0	3,630.0
Non-U.S. Manufacturers										
Captive	29.3	248.9	48.0	629.0	85.0	650.0	45.0	275.0	20.0	115.0
Distributor	732.8	1,417.8	1,046.7	2,585.5	855.0	2,120.0	270.0	680.0	105.0	265.0
OEM/Integrator	1,579.4	2,821.7	5,478.3	10,609.0	4,410.0	9,910.0	1,620.0	4,045.0	660.0	1,675.0
TOTAL NON-U.S. SHIPMENTS	2,341.5	4,488.4	6,573.0	13,823.5	5,350.0	12,680.0	1,935.0	5,000.0	785.0	2,055.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	20,049.0	36,108.7	37,628.0	67,033.5	28,515.0	52,695.0	8,447.0	16,280.0	2,876.0	5,685.0
Total Capacity (Terabytes)		259,863.7		511,659.2		378,100.0		118,959.8		42,950.7
Cumulative Shipments (Units in millions)										
WORLDWIDE TOTAL	25.9	45.1	63.6	112.2	92.1	164.9	100.5	181.1	103.4	186.8

TABLE 49

FIXED DISK DRIVES, 5 - 10 GIGABYTES

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1998 Revenues			Forecast										
	1999			2000			2001			2002		
	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"	3.5"	2.5"
U.S. MANUFACTURERS														
Captive	--	2,060.5	171.0	--	1,807.4	336.9	--	715.3	218.4	--	172.5	70.3	57.5	--
Distributor	129.2	2,023.6	13.5	66.4	2,454.1	26.5	40.7	1,609.1	17.4	13.8	387.1	5.0	125.8	1.0
OEM/Integrator	173.5	3,399.7	299.0	78.4	4,259.3	817.8	49.0	2,512.3	546.5	16.2	625.7	174.6	204.0	34.8
TOTAL U.S. REVENUES	302.7	7,483.8	483.5	144.8	8,520.8	1,181.2	89.7	4,836.7	782.3	30.0	1,185.3	249.9	387.3	35.8
NON-U.S. MANUFACTURERS														
Captive	.4	82.1	70.8	--	108.9	136.5	--	78.1	145.8	--	23.7	71.6	9.4	29.6
Distributor	--	252.8	3.6	--	352.9	16.2	--	266.3	14.7	--	75.3	7.9	27.5	2.8
OEM/Integrator	--	458.7	91.1	--	839.9	848.2	--	609.8	868.2	--	179.1	430.6	66.9	178.2
TOTAL NON-U.S. REVENUES	.4	793.6	165.5	--	1,301.7	1,000.9	--	954.2	1,028.7	--	278.1	510.1	103.8	210.6
WORLDWIDE RECAP														
Captive	.4	2,142.6	241.8	--	1,916.3	473.4	--	793.4	364.2	--	196.2	141.9	66.9	29.6
	--	+65.9%	--	--	-10.6%	+95.8%	--	-58.6%	-23.1%	--	-75.3%	-61.0%	-65.9%	-79.1%
Distributor	129.2	2,276.4	17.1	66.4	2,807.0	42.7	40.7	1,875.4	32.1	13.8	462.4	12.9	153.3	3.8
	+83.0%	+184.8%	--	-48.6%	+23.3%	+149.7%	-38.7%	-33.2%	-24.8%	-66.1%	-75.3%	-59.8%	-66.8%	-70.5%
OEM/Integrator	173.5	3,858.4	390.1	78.4	5,099.2	1,666.0	49.0	3,122.1	1,414.7	16.2	804.8	605.2	270.9	213.0
	+11.6%	+48.9%	--	-54.8%	+32.2%	+327.1%	-37.5%	-38.8%	-15.1%	-66.9%	-74.2%	-57.2%	-66.3%	-64.8%
Total Revenues	303.1	8,277.4	649.0	144.8	9,822.5	2,182.1	89.7	5,790.9	1,811.0	30.0	1,463.4	760.0	491.1	246.4
	+34.1%	+76.8%	--	-52.2%	+18.7%	+236.2%	-38.1%	-41.0%	-17.0%	-66.6%	-74.7%	-58.0%	-66.4%	-67.6%
ANNUAL SHARE, BY DIAMETER	3.3%	89.8%	6.9%	1.2%	80.9%	17.9%	1.2%	75.4%	23.4%	1.3%	65.0%	33.7%	66.7%	33.3%

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

TABLE 50

FIXED DISK DRIVES, 5 - 10 GIGABYTES

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DISK DIAMETER

	1998 Shipments			Forecast 1999			2000			2001			2002	
	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"	3.5"	2.5"
U.S. MANUFACTURERS														
Captive	--	2,915.0	300.0	--	3,210.0	660.0	--	2,510.0	480.0	--	690.0	165.0	240.0	--
Distributor	822.0	9,594.8	50.0	595.0	16,070.0	110.0	415.0	12,205.0	80.0	145.0	3,355.0	25.0	1,170.0	5.0
OEM/Integrator	1,132.0	15,656.5	1,150.0	715.0	28,320.0	3,530.0	510.0	21,175.0	2,640.0	175.0	5,825.0	900.0	2,030.0	185.0
TOTAL U.S. SHIPMENTS	1,954.0	28,166.3	1,500.0	1,310.0	47,600.0	4,300.0	925.0	35,890.0	3,200.0	320.0	9,870.0	1,090.0	3,440.0	190.0
NON-U.S. MANUFACTURERS														
Captive	.1	125.0	123.8	--	358.0	271.0	--	315.0	335.0	--	100.0	175.0	40.0	75.0
Distributor	--	1,404.5	13.3	--	2,515.5	70.0	--	2,050.0	70.0	--	640.0	40.0	250.0	15.0
OEM/Integrator	--	2,468.1	353.6	--	6,669.0	3,940.0	--	5,525.0	4,385.0	--	1,730.0	2,315.0	680.0	995.0
TOTAL NON-U.S. SHIPMENTS	.1	3,997.6	490.7	--	9,542.5	4,281.0	--	7,890.0	4,790.0	--	2,470.0	2,530.0	970.0	1,085.0
WORLDWIDE RECAP														
Captive	.1	3,040.0	423.8	--	3,568.0	931.0	--	2,825.0	815.0	--	790.0	340.0	280.0	75.0
	--	+247.4%	--	--	+17.4%	+119.7%	--	-20.8%	-12.5%	--	-72.0%	-58.3%	-64.6%	-77.9%
Distributor	822.0	10,999.3	63.3	595.0	18,585.5	180.0	415.0	14,255.0	150.0	145.0	3,995.0	65.0	1,420.0	20.0
	+267.0%	+552.3%	--	-27.6%	+69.0%	+184.4%	-30.3%	-23.3%	-16.7%	-65.1%	-72.0%	-56.7%	-64.5%	-69.2%
OEM/Integrator	1,132.0	18,124.6	1,503.6	715.0	34,989.0	7,470.0	510.0	26,700.0	7,025.0	175.0	7,555.0	3,215.0	2,710.0	1,180.0
	+138.3%	+328.2%	--	-36.8%	+93.0%	+396.8%	-28.7%	-23.7%	-6.0%	-65.7%	-71.7%	-54.2%	-64.1%	-63.3%
Total Shipments	1,954.1	32,163.9	1,990.7	1,310.0	57,142.5	8,581.0	925.0	43,780.0	7,990.0	320.0	12,340.0	3,620.0	4,410.0	1,275.0
	+179.6%	+373.4%	--	-33.0%	+77.7%	+331.1%	-29.4%	-23.4%	-6.9%	-65.4%	-71.8%	-54.7%	-64.3%	-64.8%
ANNUAL SHARE, BY DIAMETER	5.4%	89.2%	5.4%	2.0%	85.3%	12.7%	1.8%	83.2%	15.0%	2.0%	75.9%	22.1%	77.7%	22.3%
TOTAL CAPACITY (Terabytes)	13,687.4	233,998.0	12,178.3	9,345.0	445,825.2	56,489.0	6,567.5	320,270.8	51,261.8	2,272.0	93,500.9	23,187.0	34,782.8	8,167.9

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

TABLE 51

FIXED DISK DRIVES, 5 - 10 GIGABYTES

SUMMARY BY PLATFORM

UNIT SHIPMENTS IN THOUSANDS	1998 Shipments Units	%	1999 Forecast Units	%	2000 Forecast Units	%	2001 Forecast Units	%	2002 Forecast Units	%
MOBILE SYSTEM DRIVES	1,990.7	5.5%	8,581.0	12.8%	7,990.0	15.1%	3,620.0	22.2%	1,275.0	22.4%
	+1,709.7%		+331.0%		-6.8%		-54.6%		-64.7%	
2.5 INCH	1,990.7		8,581.0		7,990.0		3,620.0		1,275.0	
DESKTOP SYSTEM DRIVES	26,191.5	72.5%	48,297.0	72.0%	39,325.0	74.6%	11,635.0	71.4%	4,105.0	72.2%
	+698.1%		+84.4%		-18.5%		-70.4%		-64.7%	
5.25 INCH	1,950.0		1,310.0		925.0		320.0		--	
3.5 INCH	24,241.5		46,987.0		38,400.0		11,315.0		4,105.0	
SERVER SYSTEM DRIVES	7,926.5	21.9%	10,155.5	15.1%	5,380.0	10.2%	1,025.0	6.3%	305.0	5.3%
	+88.2%		+28.1%		-47.0%		-80.9%		-70.2%	
5.25 INCH	4.1		--		--		--		--	
3.5 INCH	7,922.4		10,155.5		5,380.0		1,025.0		305.0	
Total Shipments	36,108.7	100.0%	67,033.5	100.0%	52,695.0	100.0%	16,280.0	100.0%	5,685.0	100.0%
	+374.9%		+85.6%		-21.4%		-69.1%		-65.1%	

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.

TABLE 52

FIXED DISK DRIVES, 5 - 10 GIGABYTES

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1998 Estimate Units (000)	1998 Estimate %	2002 Projection Units (000)	2002 Projection %
SPECIALIZED HIGH PERFORMANCE Supercomputers, video and high end imaging	72.2	.2	5.7	.1
MAINFRAME SYSTEMS General purpose	1,011.0	2.8	--	--
NETWORK/MIDRANGE SYSTEMS Midrange systems, network servers and workstations	6,860.7	19.0	460.5	8.1
DESKTOP PERSONAL COMPUTERS Business and professional, single user	24,048.4	66.6	3,303.0	58.1
CONSUMER COMPUTERS Desktop PCs, game, and hobby computers	2,130.4	5.9	642.4	11.3
PORTABLE COMPUTERS Notebook and smaller mobile computers	1,913.8	5.3	1,256.3	22.1
OTHER APPLICATIONS	72.2	.2	17.1	.3
Total	36,108.7	100.0	5,685.0	100.0

TABLE 53

FIXED DISK DRIVES, 5 - 10 GIGABYTES

WORLDWIDE PRICE PER MEGABYTE ($/MB)

DISK DIAMETER	1998	Forecast 1999	2000	2001	2002
Captive					
5.25"	.400	--	--	--	--
3.5"	.082	.063	.036	.032	.031
2.5"	.093	.076	.068	.065	.061
Captive Average	.083	.065	.043	.041	.037
Distributor					
5.25"	.022	.015	.014	.013	--
3.5"	.029	.019	.018	.015	.014
2.5"	.044	.036	.033	.031	.030
Distributor Average	.029	.019	.018	.015	.014
OEM/Integrator					
5.25"	.022	.016	.014	.013	--
3.5"	.030	.019	.016	.014	.013
2.5"	.042	.034	.031	.029	.028
OEM/Integrator Average	.030	.021	.019	.018	.017

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.

2.5 inch totals include mobile platform 3 inch drives.

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

TABLE 54

FIXED DISK DRIVES, 5 - 10 GIGABYTES

MARKET SHARE SUMMARY
Worldwide Shipments of Noncaptive Disk Drives

	1998 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	
Quantum	835.0	2480.0	--	3315.0	18.5	1950.0	5596.0	--	7546.0	23.1
Seagate Technology	3.3	2040.0	--	2043.3	11.4	4.0	5968.5	--	5972.5	18.3
IBM	--	2565.0	838.0	3403.0	19.0	--	3900.0	1200.0	5100.0	15.6
Western Digital	--	3555.0	--	3555.0	19.9	--	4964.0	--	4964.0	15.2
Maxtor	--	3256.2	--	3256.2	18.2	--	4822.8	--	4822.8	14.8
Fujitsu	--	1634.8	39.3	1674.1	9.4	--	2791.0	112.7	2903.7	8.9
Other U.S.	--	--	--	--	--	--	--	--	--	--
Other Non-U.S.	--	543.6	94.5	638.1	3.6	--	1081.6	254.2	1335.8	4.1
TOTAL	838.3	16074.6	971.8	17884.7	100.0	1954.0	29123.9	1566.9	32644.8	100.0

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

FIXED DISK DRIVES, 10 - 20 GIGABYTES

1999 DISK/TREND REPORT

FIXED DISK DRIVES, 10 - 20 GIGABYTES

Coverage

Examples of disk drives in this group include:

5.25" disk diameter

Quantum	Bigfoot TS**

3"-3.5" disk diameter (Desktop and server drives)

Fujitsu	MAG3182**, MPD3182AH**
Hitachi	DK319H-18*, DK32AH-18**
IBM	DMVS-18D/V**, DPLA-351500**
Maxtor	91792D7**, 91700U5**
NEC	DJNA-351520**
Quantum	Atlas IV**, Atlas 10K**, Fireball CR**
Samsung Electronics	SP1828D**, SV1003D**
Seagate Technology	Medalist**, Barracuda*, Cheetah*
Western Digital	WDE18310**, WD172AA**

2.5" disk diameter (Mobile drives)

Fujitsu	MHG2102AT****
Hitachi	DK229A-10****
IBM	DCYA-214000***, DCXA-210000****
Toshiba	MK-1011GAV****

2.5" disk diameter (Server drives)

Hitachi	DK3F2-15

*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.

The 10-20 gigabyte product group is a capacity range with very limited previous activity. Prior to the first shipments of 3.5" drives in 1997, the only earlier disk drive available in this capacity range was the IBM 17 gigabyte 3390-9, using 10.8" disks, with shipments from 1993 to 1995.

IBM's widely anticipated "Marlin" drive, a 3.5" server disk drive with 18.2 gigabytes capacity, commenced shipments in October, 1997, the first of a new breed. The 18.2 gigabytes capacity point became a new industry standard, and most of the disk drive manufacturers participating in the server drive market now

offer 7,200 RPM 3.5" drives with that capacity. Seagate's second generation Cheetah server drives became available in 1998, the first 10,000 RPM drives in the 10-20 gigabyte product group. The 18.2 gigabyte Cheetah family was the industry's pioneer in utilizing 3" disks with 10,000 RPM drives, a tactic intended to minimize problems with vibration and power utilization, and later matched by most of Seagate's server drive competitors.

Availability of disk drives for desktop markets has followed closely behind the surge of server drives in this product group. IBM's 3.5" desktop "Titan" series pioneered the area in late 1997, providing 5,400 RPM models with up to 16.8 gigabytes capacity and 7,200 RPM drives with capacities up to 14.4 gigabytes. Similar programs have been launched by all of the other manufacturers active in desktop disk drives. The first 2.5" mobile disk drives in the 10-20 gigabyte range were shipped by IBM in late 1998, and the other three companies currently active in the 2.5" drive market added their products in early 1999.

Market status

Although the first significant shipments of disk drives in the 10-20 gigabyte product group did not occur until late 1997, an impressive range of drives was introduced in 1998. With server, desktop and mobile drives available, the shipment ramp has moved up swiftly in 1999. 1998 unit shipments were 6.6 million drives, and the 1999 total is projected to reach 39.4 million units, up 490.1%. 1998 sales revenues of $3.7 billion are forecasted to grow to $10.6 billion in 1999, an increase of 183.8% -- with the rate of increase held down by the shift in product mix toward a higher proportion of desktop models, and the inevitable downward price trend.

This product group has quickly transitioned from complete reliance on the server drive market to a broad assortment of the disk drive industry's current products. While growing to an expected total of 9.5 million server drives in 1999, the portion of the product group's total shipments held by server drives will have fallen to 17.8%. During the same period, desktop drives are expected to provide 75.6% of 1999's shipments, with 29.8 million drives. 2.5" mobile drives are having a year of broad sales in this capacity range during 1999, with an expected 6.5% of the group's total shipments, at 2.5 million units.

As might be expected, classic server drive applications were a major part of 1998 shipments. Mainframe applications used 12.4% of 1998 total shipments, but mainframe usage is expected to drop to zero in 2002. Network/midrange systems drives were 23.2% of the 1998 shipments, with 6.9% projected for 2002. 60.1% of shipments were used with business desktop computers in 1998, and that pattern is projected to fall slightly in 2002, with 57.5%. During that period consumer computer usage will grow from 2.7% to 8.7%, and portable computer applications will rise sharply from 1.5% to 23.6%. Emerging consumer electronic applications, not a factor in 1998, are projected to use 3.1% of the 2002 shipments.

Maxtor's success during 1998 in developing the high-end portion of the desktop 3.5" drive market put the company in first place in noncaptive shipments for that year, with 26.5% of the worldwide total. Quantum was second with 23.7%, including shipments of both 3.5" and 5.25" drives, and IBM's shipments of a broad range of server, desktop and mobile drives put the company in third place, with 18.9%.

Marketing trends

Life cycles are short in today's disk drive industry, and this product group is maturing rapidly. 10-20 gigabyte drives are expected to lead the industry in unit shipments in 2000, with 77.2 million drives, after only two years of full-scale shipments. However, after the shipment peak in 2000, the trend will be down, with 20.1 million drives projected for 2002, as the market moves to higher drive capacities. Sales revenue is also expected to peak in 2000, at $14.1 billion, then decline to $2.9 billion in 2002.

Server drives are expected to remain a significant factor in the 10-20 gigabyte range through 2002, but their share of total unit shipments will decline to an estimated 6.9%. Server drive shipments will remain substantial due to continuing expected market growth for PC file servers and other low end servers. Server drive shipments will also be helped by the inclination of many disk drive array users to utilize several drives in each array, rather than concentrate all data in one or two very large disk drives.

Following the impressive 2000 peak estimated at 57.9 million units, shipments of desktop drives will also head downward, but not as drastically. 2001 desktop drive shipments are forecasted at 43.0 million, declining to 14.0 million in 2002. After peaking in 2000, shipments of mobile drives will decline relatively slowly, with their share of the group total increasing to 23.6% in 2002. The notebook computer market frequently lags behind desktop PCs in utilizing disk capacity growth.

In the mainframe and file server applications which provided the initial markets for 10-20 gigabyte disk drives, price per megabyte is a principal driving influence, since the cost of the total storage capacity of a server, not the drive unit price, is usually the most important factor. The price per megabyte selling price produced by drives in this product group will evolve with changes in product mix and shipment volume. The initial 18.2 gigabyte server drives in this product group offered an attractive price per megabyte when compared with earlier server drives with lower capacities, with the OEM/Integrator average in 1997 at 6 cents. With the group's shipments now dominated by drives for desktop personal computer applications, the OEM/Integrator average price per megabyte for 3.5" drives has fallen to 1.5 cents in 1999 and is projected at 0.6 cents in 2002.

Technical trends

The specific product requirements of desktop, mobile and server drive markets create important areas of divergence in the application of the disk drive industry's leading edge product development programs. All drive platforms benefit from the industry's basic advances in head and disk recording technology, but each market has different requirements.

The industry's current generation of 18.2 gigabyte server drives are now one inch high models, including both 7,200 and 10,000 RPM motor speeds, which have been developed as portions of product platforms, or families, which also cover capacity ranges above and below this product group. Most now utilize 5 disks, generate exceptionally high internal data rates, incorporate some of the world's more difficult mechanical engineering challenges, and provide MTBF specifications of a million hours.

Mobile drive development programs are no less of a challenge, using the industry's highest areal densities, but emphasizing low power consumption and excellent shock and vibration specifications. Desktop drive designers must enable the factory to produce reasonably reliable products, allow for regular introductions of new models with increased capacity, and achieve the world's lowest disk drive cost.

Forecasting assumptions

1. 5.25" desktop drive shipments will decline each year, with final shipments in 2001.
2. 3.5" desktop drive shipments will peak in 2000, then decline through 2002, losing market share to drives with higher capacities.
3. 3.5" server drive shipments will peak in 2000, declining thereafter.
4. 2.5" mobile drives in this product group will peak in 2000, achieving higher shipments than for 2.5" drives in any other product group, drop slightly in 2001, then start a more rapid decline while losing share to higher capacity mobile drives.

TABLE 55

FIXED DISK DRIVES, 10 - 20 GIGABYTES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1998 Revenues		Forecast 1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Captive	1,006.8	1,519.1	1,323.9	2,008.4	1,465.8	2,218.6	725.4	1,098.8	214.7	322.9
Distributor	368.5	562.6	1,473.4	2,303.0	1,723.6	2,658.3	941.5	1,490.4	254.7	412.7
OEM/Integrator	893.3	1,379.3	3,124.9	4,634.6	3,930.4	5,954.5	2,322.8	3,487.3	712.1	1,052.9
TOTAL U.S. REVENUES	2,268.6	3,461.0	5,922.2	8,946.0	7,119.8	10,831.4	3,989.7	6,076.5	1,181.5	1,788.5
Non-U.S. Manufacturers										
Captive	--	35.2	5.3	202.5	27.0	414.7	28.0	326.4	15.2	144.6
Distributor	25.9	30.6	66.7	93.2	230.4	355.5	156.3	249.2	49.2	84.9
OEM/Integrator	166.5	209.7	994.5	1,363.0	1,393.3	2,570.1	1,070.3	2,119.0	428.5	908.3
TOTAL NON-U.S. REVENUES	192.4	275.5	1,066.5	1,658.7	1,650.7	3,340.3	1,254.6	2,694.6	492.9	1,137.8
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	2,461.0	3,736.5	6,988.7	10,604.7	8,770.5	14,171.7	5,244.3	8,771.1	1,674.4	2,926.3
OEM Average Price ($000)		.407		.227		.158		.137		.133

TABLE 56

FIXED DISK DRIVES, 10 - 20 GIGABYTES

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1998		Forecast							
	Shipments		1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Captive	710.0	1,070.0	1,440.0	2,185.0	2,135.0	3,235.0	1,520.0	2,305.0	490.0	735.0
Distributor	1,021.0	1,620.4	6,095.0	10,190.0	10,605.0	17,100.0	7,335.0	11,970.0	2,260.0	3,725.0
OEM/Integrator	2,227.6	3,564.4	12,755.0	20,000.0	25,285.0	39,320.0	18,335.0	27,915.0	6,095.0	9,065.0
TOTAL U.S. SHIPMENTS	3,958.6	6,254.8	20,290.0	32,375.0	38,025.0	59,655.0	27,190.0	42,190.0	8,845.0	13,525.0
Non-U.S. Manufacturers										
Captive	--	18.5	10.0	332.5	55.0	905.0	60.0	820.0	35.0	375.0
Distributor	66.0	78.7	241.0	376.0	1,395.0	2,260.0	1,120.0	1,840.0	390.0	670.0
OEM/Integrator	276.7	336.8	4,805.0	6,384.0	8,255.0	14,385.0	6,905.0	12,750.0	2,830.0	5,620.0
TOTAL NON-U.S. SHIPMENTS	342.7	434.0	5,056.0	7,092.5	9,705.0	17,550.0	8,085.0	15,410.0	3,255.0	6,665.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	4,301.3	6,688.8	25,346.0	39,467.5	47,730.0	77,205.0	35,275.0	57,600.0	12,100.0	20,190.0
Total Capacity (Terabytes)		92,372.8		569,904.3		1,029,267.0		861,198.0		336,655.0
Cumulative Shipments (Units in millions)										
WORLDWIDE TOTAL	4.4	6.9	29.8	46.3	77.5	123.5	112.8	181.1	124.9	201.3

TABLE 57

FIXED DISK DRIVES, 10 - 20 GIGABYTES

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1998 Revenues			Forecast										
				1999			2000			2001			2002	
	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"	3.5"	2.5"
U.S. MANUFACTURERS														
Captive	--	1,502.6	16.5	--	1,916.0	92.4	--	2,012.0	206.6	--	942.2	156.6	269.6	53.3
Distributor	31.5	529.2	1.9	20.5	2,275.7	6.8	8.4	2,635.3	14.6	3.2	1,475.7	11.5	407.4	5.3
OEM/Integrator	41.0	1,310.1	28.2	27.9	4,444.8	161.9	11.7	5,375.5	567.3	5.0	3,021.3	461.0	840.8	212.1
TOTAL U.S. REVENUES	72.5	3,341.9	46.6	48.4	8,636.5	261.1	20.1	10,022.8	788.5	8.2	5,439.2	629.1	1,517.8	270.7
NON-U.S. MANUFACTURERS														
Captive	--	35.2	--	--	145.4	57.1	--	181.9	232.8	--	106.9	219.5	36.1	108.5
Distributor	--	30.6	--	--	90.6	2.6	--	330.1	25.4	--	226.3	22.9	73.2	11.7
OEM/Integrator	--	209.5	.2	--	983.6	379.4	--	1,170.0	1,400.1	--	805.0	1,314.0	262.1	646.2
TOTAL NON-U.S. REVENUES	--	275.3	.2	--	1,219.6	439.1	--	1,682.0	1,658.3	--	1,138.2	1,556.4	371.4	766.4
WORLDWIDE RECAP														
Captive	--	1,537.8	16.5	--	2,061.4	149.5	--	2,193.9	439.4	--	1,049.1	376.1	305.7	161.8
	--	--	--	--	+34.0%	+806.1%	--	+6.4%	+193.9%	--	-52.2%	-14.4%	-70.9%	-57.0%
Distributor	31.5	559.8	1.9	20.5	2,366.3	9.4	8.4	2,965.4	40.0	3.2	1,702.0	34.4	480.6	17.0
	--	--	--	-34.9%	+322.7%	+394.7%	-59.0%	+25.3%	+325.5%	-61.9%	-42.6%	-14.0%	-71.8%	-50.6%
OEM/Integrator	41.0	1,519.6	28.4	27.9	5,428.4	541.3	11.7	6,545.5	1,967.4	5.0	3,826.3	1,775.0	1,102.9	858.3
	--	+721.4%	--	-32.0%	+257.2%	--	-58.1%	+20.6%	+263.5%	-57.3%	-41.5%	-9.8%	-71.2%	-51.6%
Total Revenues	72.5	3,617.2	46.8	48.4	9,856.1	700.2	20.1	11,704.8	2,446.8	8.2	6,577.4	2,185.5	1,889.2	1,037.1
	--	--	--	-33.2%	+172.5%	--	-58.5%	+18.8%	+249.4%	-59.2%	-43.8%	-10.7%	-71.3%	-52.5%
ANNUAL SHARE, BY DIAMETER	1.9%	96.9%	1.2%	.5%	93.0%	6.5%	.1%	82.7%	17.2%	.1%	75.1%	24.8%	64.7%	35.3%

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

TABLE 58

FIXED DISK DRIVES, 10 - 20 GIGABYTES

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DISK DIAMETER

	1998 Shipments			Forecast 1999			2000			2001			2002	
	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"	5.25"	3.5"	2.5"	3.5"	2.5"
U.S. MANUFACTURERS														
Captive	--	1,050.0	20.0	--	2,020.0	165.0	--	2,830.0	405.0	--	1,980.0	325.0	615.0	120.0
Distributor	150.0	1,465.4	5.0	120.0	10,045.0	25.0	70.0	16,970.0	60.0	30.0	11,890.0	50.0	3,700.0	25.0
OEM/Integrator	210.0	3,279.4	75.0	180.0	19,185.0	635.0	100.0	36,775.0	2,445.0	50.0	25,760.0	2,105.0	8,015.0	1,050.0
TOTAL U.S. SHIPMENTS	360.0	5,794.8	100.0	300.0	31,250.0	825.0	170.0	56,575.0	2,910.0	80.0	39,630.0	2,480.0	12,330.0	1,195.0
NON-U.S. MANUFACTURERS														
Captive	--	18.5	--	--	222.5	110.0	--	430.0	475.0	--	350.0	470.0	125.0	250.0
Distributor	--	78.7	--	--	366.0	10.0	--	2,155.0	105.0	--	1,740.0	100.0	615.0	55.0
OEM/Integrator	--	336.3	.5	--	4,764.0	1,620.0	--	8,190.0	6,195.0	--	6,610.0	6,140.0	2,340.0	3,280.0
TOTAL NON-U.S. SHIPMENTS	--	433.5	.5	--	5,352.5	1,740.0	--	10,775.0	6,775.0	--	8,700.0	6,710.0	3,080.0	3,585.0
WORLDWIDE RECAP														
Captive	--	1,068.5	20.0	--	2,242.5	275.0	--	3,260.0	880.0	--	2,330.0	795.0	740.0	370.0
	--	--	--	--	+109.9%	--	--	+45.4%	+220.0%	--	-28.5%	-9.7%	-68.2%	-53.5%
Distributor	150.0	1,544.1	5.0	120.0	10,411.0	35.0	70.0	19,125.0	165.0	30.0	13,630.0	150.0	4,315.0	80.0
	--	--	--	-20.0%	+574.2%	+600.0%	-41.7%	+83.7%	+371.4%	-57.1%	-28.7%	-9.1%	-68.3%	-46.7%
OEM/Integrator	210.0	3,615.7	75.5	180.0	23,949.0	2,255.0	100.0	44,965.0	8,640.0	50.0	32,370.0	8,245.0	10,355.0	4,330.0
	--	--	--	-14.3%	+562.4%	--	-44.4%	+87.8%	+283.1%	-50.0%	-28.0%	-4.6%	-68.0%	-47.5%
Total Shipments	360.0	6,228.3	100.5	300.0	36,602.5	2,565.0	170.0	67,350.0	9,685.0	80.0	48,330.0	9,190.0	15,410.0	4,780.0
	--	--	--	-16.7%	+487.7%	--	-43.3%	+84.0%	+277.6%	-52.9%	-28.2%	-5.1%	-68.1%	-48.0%
ANNUAL SHARE, BY DIAMETER	5.4%	93.2%	1.4%	.8%	92.8%	6.4%	.2%	87.3%	12.5%	.1%	84.0%	15.9%	76.4%	23.6%
TOTAL CAPACITY (Terabytes)	4,340.1	86,827.7	1,205.0	4,200.0	537,200.3	28,504.0	2,380.0	910,667.0	116,220.0	1,120.0	731,418.0	128,660.0	260,175.0	76,480.0

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

TABLE 59

FIXED DISK DRIVES, 10 - 20 GIGABYTES

SUMMARY BY PLATFORM

UNIT SHIPMENTS IN THOUSANDS	1998 Shipments Units	1998 Shipments %	1999 Forecast Units	1999 Forecast %	2000 Forecast Units	2000 Forecast %	2001 Forecast Units	2001 Forecast %	2002 Forecast Units	2002 Forecast %
MOBILE SYSTEM DRIVES	100.5	1.5%	2,565.0	6.5%	9,685.0	12.5%	9,190.0	15.9%	4,780.0	23.6%
	--		+2,452.2%		+277.5%		-5.1%		-47.9%	
2.5 INCH	100.5		2,565.0		9,685.0		9,190.0		4,780.0	
DESKTOP SYSTEM DRIVES	4,200.3	62.8%	29,865.0	75.6%	57,960.0	75.0%	43,045.0	74.7%	14,010.0	69.3%
	--		+611.0%		+94.0%		-25.7%		-67.4%	
5.25 INCH	360.0		300.0		170.0		80.0		--	
3.5 INCH	3,840.3		29,565.0		57,790.0		42,965.0		14,010.0	
SERVER SYSTEM DRIVES	2,388.0	35.7%	7,037.5	17.8%	9,560.0	12.3%	5,365.0	9.3%	1,400.0	6.9%
	+1,137.9%		+194.7%		+35.8%		-43.8%		-73.9%	
3.5 INCH	2,388.0		7,037.5		9,560.0		5,365.0		1,400.0	
Total Shipments	6,688.8	100.0%	39,467.5	100.0%	77,205.0	100.0%	57,600.0	100.0%	20,190.0	100.0%
	+3,367.5%		+490.1%		+95.6%		-25.4%		-64.9%	

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.

TABLE 60

FIXED DISK DRIVES, 10 - 20 GIGABYTES

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1998 Estimate Units (000)	1998 Estimate %	2002 Projection Units (000)	2002 Projection %
SPECIALIZED HIGH PERFORMANCE Supercomputers, video and high end imaging	6.7	.1	40.4	.2
MAINFRAME SYSTEMS General purpose	829.4	12.4	--	--
NETWORK/MIDRANGE SYSTEMS Midrange systems, network servers and workstations	1,551.8	23.2	1,393.1	6.9
DESKTOP PERSONAL COMPUTERS Business and professional, single user	4,020.0	60.1	11,609.3	57.5
CONSUMER COMPUTERS Desktop PCs, game, and hobby computers	180.6	2.7	1,756.5	8.7
PORTABLE COMPUTERS Notebook and smaller mobile computers	100.3	1.5	4,764.8	23.6
OTHER APPLICATIONS	--	--	625.9	3.1
Total	6,688.8	100.0	20,190.0	100.0

TABLE 61

FIXED DISK DRIVES, 10 - 20 GIGABYTES

WORLDWIDE PRICE PER MEGABYTE ($/MB)

DISK DIAMETER	1998	Forecast 1999	2000	2001	2002
Captive					
5.25"	--	--	--	--	--
3.5"	.085	.056	.041	.026	.023
2.5"	.069	.035	.042	.034	.027
Captive Average	.085	.054	.041	.028	.025
Distributor					
5.25"	.017	.012	.009	.007	--
3.5"	.029	.016	.012	.009	.007
2.5"	.031	.023	.020	.016	.013
Distributor Average	.028	.016	.012	.009	.007
OEM/Integrator					
5.25"	.016	.011	.008	.007	--
3.5"	.031	.015	.011	.008	.006
2.5"	.031	.023	.019	.015	.012
OEM/Integrator Average	.030	.016	.012	.009	.008

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.

2.5 inch totals include mobile platform 3 inch drives.

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

TABLE 62

FIXED DISK DRIVES, 10 - 20 GIGABYTES

MARKET SHARE SUMMARY
Worldwide Shipments of Noncaptive Disk Drives

	1998 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	
Maxtor	--	1095.1	--	1095.1	30.5	--	1482.8	--	1482.8	26.5
Quantum	155.0	440.0	--	595.0	16.5	360.0	970.0	--	1330.0	23.7
IBM	--	655.0	53.0	708.0	19.7	--	980.0	80.0	1060.0	18.9
Seagate Technology	--	523.5	--	523.5	14.6	--	855.0	--	855.0	15.3
Western Digital	--	327.0	--	327.0	9.1	--	457.0	--	457.0	8.2
Fujitsu	--	279.3	.2	279.5	7.8	--	323.4	.5	323.9	5.8
Other U.S.	--	--	--	--	--	--	--	--	--	--
Other Non-U.S.	--	63.2	--	63.2	1.8	--	91.6	--	91.6	1.6
TOTAL	155.0	3383.1	53.2	3591.3	100.0	360.0	5159.8	80.5	5600.3	100.0

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

FIXED DISK DRIVES, 20 - 40 GIGABYTES

1999 DISK/TREND REPORT

FIXED DISK DRIVES, 20 - 40 GIGABYTES

Coverage

Examples of disk drives in this group include:

3"-3.5" disk diameter (Desktop and server drives)

Fujitsu	MAF3364*
IBM	DMVS-36D/V*, DPLA-353750**
Maxtor	92048D8**, 92720U8**
Quantum	Fireball CX**, Atlas IV*, Atlas 10K*
Samsung Electronics	SP2728D**, SV2016D**
Seagate Technology	Cheetah*, Barracuda*, Barracuda ATA**
Western Digital	WD205AA**, WD272AB**

*Maximum 41.3 mm height, or less.
**Maximum 25.4 mm height, or less.

The first disk drive to be an active participant in the 20-40 gigabyte range of capacities was the Seagate Technology 5.25" Elite 23, a 23 gigabyte descendant of the company's successful Elite 9. The Elite 23, which entered the market in the second half of 1996, offered the industry's best price per megabyte at that time for high performance drives. As a result, shipments for high-end mainframe and open systems server applications reached significant levels in 1997. The Elite 23 was superseded by Seagate's Elite 47, with a capacity above this product group, and the 23 gigabyte model was phased out in 1998.

In the second half of 1998, both desktop and server 3.5" drives became available in the 20-40 gigabyte range, joined in 1999 by 3" server drives operating at 10,000 RPM. Server drives of various types will obviously have an important role in this capacity range, but eventually shipments of desktop drives are expected to dominate the product group. Already most of the manufacturers of desktop drives are active in the product group, and growth is expected to be rapid in the next few years. The first 2.5" notebook drives with capacities in this product group have yet to be announced, but current DISK/TREND forecasts expect that event during this year.

Market status

The 20-40 gigabyte product group was still in its infancy last year, with shipments of only 57,500 drives and sales revenues of $62.4 million. A much

higher level of activity is occurring in 1999, with numerous drive manufacturers selling desktop 3.5" drives in the 20 to 37 gigabyte range and offering various types of server drives, mostly with capacities of about 36 gigabytes. Unit shipments of 2.7 million drives are forecasted for 1999, with sales revenue of $1.7 billion.

While 1999 unit shipments of server 3.5" drives are projected to reach almost a million units, shipments of desktop 3.5" drives are expected to reach 1.6 million. The demand for increased disk drive capacity in the upper third of the personal computer industry remains strong, driven by Internet, image storage and other applications. Many PC manufacturers are also anxious to add high capacity disk drives to their product offerings to increase differentiation with the highly promoted low end of the personal computer market, and are motivated to action by the attractive prices available for desktop drives. As areal density increases, and the platter count for individual drives constantly goes down, 1999 OEM average unit prices for desktop drives in this product group are about the same as last year's OEM prices for drives with half the capacity.

Marketing trends

The next three years are expected to provide dynamic growth in unit shipments for desktop, mobile and server drives in the 20-40 gigabyte product group. Explosive growth is forecasted for next year, with unit shipments jumping to 42.8 million drives, generating sales revenues of $10.6 billion. 2001 is again expected to see dynamic growth, with unit shipments rising to 88.3 million drives, up 106.4%, as the product group becomes the industry leader. While sales revenues are also projected to assume industry leadership in 2001 with $15.9 billion, the percentage increase will inevitably be more modest, at 58.8%, as the market share for higher priced server drives continues to decline, along with average price levels. By 2002, unit shipments for the product group are forecasted to drop to 66.0 million drives, with sales revenues declining to $10.2 billion, as shipment leadership again moves up to high capacities.

1998's modest unit shipments were concentrated in mainframe and network/midrange system applications, with a modest 23.5% of all drives used in various personal computer markets. In 2002, all of the midrange, mainframe and

high performance applications will be less than 10% of the total, with business and consumer PCs using almost 70%, and portable computers taking almost 15%. Notably, other applications, including new consumer electronic markets, are projected to consume 6.4% of the total, over 4 million drives.

Technical trends

The basic research essential to develop the drives for this product group has already been done, and the major challenge for manufacturers of disk drives and the components incorporated in them is to manage their development programs efficiently. The most effective competitors in these markets will be the manufacturers which are able to reduce most rapidly the quantity of critical components in each drive, with emphasis on heads, disks and semiconductors. The industry's well known areal density curve, always moving upward, makes it possible to achieve most of the parts count reductions. And, of course, the reduced parts count is what drives each of the industry's frequent product life cycles -- all to offer drives at continually lower cost. By 2002 most of the 3"-3.5" drives sold in this product group will be manufactured with one or two platters, and by the end of that year, we may even see the first of the single platter 2.5" drives.

Forecasting assumptions

1. Server drives will be improved with higher motor speeds, reduced platter count, using mostly 1" height configurations during the forecast period, and shipments will peak in 2001.
2. 3.5" desktop drives will continue to be improved in motor speed, parts count, reliability, and in generally lower prices, and shipments will peak in 2001.
3. Shipments of 2.5" mobile market drives will start by the end of 1999, with rapidly growing sales through 2001, with falling parts count and price levels throughout the forecast period.

TABLE 63

FIXED DISK DRIVES, 20 - 40 GIGABYTES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1998		Forecast							
	Revenues		1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Captive	1.6	2.7	441.0	655.0	1,294.7	1,913.5	1,570.8	2,330.4	999.4	1,481.9
Distributor	35.0	42.9	186.3	240.7	1,435.1	1,916.6	1,978.4	2,781.8	1,037.9	1,560.9
OEM/Integrator	15.5	16.8	523.1	699.3	3,422.3	4,816.0	4,746.2	7,111.9	2,608.3	4,136.9
TOTAL U.S. REVENUES	52.1	62.4	1,150.4	1,595.0	6,152.1	8,646.1	8,295.4	12,224.1	4,645.6	7,179.7
Non-U.S. Manufacturers										
Captive	--	--	--	32.9	2.5	148.8	27.2	414.7	34.9	367.3
Distributor	--	--	19.7	22.0	175.3	263.8	314.9	493.5	205.6	333.7
OEM/Integrator	--	--	89.4	107.8	652.8	994.8	1,539.8	2,836.4	1,190.9	2,366.9
TOTAL NON-U.S. REVENUES	--	--	109.1	162.7	830.6	1,407.4	1,881.9	3,744.6	1,431.4	3,067.9
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	52.1	62.4	1,259.5	1,757.7	6,982.7	10,053.5	10,177.3	15,968.7	6,077.0	10,247.6
OEM Average Price ($000)		.840		.467		.198		.160		.139

TABLE 64

FIXED DISK DRIVES, 20 - 40 GIGABYTES

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1998 Shipments		Forecast 1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Captive	3.0	5.0	380.0	565.0	1,540.0	2,290.0	2,985.0	4,445.0	2,095.0	3,120.0
Distributor	26.5	32.5	303.0	378.0	7,230.0	9,650.0	12,750.0	18,100.0	8,390.0	12,790.0
OEM/Integrator	19.0	20.0	1,062.0	1,412.0	16,955.0	24,100.0	30,340.0	46,145.0	19,870.0	32,340.0
TOTAL U.S. SHIPMENTS	48.5	57.5	1,745.0	2,355.0	25,725.0	36,040.0	46,075.0	68,690.0	30,355.0	48,250.0
Non-U.S. Manufacturers										
Captive	--	--	--	20.0	5.0	285.0	55.0	955.0	75.0	925.0
Distributor	--	--	40.0	45.0	840.0	1,345.0	1,840.0	3,000.0	1,480.0	2,450.0
OEM/Integrator	--	--	275.0	313.0	3,430.0	5,160.0	8,960.0	15,745.0	7,750.0	14,435.0
TOTAL NON-U.S. SHIPMENTS	--	--	315.0	378.0	4,275.0	6,790.0	10,855.0	19,700.0	9,305.0	17,810.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	48.5	57.5	2,060.0	2,733.0	30,000.0	42,830.0	56,930.0	88,390.0	39,660.0	66,060.0
Total Capacity (Terabytes)		1,714.5		73,336.4		1,126,439.0		2,596,362.0		2,162,140.0
Cumulative Shipments (Units in millions)										
WORLDWIDE TOTAL	.1	.2	2.2	2.9	32.2	45.7	89.1	134.1	128.8	200.2

TABLE 65

FIXED DISK DRIVES, 20 - 40 GIGABYTES

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1998 Revenues		Forecast							
			1999		2000		2001		2002	
	5.25"	3.5"	3.5"	2.5"	3.5"	2.5"	3.5"	2.5"	3.5"	2.5"
U.S. MANUFACTURERS										
Captive	--	2.7	640.2	14.8	1,792.5	121.0	2,033.2	297.2	1,296.7	185.2
Distributor	3.3	39.6	240.7	--	1,908.3	8.3	2,761.4	20.4	1,548.5	12.4
OEM/Integrator	13.2	3.6	671.1	28.2	4,439.9	376.1	6,263.0	848.9	3,634.7	502.2
TOTAL U.S. REVENUES	16.5	45.9	1,552.0	43.0	8,140.7	505.4	11,057.6	1,166.5	6,479.9	699.8
NON-U.S. MANUFACTURERS										
Captive	--	--	32.9	--	126.1	22.7	204.7	210.0	134.8	232.5
Distributor	--	--	22.0	--	261.0	2.8	469.4	24.1	309.9	23.8
OEM/Integrator	--	--	107.8	--	819.3	175.5	1,463.5	1,372.9	974.9	1,392.0
TOTAL NON-U.S. REVENUES	--	--	162.7	--	1,206.4	201.0	2,137.6	1,607.0	1,419.6	1,648.3
WORLDWIDE RECAP										
Captive	-- --	2.7 --	673.1 --	14.8 --	1,918.6 +185.0%	143.7 +870.9%	2,237.9 +16.6%	507.2 +253.0%	1,431.5 -36.0%	417.7 -17.6%
Distributor	3.3 -91.0%	39.6 --	262.7 +563.4%	-- --	2,169.3 +725.8%	11.1 --	3,230.8 +48.9%	44.5 +300.9%	1,858.4 -42.5%	36.2 -18.7%
OEM/Integrator	13.2 -93.1%	3.6 --	778.9 --	28.2 --	5,259.2 +575.2%	551.6 --	7,726.5 +46.9%	2,221.8 +302.8%	4,609.6 -40.3%	1,894.2 -14.7%
Total Revenues	16.5 -92.8%	45.9 --	1,714.7 --	43.0 --	9,347.1 +445.1%	706.4 --	13,195.2 +41.2%	2,773.5 +292.6%	7,899.5 -40.1%	2,348.1 -15.3%
ANNUAL SHARE, BY DIAMETER	26.4%	73.6%	97.7%	2.3%	93.1%	6.9%	82.7%	17.3%	77.2%	22.8%

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

TABLE 66

FIXED DISK DRIVES, 20 - 40 GIGABYTES

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DISK DIAMETER

	1998 Shipments		Forecast							
			1999		2000		2001		2002	
	5.25"	3.5"	3.5"	2.5"	3.5"	2.5"	3.5"	2.5"	3.5"	2.5"
U.S. MANUFACTURERS										
Captive	--	5.0	545.0	20.0	2,060.0	230.0	3,860.0	585.0	2,730.0	390.0
Distributor	2.5	30.0	378.0	--	9,620.0	30.0	18,015.0	85.0	12,735.0	55.0
OEM/Integrator	10.0	10.0	1,332.0	80.0	22,670.0	1,430.0	42,470.0	3,675.0	30,015.0	2,325.0
TOTAL U.S. SHIPMENTS	12.5	45.0	2,255.0	100.0	34,350.0	1,690.0	64,345.0	4,345.0	45,480.0	2,770.0
NON-U.S. MANUFACTURERS										
Captive	--	--	20.0	--	240.0	45.0	530.0	425.0	425.0	500.0
Distributor	--	--	45.0	--	1,335.0	10.0	2,900.0	100.0	2,345.0	105.0
OEM/Integrator	--	--	313.0	--	4,485.0	675.0	9,750.0	5,995.0	7,900.0	6,535.0
TOTAL NON-U.S. SHIPMENTS	--	--	378.0	--	6,060.0	730.0	13,180.0	6,520.0	10,670.0	7,140.0
WORLDWIDE RECAP										
Captive	-- --	5.0 --	565.0 --	20.0 --	2,300.0 +307.1%	275.0 --	4,390.0 +90.9%	1,010.0 +267.3%	3,155.0 -28.1%	890.0 -11.9%
Distributor	2.5 -90.0%	30.0 --	423.0 --	-- --	10,955.0 --	40.0 --	20,915.0 +90.9%	185.0 +362.5%	15,080.0 -27.9%	160.0 -13.5%
OEM/Integrator	10.0 -92.3%	10.0 --	1,645.0 --	80.0 --	27,155.0 --	2,105.0 --	52,220.0 +92.3%	9,670.0 +359.4%	37,915.0 -27.4%	8,860.0 -8.4%
Total Shipments	12.5 -91.9%	45.0 --	2,633.0 --	100.0 --	40,410.0 --	2,420.0 --	77,525.0 +91.8%	10,865.0 +349.0%	56,150.0 -27.6%	9,910.0 -8.8%
ANNUAL SHARE, BY DIAMETER	21.7%	78.3%	96.4%	3.6%	94.4%	5.6%	87.8%	12.2%	85.1%	14.9%
TOTAL CAPACITY (Terabytes)	292	1,422	71,236	2,100	1,075,619	50,820	2,335,602	260,760	1,894,570	267,570

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

TABLE 67

FIXED DISK DRIVES, 20 - 40 GIGABYTES

SUMMARY BY PLATFORM

UNIT SHIPMENTS IN THOUSANDS	1998 Shipments Units	1998 Shipments %	1999 Forecast Units	1999 Forecast %	2000 Forecast Units	2000 Forecast %	2001 Forecast Units	2001 Forecast %	2002 Forecast Units	2002 Forecast %
MOBILE SYSTEM DRIVES	--	--	100.0	3.6%	2,420.0	5.6%	10,865.0	12.2%	9,910.0	15.0%
	--		--		+2,320.0%		+348.9%		-8.7%	
2.5 INCH	--		100.0		2,420.0		10,865.0		9,910.0	
DESKTOP SYSTEM DRIVES	15.0	26.0%	1,635.0	59.8%	33,800.0	78.9%	68,145.0	77.1%	49,975.0	75.6%
	--		--		+1,967.2%		+101.6%		-26.6%	
3.5 INCH	15.0		1,635.0		33,800.0		68,145.0		49,975.0	
SERVER SYSTEM DRIVES	42.5	73.9%	998.0	36.5%	6,610.0	15.4%	9,380.0	10.6%	6,175.0	9.3%
	-72.5%		+2,248.2%		+562.3%		+41.9%		-34.1%	
5.25 INCH	12.5		--		--		--		--	
3.5 INCH	30.0		998.0		6,610.0		9,380.0		6,175.0	
Total Shipments	57.5	100.0%	2,733.0	100.0%	42,830.0	100.0%	88,390.0	100.0%	66,060.0	100.0%
	-62.9%		+4,653.0%		+1,467.1%		+106.4%		-25.3%	

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.

TABLE 68

FIXED DISK DRIVES, 20 - 40 GIGABYTES

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1998 Estimate Units (000)	1998 Estimate %	2002 Projection Units (000)	2002 Projection %
SPECIALIZED HIGH PERFORMANCE				
Supercomputers, video and high end imaging	--	--	66.1	.1
MAINFRAME SYSTEMS				
General purpose	32.9	57.3	528.5	.8
NETWORK/MIDRANGE SYSTEMS				
Midrange systems, network servers and workstations	11.0	19.2	5,615.1	8.5
DESKTOP PERSONAL COMPUTERS				
Business and professional, single user	13.1	22.7	42,674.8	64.6
CONSUMER COMPUTERS				
Desktop PCs, game, and hobby computers	.5	.8	3,104.8	4.7
PORTABLE COMPUTERS				
Notebook and smaller mobile computers	--	--	9,842.9	14.9
OTHER APPLICATIONS	--	--	4,227.8	6.4
Total	57.5	100.0	66,060.0	100.0

TABLE 69

FIXED DISK DRIVES, 20 - 40 GIGABYTES

WORLDWIDE PRICE PER MEGABYTE ($/MB)

DISK DIAMETER	1998	Forecast 1999	2000	2001	2002
Captive					
5.25"	--	--	--	--	--
3.5"	.024	.042	.026	.015	.013
2.5"	--	.035	.025	.021	.017
Captive Average	.024	.041	.026	.016	.014
Distributor					
5.25"	.057	--	--	--	--
3.5"	.036	.022	.008	.005	.004
2.5"	--	--	.013	.010	.008
Distributor Average	.037	.022	.008	.005	.004
OEM/Integrator					
5.25"	.056	--	--	--	--
3.5"	.016	.018	.007	.005	.004
2.5"	--	.017	.012	.010	.008
OEM/Integrator Average	.037	.018	.008	.006	.004

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.

2.5 inch totals include mobile platform 3 inch drives.

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

FIXED DISK DRIVES, 40 - 80 GIGABYTES

1999 DISK/TREND REPORT

FIXED DISK DRIVES, 40 - 80 GIGABYTES

Coverage

Examples of disk drives in this group include:

3.5" disk diameter

Seagate Technology	Barracuda 50

When Seagate Technology introduced the 5.25" Elite 47 in late 1997, the first disk drive with more than 40 gigabytes capacity appeared on the scene, offering that year's best price per megabyte for high performance disk drives. As the upgrade to Seagate's Elite 23, the 47 gigabyte version of the Elite family was assured of a ready market with file servers designed for mainframe systems and enterprise open systems applications, as well as video server and imaging markets. In the first half of 1999, Seagate phased out the Elite 47, as it became feasible to produce 3.5" drives with similar capacities.

Seagate's replacement for the Elite 47 is the 3.5" 50.1 gigabyte Barracuda 50. Most major manufacturers of server disk drives, including Seagate, have introduced 7,200 RPM drives with capacities of about 36 gigabytes. As the result of adding one disk and increasing recording density by a modest amount, Seagate was able to boost the capacity of its Barracuda family to 50.1 gigabytes. By using the 3.5" Barracuda 50, a storage subsystem manufacturer is able to double the capacity of a subsystem while using the same physical space for disk drives previously utilized for the same quantity of 5.25" Elite 47 drives.

It is expected that other 3.5" server drives in this capacity range will become available later in 1999, as manufacturers introduce drives with double the capacity of their current 36 gigabyte models. Desktop drives with more than 40 gigabyte capacities are expected to be available in 2000, from several drive manufacturers which already have 3.5" desktop drive families utilizing up to four disks. The recording densities which will be available in 2000 are expected to make possible the production of 3.5" desktop drives with more than 10 gigabytes per platter. The upward trend in recording densities is also expected to boost the capacity per 2.5" disk above the 10 gigabyte level in 2001, resulting in the introduction of the first mobile market drives in the 40-80 gigabyte range in that year.

Market status

The current market activity in this product group is limited to Seagate's shipments of Barracuda 50 drives. Seagate's Elite 47 shipments were the only activity in 1998, generating unit shipments of 109,500 drives, with sales revenue estimated at $159 million. The 1998 totals will include a combination of the phase out of Elite 47 sales, combined with sales of Seagate's new Barracuda 50 and the 72 gigabyte 3.5" server drives expected later in the year. The 1998 unit shipment total is forecasted at 189,000 units, with sales revenue of $269.6 million.

The market for the currently available server drives in this product group consists mostly of mainframe computer and other enterprise systems storage subsystems, plus selective usage in a variety of specialized video, medical and other imaging applications. The attractive current price per megabyte available with these drives, less than 3 cents at the OEM level, combined with reduced space requirements in storage subsystems, is especially attractive in enterprise system applications which do not demand the fastest possible drive access times, including many data warehouse systems and any file server requirement with modest transaction rates.

Marketing trends

Although the current activity level in the 40-80 gigabyte capacity range is relatively small, it is projected to become the industry's largest product group in 2002. The ramp will be impressive, with the DISK/TREND forecast for 2000 at 3.7 million drives, jumping to 46.9 million in 2001 and 101.2 million in 2002. By that year, sales revenues for the product group are expected to reach $18.5 billion.

As usual, the key factors underlying the industry's fast climb to higher disk drive capacities will be the market's continued appetite for new applications and more storage, combined with falling price per megabyte levels. In 2002, the OEM average price per megabyte for 3.5" drives in this product group will be 0.2 cents, and the OEM price per megabyte for 2.5" drives will be 0.5 cents.

Server drive shipments are expected to increase rapidly in 2000, reaching a total of 3.3 million units, with 1" high models becoming available by the end of the

year. Further growth in the market for 40-80 gigabyte server drives is expected through the end of the forecast period, with 9.2 million projected for 2002, but the server drive share of overall 2002 shipments is destined to drop to 9.1%, as desktop and mobile drives assume dominance. After a modest 2000 start, desktop drive shipments are forecasted to reach 78.8 million in 2002, consisting mostly of attractively priced two platter models, and accounting for 77.9% of the product group's shipments. 2.5" mobile drives are expected to hold 12.9% of the 40-80 gigabyte shipments in 2002, with 13.1 million drives, mostly three platter versions.

Technical trends

The basic research in disk recording technology which will be required to produce the disk drives forecasted in this report through 2002 has been done, leaving numerous product development milestones as the significant challenges. If the industry is able to achieve an average 60% annual improvement in the highest recording densities used in production drives through 2002, the highest density to be achieved in production drives by the end of that period will be at least 37 gigabits per square inch -- a level adequate to deliver the drive prices anticipated for 2002. Refinements of currently available recording heads and disks can reach these levels, and clever developments in head suspensions, motors and encoding schemes are to be expected. Semiconductor improvements and further evolution of controllers and interfaces will be required. Reaching the overall capacity levels required for the 2002 disk drives envisioned in this product group is an objective which it is expected the industry will accomplish.

Forecasting assumptions

1. IBM and other drive manufacturers will be successful in improving areal density utilized in disk drives by an average of at least 60% per year.
2. First shipments of 3.5" server drives with 72 gigabytes capacity will be initiated in 1999, with continuous shipment increases through 2002.
3. Shipments of 3.5" desktop drives for personal computer markets will start in 2000, with rapid growth in 2001.
4. The first shipments of 2.5" drives for mobile applications will start in 2001, with rapid growth in 2002.

TABLE 70

FIXED DISK DRIVES, 40 - 80 GIGABYTES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1998 Revenues		Forecast							
			1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Captive	--	--	20.9	29.8	152.0	208.4	1,361.3	1,960.0	1,643.0	2,422.2
Distributor	8.2	11.9	113.5	119.9	357.7	445.4	1,542.5	2,040.5	2,056.2	2,908.7
OEM/Integrator	100.1	147.2	89.0	119.9	946.0	1,185.8	4,314.4	5,947.0	5,973.3	8,554.8
TOTAL U.S. REVENUES	108.3	159.1	223.4	269.6	1,455.7	1,839.6	7,218.2	9,947.5	9,672.5	13,885.7
Non-U.S. Manufacturers										
Captive	--	--	--	--	--	16.4	3.5	172.0	50.8	504.4
Distributor	--	--	--	--	35.3	44.9	197.2	308.4	337.3	563.9
OEM/Integrator	--	--	--	--	108.6	143.9	784.0	1,253.2	1,862.5	3,623.2
TOTAL NON-U.S. REVENUES	--	--	--	--	143.9	205.2	984.7	1,733.6	2,250.6	4,691.5
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	108.3	159.1	223.4	269.6	1,599.6	2,044.8	8,202.9	11,681.1	11,923.1	18,577.2
OEM Average Price ($000)		1.450		1.262		.526		.220		.168

TABLE 71

FIXED DISK DRIVES, 40 - 80 GIGABYTES

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1998 Shipments		Forecast 1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Captive	--	--	7.0	10.0	155.0	215.0	1,840.0	2,660.0	3,630.0	5,350.0
Distributor	5.5	8.0	79.0	84.0	695.0	865.0	7,415.0	9,855.0	13,435.0	19,115.0
OEM/Integrator	69.0	101.5	70.0	95.0	1,790.0	2,250.0	19,420.0	26,905.0	37,215.0	53,290.0
TOTAL U.S. SHIPMENTS	74.5	109.5	156.0	189.0	2,640.0	3,330.0	28,675.0	39,420.0	54,280.0	77,755.0
Non-U.S. Manufacturers										
Captive	--	--	--	--	--	15.0	5.0	315.0	115.0	1,110.0
Distributor	--	--	--	--	65.0	85.0	955.0	1,550.0	2,130.0	3,570.0
OEM/Integrator	--	--	--	--	205.0	275.0	3,625.0	5,685.0	10,305.0	18,825.0
TOTAL NON-U.S. SHIPMENTS	--	--	--	--	270.0	375.0	4,585.0	7,550.0	12,550.0	23,505.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	74.5	109.5	156.0	189.0	2,910.0	3,705.0	33,260.0	46,970.0	66,830.0	101,260.0
Total Capacity (Terabytes)		5,152.8		11,181.1		258,463.0		2,690,452.0		6,389,163.0
Cumulative Shipments (Units in millions)										
WORLDWIDE TOTAL	--	.1	.2	.3	3.1	4.0	36.4	50.9	103.2	152.2

TABLE 72

FIXED DISK DRIVES, 40 - 80 GIGABYTES

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1998 Revenues	Forecast						
		1999		2000	2001		2002	
	5.25"	5.25"	3.5"	3.5"	3.5"	2.5"	3.5"	2.5"
U.S. MANUFACTURERS								
Captive	--	--	29.8	208.4	1,807.1	152.9	2,080.7	341.5
Distributor	11.9	12.0	107.9	445.4	2,030.3	10.2	2,884.3	24.4
OEM/Integrator	147.2	32.8	87.1	1,185.8	5,486.9	460.1	7,536.9	1,017.9
TOTAL U.S. REVENUES	159.1	44.8	224.8	1,839.6	9,324.3	623.2	12,501.9	1,383.8
NON-U.S. MANUFACTURERS								
Captive	--	--	--	16.4	136.6	35.4	218.8	285.6
Distributor	--	--	--	44.9	303.3	5.1	530.0	33.9
OEM/Integrator	--	--	--	143.9	987.5	265.7	1,596.8	2,026.4
TOTAL NON-U.S. REVENUES	--	--	--	205.2	1,427.4	306.2	2,345.6	2,345.9
WORLDWIDE RECAP								
Captive	--	--	29.8	224.8	1,943.7	188.3	2,299.5	627.1
	--	--	--	+654.4%	+764.6%	--	+18.3%	+233.0%
Distributor	11.9	12.0	107.9	490.3	2,333.6	15.3	3,414.3	58.3
	--	+.8%	--	+354.4%	+376.0%	--	+46.3%	+281.0%
OEM/Integrator	147.2	32.8	87.1	1,329.7	6,474.4	725.8	9,133.7	3,044.3
	--	-77.7%	--	--	+386.9%	--	+41.1%	+319.4%
Total Revenues	159.1	44.8	224.8	2,044.8	10,751.7	929.4	14,847.5	3,729.7
	--	-71.8%	--	+809.6%	+425.8%	--	+38.1%	+301.3%
ANNUAL SHARE, BY DIAMETER	100.0%	16.6%	83.4%	100.0%	92.1%	7.9%	80.0%	20.0%

Note: 3.5 inch totals include server platform 3 inch drives.

TABLE 73

FIXED DISK DRIVES, 40 - 80 GIGABYTES

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DISK DIAMETER

	1998 Shipments	Forecast						
		1999		2000	2001		2002	
	5.25"	5.25"	3.5"	3.5"	3.5"	2.5"	3.5"	2.5"
U.S. MANUFACTURERS								
Captive	--	--	10.0	215.0	2,450.0	210.0	4,755.0	595.0
Distributor	8.0	9.0	75.0	865.0	9,825.0	30.0	19,025.0	90.0
OEM/Integrator	101.5	25.0	70.0	2,250.0	25,515.0	1,390.0	49,390.0	3,900.0
TOTAL U.S. SHIPMENTS	109.5	34.0	155.0	3,330.0	37,790.0	1,630.0	73,170.0	4,585.0
NON-U.S. MANUFACTURERS								
Captive	--	--	--	15.0	265.0	50.0	600.0	510.0
Distributor	--	--	--	85.0	1,535.0	15.0	3,445.0	125.0
OEM/Integrator	--	--	--	275.0	4,870.0	815.0	10,940.0	7,885.0
TOTAL NON-U.S. SHIPMENTS	--	--	--	375.0	6,670.0	880.0	14,985.0	8,520.0
WORLDWIDE RECAP								
Captive	-- --	-- --	10.0 --	230.0 --	2,715.0 --	260.0 --	5,355.0 +97.2%	1,105.0 +325.0%
Distributor	8.0 --	9.0 +12.5%	75.0 --	950.0 --	11,360.0 --	45.0 --	22,470.0 +97.8%	215.0 +377.8%
OEM/Integrator	101.5 --	25.0 -75.4%	70.0 --	2,525.0 --	30,385.0 --	2,205.0 --	60,330.0 +98.6%	11,785.0 +434.5%
Total Shipments	109.5 --	34.0 -68.9%	155.0 --	3,705.0 --	44,460.0 --	2,510.0 --	88,155.0 +98.3%	13,105.0 +422.1%
ANNUAL SHARE, BY DIAMETER	100.0%	18.0%	82.0%	100.0%	94.8%	5.2%	87.2%	12.8%
TOTAL CAPACITY (Terabytes)	5,152	1,599	9,581	258,463	2,585,032	105,420	5,760,123	629,040

Note: 3.5 inch totals include server platform 3 inch drives.

TABLE 74

FIXED DISK DRIVES, 40 - 80 GIGABYTES

SUMMARY BY PLATFORM

UNIT SHIPMENTS IN THOUSANDS	1998 Shipments Units	1998 Shipments %	Forecast 1999 Units	1999 %	2000 Units	2000 %	2001 Units	2001 %	2002 Units	2002 %
MOBILE SYSTEM DRIVES	--	--	--	--	--	--	2,510.0	5.3%	13,105.0	12.9%
	--		--		--		--		+422.1%	
2.5 INCH	--		--		--		2,510.0		13,105.0	
DESKTOP SYSTEM DRIVES	--	--	--	--	395.0	10.6%	35,520.0	75.6%	78,895.0	77.9%
	--		--		--		+8,892.4%		+122.1%	
3.5 INCH	--		--		395.0		35,520.0		78,895.0	
SERVER SYSTEM DRIVES	109.5	100.0%	189.0	100.0%	3,310.0	89.3%	8,940.0	19.0%	9,260.0	9.1%
	--		+72.6%		+1,651.3%		+170.0%		+3.5%	
5.25 INCH	109.5		34.0		--		--		--	
3.5 INCH	--		155.0		3,310.0		8,940.0		9,260.0	
Total Shipments	109.5		189.0		3,705.0		46,970.0		101,260.0	
	--		+72.6%		+1,860.3%		+1,167.8%		+115.6%	

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.

TABLE 75

FIXED DISK DRIVES, 40 - 80 GIGABYTES

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1998 Estimate Units (000)	1998 Estimate %	2002 Projection Units (000)	2002 Projection %
SPECIALIZED HIGH PERFORMANCE				
Supercomputers, video and high end imaging	--	--	101.3	.1
MAINFRAME SYSTEMS				
General purpose	78.6	71.8	202.5	.2
NETWORK/MIDRANGE SYSTEMS				
Midrange systems, network servers and workstations	30.9	28.2	9,113.4	9.0
DESKTOP PERSONAL COMPUTERS				
Business and professional, single user	--	--	77,666.4	76.7
CONSUMER COMPUTERS				
Desktop PCs, game, and hobby computers	--	--	1,113.9	1.1
PORTABLE COMPUTERS				
Notebook and smaller mobile computers	--	--	13,062.5	12.9
OTHER APPLICATIONS	--	--	--	--
Total	109.5	100.0	101,260.0	100.0

TABLE 76

FIXED DISK DRIVES, 40 - 80 GIGABYTES

WORLDWIDE PRICE PER MEGABYTE ($/MB)

DISK DIAMETER	1998	Forecast 1999	2000	2001	2002
Captive					
5.25"	--	--	--	--	--
3.5"	--	.041	.015	.011	.006
2.5"	--	--	--	.017	.012
Captive Average	--	.041	.015	.011	.007
Distributor					
5.25"	.032	.028	--	--	--
3.5"	--	.021	.008	.004	.002
2.5"	--	--	--	.008	.006
Distributor Average	.032	.022	.008	.004	.002
OEM/Integrator					
5.25"	.031	.028	--	--	--
3.5"	--	.023	.007	.004	.002
2.5"	--	--	--	.008	.005
OEM/Integrator Average	.031	.024	.007	.004	.003

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.

3.5 inch totals include server platform 3 inch drives.

FIXED DISK DRIVES, MORE THAN 80 GIGABYTES

1999 DISK/TREND REPORT

FIXED DISK DRIVES, MORE THAN 80 GIGABYTES

Coverage

At this time, there are no announced rigid disk drives with capacities greater than 80 gigabytes, and the current DISK/TREND Report forecasts assume that the first shipments will not occur until next year.

Following the pattern established by the disk drive industry in recent years for movement into high capacity ranges, server drives are expected to be the first to move above 80 gigabytes. If the model of recent years is repeated again, the capacity of high-end 3.5" server drives will continue to be doubled each year, as it was with 9.1, to 18.2, to 36.4 gigabytes. Many industry participants assume that 72.8 gigabytes will be the server drive high point for 1999, followed by 145.6 gigabytes in 2000. Although a variety of engineering, sales or management considerations could cause disk drive manufacturers to modify the annual pattern of recent years, it is expected that server drives with capacities greater than 80 gigabytes will be shipped for the first time in 2000.

Desktop and mobile drive capacity enhancements have followed a less predictable pattern, with more frequent capacity upgrades, and have quickly exploited areal density improvements as soon as volume production is practical. On that basis, it is expected that 3.5" desktop drives with more than 80 gigabytes capacity will first enter volume production in 2001, using four or five platters. The first 2.5" mobile drives are expected in 2002, also using four or five platters.

Market status

Although there are no disk drives with capacities greater than 80 gigabytes currently available, it is believed that a latent market exists with current mainframe systems and network file servers. A decade ago all disk drives intended for the server market were designed to be the biggest, fastest and most reliable that the technology of the period would make possible. Most server drives are still intended to be as reliable as possible, but individual server drive families are now designed for the requirements of specific applications. Some of those applications, such as data warehousing, image and video processing, and many others, do not need drives capable of the highest transaction rates. Instead, access to

extremely large servers with the lowest possible cost per megabyte is the most important requirement. It is clear that server disk drives with capacities above 80 gigabytes would be welcomed immediately if they were available in 1999.

Marketing trends

Despite the absence of disk drives with capacities above 80 gigabytes during 1998-99, shipments of server, desktop and mobile drives are all expected to undergo rapid growth when production commences. The first drive shipments for the product group are forecasted for 2001, with a modest 230,000 units, but growing rapidly to 6.0 million units in 2002, then jumping to 55.9 million drives in 2002. After starting with sales revenues of $170.2 million in 2000, the product group is projected to reach a revenue level of $17.3 billion in 2002.

Following initial introduction next year, 5.7 million server drives are forecasted for 2001 shipment, growing in 2002 to 18.9 million units. As always, the availability of extremely large disk storage capacities at continually lower prices will provide much of the stimulus in sales growth for higher capacity disk drives. While buyers of drives for single user computer applications are frequently sensitive to the unit price per drive, the market for high-end server drives is much more responsive to improved price per megabyte, since individual storage subsystems usually contain numerous drives, and total disk capacity is the main concern.

The improved price per megabyte available with each new generation of higher capacity server drives is welcomed by buyers. In many situations, the ability to package double the disk capacity in the same physical space as the previous drive generation can trigger a movement to the new drives, enabling storage subsystem manufacturers to improve the value of their products at minimal cost. By 2002, a significant share of the group's server drive shipments are expected to be 1" high models, further enhancing the server packaging possibilities.

After initial shipments of desktop 3.5" drives in 2001, a major boost in shipments is projected for the following year, with four platter drives in high volume production and three platter models starting up the manufacturing ramp. In view of the probable increased size of the desktop personal computer market by that period, and considering the nonstop increases in disk storage demand created

by the parade of existing and new computer applications, excellent growth is expected for the new desktop drives, with 2002 shipments of 34.7 million units. It is expected that capacities for 2.5" notebook drives will still follow those for desktop drives in 2002, with an initial year of shipments totaling 2.2 million units.

Technical trends

Continuing refinement of the technology currently employed in today's disk drives will be needed to manufacture the drives discussed in this product group, but nothing new will have to be invented. It's clear that advances in basic research will be required to enable future conventional magnetic disk drives to record at densities twice those used by drives discussed in this report, as magnetic domains become too small to be kept stable without special efforts.

But basic research isn't needed to produce the drives involved here -- what's needed are aggressive, well managed development programs. It's assumed that the disk drive manufacturers which manage those development programs most effectively will probably be the winners in the disk drive industry's continuous "time to market" contests for each new product generation.

Forecasting assumptions

1. IBM and other drive manufacturers will be successful in improving areal density utilized in disk drives by an average of 60% per year.
2. First shipments of 3.5" server drives with capacities in the range of 145 gigabytes will start in 2000, with continuous shipment increases through 2002.
3. Shipments of 3.5" desktop drives will start in 2001, with a major increase in shipments in the following year.
4. The first shipments of 2.5" drives will start in 2002.

TABLE 77

FIXED DISK DRIVES, MORE THAN 80 GIGABYTES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1998		Forecast							
	Revenues		1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Captive	--	--	--	--	13.6	20.4	267.8	370.5	1,821.8	2,609.4
Distributor	--	--	--	--	--	--	534.6	669.1	1,783.9	2,378.7
OEM/Integrator	--	--	--	--	109.0	136.2	1,418.6	1,891.2	6,795.2	9,479.2
TOTAL U.S. REVENUES	--	--	--	--	122.6	156.6	2,221.0	2,930.8	10,400.9	14,467.3
Non-U.S. Manufacturers										
Captive	--	--	--	--	--	6.8	--	34.3	9.0	229.8
Distributor	--	--	--	--	--	--	88.4	117.6	387.9	593.4
OEM/Integrator	--	--	--	--	3.4	6.8	241.9	336.3	1,343.7	2,051.4
TOTAL NON-U.S. REVENUES	--	--	--	--	3.4	13.6	330.3	488.2	1,740.6	2,874.6
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	--	--	--	--	126.0	170.2	2,551.3	3,419.0	12,141.5	17,341.9
OEM Average Price ($000)		--		--		.681		.532		.293

TABLE 78

FIXED DISK DRIVES, MORE THAN 80 GIGABYTES

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1998		Forecast							
	Shipments		1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Captive	--	--	--	--	10.0	15.0	260.0	360.0	2,315.0	3,315.0
Distributor	--	--	--	--	--	--	980.0	1,225.0	8,055.0	10,740.0
OEM/Integrator	--	--	--	--	160.0	200.0	2,645.0	3,525.0	23,035.0	32,105.0
TOTAL U.S. SHIPMENTS	--	--	--	--	170.0	215.0	3,885.0	5,110.0	33,405.0	46,160.0
Non-U.S. Manufacturers										
Captive	--	--	--	--	--	5.0	--	35.0	25.0	400.0
Distributor	--	--	--	--	--	--	160.0	215.0	1,385.0	2,200.0
OEM/Integrator	--	--	--	--	5.0	10.0	470.0	655.0	4,730.0	7,210.0
TOTAL NON-U.S. SHIPMENTS	--	--	--	--	5.0	15.0	630.0	905.0	6,140.0	9,810.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	--	--	--	--	175.0	230.0	4,515.0	6,015.0	39,545.0	55,970.0
Total Capacity (Terabytes)		--		--		33,488.0		1,064,052.0		7,659,750.0
Cumulative Shipments (Units in millions)										
WORLDWIDE TOTAL	--	--	--	--	.1	.2	4.6	6.2	44.2	62.2

TABLE 79

FIXED DISK DRIVES, MORE THAN 80 GIGABYTES

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1998 Revenues All Dia.	Forecast 1999 All Dia.	2000 3.5"	2001 3.5"	2002 3.5"	2002 2.5"
U.S. MANUFACTURERS						
Captive	--	--	20.4	370.5	2,446.0	163.4
Distributor	--	--	--	669.1	2,367.0	11.7
OEM/Integrator	--	--	136.2	1,891.2	8,974.3	504.9
TOTAL U.S. REVENUES	--	--	156.6	2,930.8	13,787.3	680.0
NON-U.S. MANUFACTURERS						
Captive	--	--	6.8	34.3	216.8	13.0
Distributor	--	--	--	117.6	589.4	4.0
OEM/Integrator	--	--	6.8	336.3	1,815.1	236.3
TOTAL NON-U.S. REVENUES	--	--	13.6	488.2	2,621.3	253.3
WORLDWIDE RECAP						
Captive	-- --	- --	27.2 --	404.8 --	2,662.8 +557.8%	176.4 --
Distributor	-- --	-- --	-- --	786.7 --	2,956.4 +275.8%	15.7 --
OEM/Integrator	-- --	-- --	143.0 --	2,227.5 --	10,789.4 +384.4%	741.2 --
Total Revenues	1.0 --	1.0 --	170.2 --	3,419.0 --	16,408.6 +379.9%	933.3 --
ANNUAL SHARE, BY DIAMETER	100.0%	100.0%	100.0%	100.0%	94.7%	5.3%

Note: 3.5 inch totals include server platform 3 inch drives.

TABLE 80

FIXED DISK DRIVES, MORE THAN 80 GIGABYTES

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DISK DIAMETER

	1998 Shipments All Dia.	Forecast 1999 All Dia.	2000 3.5"	2001 3.5"	2002 3.5"	2002 2.5"
U.S. MANUFACTURERS						
Captive	--	--	15.0	360.0	3,120.0	195.0
Distributor	--	--	--	1,225.0	10,710.0	30.0
OEM/Integrator	--	--	200.0	3,525.0	30,780.0	1,325.0
TOTAL U.S. SHIPMENTS	--	--	215.0	5,110.0	44,610.0	1,550.0
NON-U.S. MANUFACTURERS						
Captive	--	--	5.0	35.0	365.0	35.0
Distributor	--	--	--	215.0	2,190.0	10.0
OEM/Integrator	--	--	10.0	655.0	6,580.0	630.0
TOTAL NON-U.S. SHIPMENTS	--	--	15.0	905.0	9,135.0	675.0
WORLDWIDE RECAP						
Captive	--	--	20.0	395.0	3,485.0	230.0
	--	--	--	--	+782.3%	--
Distributor	--	--	--	1,440.0	12,900.0	40.0
	--	--	--	--	+795.8%	--
OEM/Integrator	--	--	210.0	4,180.0	37,360.0	1,955.0
	--	--	--	--	+793.8%	--
Total Shipments	--	--	230.0	6,015.0	53,745.0	2,225.0
	--	--	--	--	+793.5%	--
ANNUAL SHARE, BY DIAMETER	100.0%	100.0%	100.0%	100.0%	96.1%	3.9%
TOTAL CAPACITY (Terabytes)	--	--	33,488	1,064,052	7,479,525	180,225

Note: 3.5 inch totals include server platform 3 inch drives.

TABLE 81

FIXED DISK DRIVES, MORE THAN 80 GIGABYTES

SUMMARY BY PLATFORM

UNIT SHIPMENTS IN THOUSANDS	1998 Shipments Units	1998 Shipments %	1999 Units	1999 %	2000 Units	2000 %	2001 Units	2001 %	2002 Units	2002 %
MOBILE SYSTEM DRIVES	--	--	--	--	--	--	--	--	2,225.0	3.9%
	--		--		--		--		--	
2.5 INCH	--		--		--		--		2,225.0	
DESKTOP SYSTEM DRIVES	--	--	--	--	--	--	300.0	4.9%	34,755.0	62.1%
	--		--		--		--		--	
3.5 INCH	--		--		--		300.0		34,755.0	
SERVER SYSTEM DRIVES	--	--	--	--	230.0	100.0%	5,715.0	95.0%	18,990.0	33.9%
	--		--		--		+2,384.7%		+232.2%	
3.5 INCH	--		--		230.0		5,715.0		18,990.0	
Total Shipments	--	--	--	--	230.0	100.0%	6,015.0	100.0%	55,970.0	100.0%
	--		--		--		+2,515.2%		+830.5%	

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.

TABLE 82

FIXED DISK DRIVES, MORE THAN 80 GIGABYTES

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1998 Estimate Units (000)	1998 Estimate %	2002 Projection Units (000)	2002 Projection %
SPECIALIZED HIGH PERFORMANCE				
Supercomputers, video and high end imaging	--	--	56.0	.1
MAINFRAME SYSTEMS				
General purpose	--	--	111.9	.2
NETWORK/MIDRANGE SYSTEMS				
Midrange systems, network servers and workstations	--	--	18,861.9	33.7
DESKTOP PERSONAL COMPUTERS				
Business and professional, single user	--	--	34,533.5	61.7
CONSUMER COMPUTERS				
Desktop PCs, game, and hobby computers	--	--	167.9	.3
PORTABLE COMPUTERS				
Notebook and smaller mobile computers	--	--	2,238.8	4.0
OTHER APPLICATIONS	--	--	--	--
Total	--	--	55,970.0	100.0

TABLE 83

FIXED DISK DRIVES, MORE THAN 80 GIGABYTES

WORLDWIDE PRICE PER MEGABYTE ($/MB)

DISK DIAMETER	1998	1999	2000	2001	2002
		Forecast			
Captive					
3.5"	--	--	.009	.005	.004
2.5"	--	--	--	--	.009
Captive Average	--	--	.009	.005	.004
Distributor					
3.5"	--	--	--	.004	.002
2.5"	--	--	--	--	.005
Distributor Average	--	--	--	.004	.002
OEM/Integrator					
3.5"	--	--	.005	.003	.002
2.5"	--	--	--	--	.005
OEM/Integrator Average	--	--	.005	.003	.002

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.

3.5 inch totals include server platform 3 inch drives.

RIGID DISK DRIVE SPECIFICATIONS

1999 DISK/TREND REPORT

RIGID MAGNETIC DISK DRIVE SPECIFICATIONS

Coverage

This section includes most rigid disk drives intended for computer data storage which are now in new production or announced, arranged alphabetically by manufacturer. Specifications on drive models sold by computer system manufacturers, but purchased on an OEM basis from others, have been included in some cases, for identification purposes. In the case of IBM's disk drives and those produced by some other system manufacturers, captive drives which are similar to OEM/Integrator models made by the same manufacturer are not listed.

Capacities

Formatted capacity defines the appropriate DISK/TREND product group for each disk drive. Prior to 1992, drives were grouped by unformatted capacity, but the industry movement to embedded controllers eventually made that practice obsolete, since most rigid disk drives are now specified in formatted capacities.

In the specifications, capacities are listed as "U" for unformatted or "F" for formatted. In general, unformatted capacities are shown only for OEM/Integrator and Distributor drives without embedded controllers, and formatted capacities are given for captive drives and noncaptive drives with embedded controllers, such as SCSI and IDE variations, or the newer serial interfaces, SSA and FC-AL. Capacities per track are listed for some older drives, but most current drives use zoned recording, in which each band of tracks has a different capacity.

Linear density, recording code, areal density

When specified by the drive manufacturer, both BPI (bits per inch) and FCI (flux changes per inch) are listed. The ratio between BPI and FCI varies, depending upon the recording code used. For example, with 1,7 RLL (run length limited) encoding, the value for BPI is 133% of the value for FCI. With PRML (partial response maximum likelihood), several variations are used and some manufacturers have not specified FCI. Areal density (BPI multiplied by TPI) is useful in comparing the recording density used in various disk drives.

Average access time

DISK/TREND specifications use the term "average access time" to describe the combination of average positioning time and average rotational delay. Some

in the industry have fallen into the habit of using the term average access time to describe average positioning time, or "seek" time, but this usage fails to adequately describe the time required for a disk drive to start to respond to a system request. DISK/TREND specifications show separately average positioning time, average rotational delay, and average access time, in order to avoid confusion.

Transfer rate

The transfer rate shown in the specifications is the highest rate at which data is transferred between the drive and the computer to which it is attached, in the case of drives with embedded controllers, or the data rate between the drive and its controller, if the controller is not embedded. If the manufacturer has specified more than one communication mode (such as synchronous and asynchronous for SCSI drives, or PIO and DMA for IDE drives), both data rates are indicated.

Interfaces

Specific interfaces available are indicated for most drives, using references to manufacturers' own unique interfaces or to industry standards, either de facto or formalized. However, this is a rapidly changing area, so please be alert to the need to check for manufacturers' latest information if you need precise data.

Accuracy

All information in this section has been cross-checked for accuracy. However, it is anticipated that some errors may be included, since many manufacturers' published specifications do not cover all of the items listed, and numerous verbal inquiries have been required.

1999 DISK/TREND product groups for rigid magnetic disk drives

Removable magnetic media:

1. Disk cartridge drives

Fixed magnetic media:

2. Fixed disk drives, less than 2 gigabytes
3. Fixed disk drives, 2 - 3 gigabytes
4. Fixed disk drives, 3 - 5 gigabytes
5. Fixed disk drives, 5 - 10 gigabytes
6. Fixed disk drives, 10 - 20 gigabytes
7. Fixed disk drives, 20 - 40 gigabytes
8. Fixed disk drives, 40 - 80 gigabytes
9. Fixed disk drives, more than 80 gigabytes

MANUFACTURER	BELFORT MEMORY INTERNATIONAL	BELFORT MEMORY INTERNATIONAL	BELFORT MEMORY INTERNATIONAL	CALLUNA TECHNOLOGY	CALLUNA TECHNOLOGY
DRIVE	P402U	P53-1U	P804U	CT-1040RM callunacard	CT-260T2 callunacard
DISK/TREND GROUP	4	4	5	2	2
PLATFORM	Desktop	Desktop	Desktop	Mobile	Mobile
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	130 mm	130 mm	130 mm	48 mm	48 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Glass	Glass
DRIVE: Heads	Thin Film	Thin Film	Thin Film	MR Thin Film	MR Thin Film
Interface	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33	PCMCIA-ATA	PCMCIA-ATA
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 4,000	F: 3,000	F: 8,000	--	--
REMOVABLE	--	--	--	F: 1,040	F: 260
Data surfaces per spindle	2	2	4	4	1
Tracks per surface				4030	4030
Track density (TPI)	9000	8500	9000	9000	9000
Maximum linear density (BPI) (FCI)	152200	126200	152200	169520	169520
Areal density (Gb/square inch)	1.370	1.073	1.370	1.526	1.526
Recording code	PRML	PRML	PRML	1,7 PRML	1,7 PRML
Rotational speed (RPM)	4000	4000	4000	3750	3750
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	12	12	12	12	12
Average rotational delay (msec)	7.5	7.5	7.5	8	8
Average access time (msec)	19.5	19.5	19.5	20	20
Data transfer rate (MBytes/sec) Internal, min/max	--/18.5	--/18.5	--/18.5	3.7/5.9	3.7/5.9
External	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	20.0	20.0
SIZE: (mm) H x W x D	25.4 x 146 x 210	25.4 x 146 x 210	25.4 x 146 x 210	10.5 x 54 x 85.6	5 x 54 x 85.6
FIRST CUSTOMER SHIPMENT	2/99	11/98	3/99	10/98	2099
COMMENTS				PCMCIA Type III	PCMCIA Type II.

MANUFACTURER	CALLUNA TECHNOLOGY	CASTLEWOOD SYSTEMS	CASTLEWOOD SYSTEMS	CASTLEWOOD SYSTEMS	CASTLEWOOD SYSTEMS
DRIVE	CT-521RM callunacard	ORB2I100 IDE Internal	ORB2PE00 Parallel Port	ORB2SE00 SCSI External	ORB2SI00 SCSI Internal
DISK/TREND GROUP	2	1	1	1	1
PLATFORM	Mobile	Desktop	Desktop	Desktop	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	48 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Glass	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film
Interface	PCMCIA-ATA	IDE	Parallel Port	Ultra SCSI	Ultra SCSI
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	--	--	--	--	--
REMOVABLE	F: 520	F: 2,200	F: 2,200	F: 2,200	F: 2,200
Data surfaces per spindle	2	2	2	2	2
Tracks per surface	4030	8589	8589	8589	8589
Track density (TPI)	9000	9300	9300	9300	9300
Maximum linear density (BPI) (FCI)	169520	181000 204000	181000 204000	181000 204000	181000 204000
Areal density (Gb/square inch)	1.526	1.683	1.683	1.683	1.683
Recording code	1,7 PRML	8,9 PRML	8,9 PRML	8,9 PRML	8,9 PRML
Rotational speed (RPM)	3750	5400	5400	5400	5400
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	12	10 RD/12 WR	10 RD/12 WR	10 RD/12 WR	10 RD/12 WR
Average rotational delay (msec)	8	5.6	5.6	5.6	5.6
Average access time (msec)	20	15.6 RD/17.6 WR	15.6 RD/17.6 WR	15.6 RD/17.6 WR	15.6 RD/17.6 WR
Data transfer rate (MBytes/sec) Internal, min/max External	3.7/5.9 20.0	6.9/12.2 2.2	6.9/12.2 16.6 PIO Mode 4 16.6 DMA Mode 2	6.9/12.2 20.0 synch.	6.9/12.2 20.0 synch.
SIZE: (mm) H x W x D	10.5 x 54 x 85.6	25.4 x 101.1 x 152.4	38.1 x 133.4 x 165.1	38.1 x 133.4 x 165.1	25.4 x 101.6 x 152.4
FIRST CUSTOMER SHIPMENT	10/98	11/98	4/99	5/99	5/99
COMMENTS	PCMCIA Type III	Internal model.	External model.	External model.	Internal model.

MANUFACTURER	CASTLEWOOD SYSTEMS	CONNER TECHNOLOGY	CONNER TECHNOLOGY	FUJITSU	FUJITSU
DRIVE	ORB2UE00 USB External	CT-204 Titan	CT-408 Titan	M2722 (Hornet-7')	M2723TAM (Hornet-7')
DISK/TREND GROUP	1	4	5	2	2
PLATFORM	Desktop	Desktop	Desktop	Mobile	Mobile
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM	OEM
MEDIA: Disk diameter	95 mm	95 mm	95 mm	65 mm	65 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Glass	Glass
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film
Interface	USB	Ultra DMA/66	Ultra DMA/66	IDE	IDE
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	--	F: 4,300	F: 8,600	F: 816	F: 1,224
REMOVABLE	F: 2,200	--	--	--	--
Data surfaces per spindle	2	2	4	2	3
Tracks per surface	8589			5157	5157
Track density (TPI)	9300	13000	13000	8537	8537
Maximum linear density (BPI) (FCI)	181000 204000	230000	230000	150388	150388
Areal density (Gb/square inch)	1.683	2.990	2.990	1.284	1.284
Recording code	8,9 PRML	EPR4	EPR4	PR4ML	PR4ML
Rotational speed (RPM)	5400	5400	5400	4000	4000
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	10 RD/12 WR	10	10	12	12
Average rotational delay (msec)	5.6	5.6	5.6	7.5	7.5
Average access time (msec)	15.6 RD/17.6 WR	15.6	15.6	19.5	19.5
Data transfer rate (MBytes/sec) Internal, min/max External	6.9/12.2 20.0	--/27.5 16.6 PIO4/DMA2 66.6 Ultra DMA4	--/27.5 16.6 PIO4/DMA2 66.6 Ultra DMA4	4.5/8.4 16.6 PIO Mode 4 16.6 DMA Mode 2	4.5/8.4 16.6 PIO Mode 4 16.6 DMA Mode 2
SIZE: (mm) H x W x D	38.1 x 133.4 x 165.1	25.4 x 101.6 x 146.6	25.4 x 101.6 x 146.6	12.5 x 70 x 100	12.5 x 70 x 100
FIRST CUSTOMER SHIPMENT	2Q99	6/99	6/99	9/96	9/96
COMMENTS	External model.				

MANUFACTURER	FUJITSU	FUJITSU	FUJITSU	FUJITSU	FUJITSU
DRIVE	M2724TAM (Hornet-7")	MPA3017AT (Picobird-10)	M2903 (Allegro-1)	M2915 (Allegro-1)	M2932S/H/Q/R (Allegro-2)
DISK/TREND GROUP	2	2	3	3	3
PLATFORM	Mobile	Desktop	Server	Server	Server
MARKET	OEM	OEM	OEM	OEM	OEM, DIST
MEDIA: Disk diameter	65 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Glass	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film
Interface	IDE	IDE	SCSI-2	SCSI-2	SCSI-2
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 1,632	F: 1,750	F: 2,118	F: 2,170	F: 2,170
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	4	2	13	15	9
Tracks per surface	5157	8713	3150	3018	3422
Track density (TPI)	8537	9202	3553	3553	3871
Maximum linear density (BPI) (FCI)	150388	137285	75534	71627	100946
Areal density (Gb/square inch)	1.284	1.263	.268	.254	.391
Recording code	PR4ML	8,9 PRML	PRML	PRML	8,9 RLL
Rotational speed (RPM)	4000	5400	5400	7200	7200
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Dedicated Surf.	Dedicated Surf.	Dedicated Surf.
Average positioning time (msec)	12	10 RD/12 WR	10.3 RD/11.2 WR	10.1 RD/11 WR	10 RD/11.2 WR
Average rotational delay (msec)	7.5	5.56	5.6	4.17	4.17
Average access time (msec)	19.5	15.56RD/17.56WR	15.9 RD/16.8 WR	14.27RD/15.17WR	14.17RD/16.17WR
Data transfer rate (MBytes/sec) Internal, min/max External	4.5/8.4 16.6 PIO Mode 4 16.6 DMA Mode 2	8.0/15.0 16.7 PIO4/DMA2 33.3 Ultra DMA2	4.7/6.8 20.0 synch. 6.0 asynch.	6.2/8.0 20.0 synch. 6.0 asynch.	8.6/11.3 20.0 synch. 12.0 asynch.
SIZE: (mm) H x W x D	12.5 x 70 x 100	25.4 x 101 x 146	41.3 x 101.6 x 146.1	41.3 x 101.6 x 146.1	41.3 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	9/96	6/97	2/94	12/94	3/95
COMMENTS					

MANUFACTURER	FUJITSU	FUJITSU	FUJITSU	FUJITSU	FUJITSU
DRIVE	M2952S/Q/R/E (Allegro-3')	MHA2021 Mobile 3 (Hornet-8)	MHD2021AT Mobile 4L (Hornet-9L)	MHF2021AT Mobile 6A (Hornet-10L)	MPA3026AT (Picobird-10)
DISK/TREND GROUP	3	3	3	3	3
PLATFORM	Server	Mobile	Mobile	Mobile	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM	OEM	OEM
MEDIA: Disk diameter	95 mm	65 mm	65 mm	65 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Glass	Glass	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	GMR Thin Film	MR Thin Film
Interface	Ultra SCSI	IDE	Ultra DMA/33	Ultra DMA/33	IDE
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 2,400	F: 2,160	F: 2,160	F: 2,100	F: 2,600
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	5	4	3	2	3
Tracks per surface	5713	6372	7289	8647	8713
Track density (TPI)	6500	10555	11960	14200	9202
Maximum linear density (BPI) (FCI)	118737	157422	191000	238000	137285
Areal density (Gb/square inch)	.772	1.662	2.284	3.380	1.263
Recording code	8,9 RLL	PRML	16,17 EPR4ML	16,17 EPR4ML	8,9 PRML
Rotational speed (RPM)	7200	4000	4000	4200	5400
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Dedicated Surf.	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	8 RD/9 WR	13	13	13	10 RD/12 WR
Average rotational delay (msec)	4.17	7.5	7.5	7.14	5.56
Average access time (msec)	12.17RD/13.17WR	20.5	20.5	20.14	15.56RD/17.56WR
Data transfer rate (MBytes/sec) Internal, min/max	9.9/14.9	4.9/8.9	5.9/10.1	7.7/13.6	8.0/15.0
External	40.0 synch. 12.0 asynch.	16.6 PIO Mode 4 16.6 DMA Mode 2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2
SIZE: (mm) H x W x D	25.4 x 101.6 x 146	12.5 x 70 x 100	9.5 x 70 x 100	9.5 x 70 x 100	25.4 x 101 x 146
FIRST CUSTOMER SHIPMENT	10/95	11/97	4/98	9/98	6/97
COMMENTS					

MANUFACTURER	FUJITSU	FUJITSU	FUJITSU	FUJITSU	FUJITSU
DRIVE	MPB3021AT Desktop 6 (Picobird-11)	M2909 (Allegro-1)	M2934S/H/Q/R (Allegro-2)	M2954S/Q/R/E (Allegro-3`)	MAB3045-FC Enterprise 18 (Allegro-4)
DISK/TREND GROUP	3	4	4	4	4
PLATFORM	Desktop	Server	Server	Server	Server
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film
Interface	Ultra DMA/33	SCSI-2	SCSI-2	Ultra SCSI	FC-AL
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 2,162	F: 3,087	F: 4,350	F: 4,350	F: 4,550
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	2	19	18	9	5
Tracks per surface	8983	3150	3429	5713	8490
Track density (TPI)	9531	3553	3871	6500	9620
Maximum linear density (BPI) (FCI)	161815	75534	100946	118759	159000
Areal density (Gb/square inch)	1.542	.268	.391	.772	1.530
Recording code	8,9 PRML	PRML	8,9 RLL	8,9 RLL	PRML
Rotational speed (RPM)	5400	5400	7200	7200	7200
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Dedicated Surf.	Dedicated Surf.	Dedicated Surf.	Embedded
Average positioning time (msec)	10 RD/11 WR	10.3 RD/11.2 WR	10 RD/11.2 WR	8 RD/9 WR	7.5 RD/8.5 WR
Average rotational delay (msec)	5.6	5.6	4.17	4.17	4.17
Average access time (msec)	15.6 RD/16.6 WR	15.9 RD/16.8 WR	14.17RD/16.17WR	12.17RD/13.17WR	11.67RD/12.67WR
Data transfer rate (MBytes/sec) Internal, min/max	9.6/16.7	4.7/6.8	8.6/11.3	9.9/14.9	13.3/19.5
External	16.6 PIO4/DMA2 33.3 Ultra DMA2	20.0 synch. 6.0 asynch.	20.0 synch. 12.0 asynch.	40.0 synch. 12.0 asynch.	100.0
SIZE: (mm) H x W x D	25.4 x 101 x 146	41.3 x 101.6 x 146.1	41.3 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	9/97	2/94	3/95	10/95	1H98
COMMENTS					

MANUFACTURER	FUJITSU	FUJITSU	FUJITSU	FUJITSU	FUJITSU
DRIVE	MAB3045-LV Enterprise 18 (Allegro-4)	MAB3045-SC/SP Enterprise 18 (Allegro-4)	MAC3045-FC Enterprise 10K (Allegro-4LE)	MAC3045-LV Enterprise 10K (Allegro-4LE)	MAC3045-SC/SP Enterprise 10K (Allegro-4LE)
DISK/TREND GROUP	4	4	4	4	4
PLATFORM	Server	Server	Server	Server	Server
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film
Interface	Ultra2 SCSI	Ultra SCSI	FC-AL	Ultra2 SCSI	Ultra SCSI
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 4,550	F: 4,550	F: 4,500	F: 4,500	F: 4,500
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	5	5	5	5	5
Tracks per surface	8490	8490	8690	8690	8690
Track density (TPI)	9620	9620	9200	9200	9200
Maximum linear density (BPI) (FCI)	159000	159000	159000	159000	159000
Areal density (Gb/square inch)	1.530	1.530	1.463	1.463	1.463
Recording code	PRML	PRML	PRML	PRML	PRML
Rotational speed (RPM)	7200	7200	10033	10033	10033
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	7.5 RD/8.5 WR	7.5 RD/8.5 WR	7.5 RD/8.5 WR	7.5 RD/8.5 WR	7.5 RD/8.5 WR
Average rotational delay (msec)	4.17	4.17	2.99	2.99	2.99
Average access time (msec)	11.67RD/12.67WR	11.67RD/12.67WR	10.49RD/11.49WR	10.49RD/11.49WR	10.49RD/11.49WR
Data transfer rate (MBytes/sec) Internal, min/max	13.3/19.5	13.3/19.5	15.5/27.5	15.5/27.5	15.5/27.5
External	80.0 synch.	40.0 synch.	100.0	80.0 synch.	40.0 synch.
SIZE: (mm) H x W x D	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	1H98	11/97	1H98	1H98	11/97
COMMENTS					

MANUFACTURER	FUJITSU	FUJITSU	FUJITSU	FUJITSU	FUJITSU
DRIVE	MHA2032 Mobile 3 (Hornet-8)	MHC2040AT Mobile 4 (Hornet-9)	MHD2032AT Mobile 4L (Hornet-9L)	MHE2043AT Mobile 6 (Hornet-10)	MHF2043AT Mobile 6A (Hornet-10L)
DISK/TREND GROUP	4	4	4	4	4
PLATFORM	Mobile	Mobile	Mobile	Mobile	Mobile
MARKET	OEM, DIST	OEM	OEM	OEM	OEM
MEDIA: Disk diameter	65 mm	65 mm	65 mm	65 mm	65 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Glass	Glass	Glass	Glass	Glass
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	GMR Thin Film	GMR Thin Film
Interface	IDE	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 3,240	F: 4,090	F: 3,250	F: 4,320	F: 4,320
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	6	6	4	4	4
Tracks per surface	6372	7229	7317	8647	8647
Track density (TPI)	10555	11960	11960	14200	14200
Maximum linear density (BPI) (FCI)	157422	178000	217000	238000	238000
Areal density (Gb/square inch)	1.662	2.129	2.595	3.380	3.380
Recording code	PRML	16,17 EPR4ML	16,17 EPR4ML	16,17 PRML	16,17 EPR4ML
Rotational speed (RPM)	4000	4000	4000	4200	4200
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	13	13	13	13	13
Average rotational delay (msec)	7.5	7.5	7.5	7.14	7.14
Average access time (msec)	20.5	20.5	20.5	20.14	20.14
Data transfer rate (MBytes/sec) Internal, min/max External	4.9/8.9 16.6 PIO Mode 4 16.6 DMA Mode 2	5.5/9.8 16.6 PIO4/DMA2 33.3 Ultra DMA2	6.3/10.6 16.6 PIO4/DMA2 33.3 Ultra DMA2	7.7/13.6 16.6 PIO4/DMA2 33.3 Ultra DMA2	7.7/13.6 16.6 PIO4/DMA2 33.3 Ultra DMA2
SIZE: (mm) H x W x D	12.5 x 70 x 100	12.5 x 70 x 100	9.5 x 70 x 100	12.5 x 70 x 100	9.5 x 70 x 100
FIRST CUSTOMER SHIPMENT	11/97	4/98	4/98	9/98	9/98
COMMENTS					

MANUFACTURER	FUJITSU	FUJITSU	FUJITSU	FUJITSU	FUJITSU
DRIVE	MHH2032AT Mobile 10L (Hornet-11L)	MHH2048AT Mobile 10L (Hornet-11L)	MPA3035AT (Picobird-10)	MPA3043AT (Picobird-10)	MPB3032AT Desktop 6 (Picobird-11)
DISK/TREND GROUP	4	4	4	4	4
PLATFORM	Mobile	Mobile	Desktop	Desktop	Desktop
MARKET	OEM	OEM	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	65 mm	65 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Glass	Glass	Aluminum	Aluminum	Aluminum
DRIVE: Heads	GMR Thin Film	GMR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film
Interface	Ultra DMA/33	Ultra DMA/33	IDE	IDE	Ultra DMA/33
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 3,250	F: 4,800	F: 3,500	F: 4,320	F: 3,243
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	2	3	4	5	3
Tracks per surface	8647	8647	8713	8713	8983
Track density (TPI)	18200	18200	9202	9202	9531
Maximum linear density (BPI) (FCI)	281800	281800	137285	137285	161815
Areal density (Gb/square inch)	5.129	5.129	1.263	1.263	1.542
Recording code	16,17 EPR4ML	16,17 EPR4ML	8,9 PRML	8,9 PRML	8,9 PRML
Rotational speed (RPM)	4200	4200	5400	5400	5400
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	13	13	10 RD/12 WR	10 RD/12 WR	10 RD/11 WR
Average rotational delay (msec)	7.14	7.14	5.56	5.56	5.6
Average access time (msec)	20.14	20.14	15.56RD/17.56WR	15.56RD/17.56WR	15.6 RD/16.6 WR
Data transfer rate (MBytes/sec) Internal, min/max External	9.2/15.8 16.6 PIO4/DMA2 33.3 Ultra DMA2	9.2/15.8 16.6 PIO4/DMA2 33.3 Ultra DMA2	8.0/15.0 16.6 PIO4/DMA2 33.3 Ultra DMA2	8.0/15.0 16.6 PIO4/DMA2 33.3 Ultra DMA2	9.6/16.7 16.6 PIO4/DMA2 33.3 Ultra DMA2
SIZE: (mm) H x W x D	9.5 x 70 x 100	9.5 x 70 x 100	25.4 x 101 x 146	25.4 x 101 x 146	25.4 x 101 x 146
FIRST CUSTOMER SHIPMENT	2/99	2/99	6/97	6/97	9/97
COMMENTS					

MANUFACTURER	FUJITSU	FUJITSU	FUJITSU	FUJITSU	FUJITSU
DRIVE	MPB3043AT Desktop 6 (Picobird-11)	MPC3032AT (Picobird-12)	MPC3043AT (Picobird-12)	MPC3045AH (Picobird-12H)	MPD3043AT (Picobird-13)
DISK/TREND GROUP	4	4	4	4	4
PLATFORM	Desktop	Desktop	Desktop	Desktop	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	GMR Thin Film
Interface	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33	Ultra DMA/66
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 4,325	F: 3,243	F: 4,325	F: 4,551	F: 4,325
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	4	2	3	4	2
Tracks per surface	8983	11116	11116	10424	13033
Track density (TPI)	9531	11800	11800	11000	13750
Maximum linear density (BPI) (FCI)	161815	200882 213437	200882 213437	162754 183098	243487
Areal density (Gb/square inch)	1.542	2.370	2.370	1.790	3.348
Recording code	8,9 PRML	16,17 EPRML	16,17 EPRML	8,9 PRML	16,17 EPR4ML
Rotational speed (RPM)	5400	5400	5400	7200	5400
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	10 RD/11 WR	10 RD/11 WR	10 RD/11 WR	9 RD/10 WR	9.5 RD/10.5 WR
Average rotational delay (msec)	5.6	5.6	5.6	4.2	5.6
Average access time (msec)	15.6 RD/16.6 WR	15.6 RD/16.6 WR	15.6 RD/16.6 WR	13.2 RD/14.2 WR	15.1 RD/16.1 WR
Data transfer rate (MBytes/sec) Internal, min/max	9.6/16.7	11.4/19.8	11.4/19.8	12.7/19.2	14.5/26.1
External	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 66.6 Ultra DMA4
SIZE: (mm) H x W x D	25.4 x 101 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146	26.1 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	9/97	6/98	6/98	10/98	1/99
COMMENTS					

MANUFACTURER	FUJITSU	FUJITSU	FUJITSU	FUJITSU	FUJITSU
DRIVE	M2949S/Q/R/E (Allegro-3)	MAB3091-FC Enterprise 18 (Allegro-4)	MAB3091-LV Enterprise 18 (Allegro-4)	MAB3091-SC/SP Enterprise 18 (Allegro-4)	MAC3091-FC Enterprise 10K (Allegro-4LE)
DISK/TREND GROUP	5	5	5	5	5
PLATFORM	Server	Server	Server	Server	Server
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film
Interface	Ultra SCSI	FC-AL	Ultra2 SCSI	Ultra SCSI	FC-AL
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 9,100	F: 9,100	F: 9,100	F: 9,100	F: 9,100
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	18	10	10	10	10
Tracks per surface	5770	8490	8490	8490	8690
Track density (TPI)	6500	9620	9620	9620	9200
Maximum linear density (BPI) (FCI)	118574	159000	159000	159000	159000
Areal density (Gb/square inch)	.771	1.530	1.530	1.530	1.463
Recording code	PR4ML	PRML	PRML	PRML	PRML
Rotational speed (RPM)	7200	7200	7200	7200	10033
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Dedicated Surf.	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	10 RD/11.5 WR	7.5 RD/8.5 WR	7.5 RD/8.5 WR	7.5 RD/8.5 WR	7.5 RD/8.5 WR
Average rotational delay (msec)	4.17	4.17	4.17	4.17	2.99
Average access time (msec)	14.17RD/15.67WR	11.67RD/12.67WR	11.67RD/12.67WR	11.67RD/12.67WR	10.49RD/11.49WR
Data transfer rate (MBytes/sec) Internal, min/max External	9.9/14.9 40.0 synch. 12.0 asynch.	13.3/19.5 100.0	13.3/19.5 80.0 synch.	13.3/19.5 40.0 synch.	15.5/27.5 100.0
SIZE: (mm) H x W x D	41.3 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146
FIRST CUSTOMER SHIPMENT		1H98	1H98	11/97	1H98
COMMENTS					

MANUFACTURER	FUJITSU	FUJITSU	FUJITSU	FUJITSU	FUJITSU
DRIVE	MAC3091-LV Enterprise 10K (Allegro-4LE)	MAC3091-SC/SP Enterprise 10K (Allegro-4LE)	MAE3091 (Allegro-5L)	MAG3091-FC (Allegro-5LE)	MAG3091-LV (Allegro-5LE)
DISK/TREND GROUP	5	5	5	5	5
PLATFORM	Server	Server	Server	Server	Server
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	84 mm	84 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	GMR Thin Film	GMR Thin Film	GMR Thin Film
Interface	Ultra2 SCSI	Ultra SCSI	Ultra2 SCSI	FC-AL	Ultra2 SCSI
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 9,100	F: 9,100	F: 9,100	F: 9,100	F: 9,100
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	10	10	4	5	5
Tracks per surface	8690	8690	12000	9866	9866
Track density (TPI)	9200	9200	13250	13500	13500
Maximum linear density (BPI) (FCI)	159000	159000	275000	275000	275000
Areal density (Gb/square inch)	1.463	1.463	3.644	3.713	3.713
Recording code	PRML	PRML	16,17 EPR4ML	16,17 EPR4ML	16,17 EPR4ML
Rotational speed (RPM)	10033	10033	7200	10025	10025
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	7.5 RD/8.5 WR	7.5 RD/8.5 WR	7.0 RD/7.6 WR	5.2 RD/5.8 WR	5.2 RD/5.8 WR
Average rotational delay (msec)	2.99	2.99	4.17	2.99	2.99
Average access time (msec)	10.49RD/11.49WR	10.49RD/11.49WR	11.17RD/11.77WR	8.19 RD/8.79 WR	8.19 RD/8.79 WR
Data transfer rate (MBytes/sec) Internal, min/max	15.5/27.5	15.5/27.5	21.7/32.8	29.5/45.0	29.5/45.0
External	80.0 synch.	40.0 synch.	80.0 synch.	100.0	80.0 synch.
SIZE: (mm) H x W x D	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146.0	24.5 x 101.6 x 146	24.5 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	1H98	11/97	1Q99	2Q99	1Q99
COMMENTS					

MANUFACTURER	FUJITSU	FUJITSU	FUJITSU	FUJITSU	FUJITSU
DRIVE	MHE2064AT Mobile 6 (Hornet-10)	MHH2064AT Mobile 10L (Hornet-11L)	MPA3052T (Picobird-10)	MPB3052AT Desktop 6 (Picobird-11)	MPB3064AT Desktop 6 (Picobird-11)
DISK/TREND GROUP	5	5	5	5	5
PLATFORM	Mobile	Mobile	Desktop	Desktop	Desktop
MARKET	OEM	OEM	OEM	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	65 mm	65 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Glass	Glass	Aluminum	Aluminum	Aluminum
DRIVE: Heads	GMR Thin Film	GMR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film
Interface	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 6,480	F: 6,480	F: 5,250	F: 5,249	F: 6,488
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	6	4	6	5	6
Tracks per surface	8647	8647	8713	8983	8983
Track density (TPI)	14200	18200	9202	9531	9531
Maximum linear density (BPI) (FCI)	238000	281800	137285	161815	161815
Areal density (Gb/square inch)	3.380	5.129	1.263	1.542	1.542
Recording code	16,17 EPR4ML	16,17 EPR4ML	8,9 PRML	8,9 PRML	8,9 PRML
Rotational speed (RPM)	4200	4200	5400	5400	5400
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	13	13	10 RD/12 WR	10 RD/11 WR	10 RD/11 WR
Average rotational delay (msec)	7.14	7.14	5.56	5.6	5.6
Average access time (msec)	20.14	20.14	15.56RD/17.56WR	15.6 RD/16.6 WR	15.6 RD/16.6 WR
Data transfer rate (MBytes/sec) Internal, min/max	7.7/13.6	9.2/15.8	8.0/14.9	9.6/16.7	9.6/16.7
External	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.7 PIO Mode 4 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2
SIZE: (mm) H x W x D	12.5 x 70 x 100	9.5 x 70 x 100	25.4 x 101 x 146	25.4 x 101 x 146	25.4 x 101 x 146
FIRST CUSTOMER SHIPMENT	9/98	2/99	6/97	9/97	9/97
COMMENTS					

MANUFACTURER	FUJITSU	FUJITSU	FUJITSU	FUJITSU	FUJITSU
DRIVE	MPC3064AT (Picobird-12)	MPC3065AH (Picobird-12H)	MPC3084AT (Picobird-12)	MPC3096AT (Picobird-12)	MPD3064AT (Picobird-13)
DISK/TREND GROUP	5	5	5	5	5
PLATFORM	Desktop	Desktop	Desktop	Desktop	Desktop
MARKET	OEM, DIST	OEM	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	GMR Thin Film
Interface	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33	Ultra DMA/66
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 6,488	F: 6,510	F: 8,455	F: 9,747	F: 6,488
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	4	6	6	6	3
Tracks per surface	11116	10424	11116	11116	13033
Track density (TPI)	11800	11000	11800	11800	13750
Maximum linear density (BPI) (FCI)	200882 213437	162754 183098	200882 213437	200882 213437	243487
Areal density (Gb/square inch)	2.370	1.790	2.370	2.370	3.348
Recording code	16,17 EPRML	8,9 PRML	16,17 EPRML	16,17 EPRML	16,17 EPR4ML
Rotational speed (RPM)	5400	7200	5400	5400	5400
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	10 RD/11 WR	9 RD/10 WR	10 RD/11 WR	10 RD/11 WR	9.5 RD/10.5 WR
Average rotational delay (msec)	5.6	4.2	5.6	5.6	5.6
Average access time (msec)	15.6 RD/16.6 WR	13.2 RD/14.2 WR	15.6 RD/16.6 WR	15.6 RD/16.6 WR	15.1 RD/16.1 WR
Data transfer rate (MBytes/sec) Internal, min/max External	11.4/19.8 16.6 PIO4/DMA2 33.3 Ultra DMA2	12.7/19.2 16.6 PIO4/DMA2 33.3 Ultra DMA2	11.4/19.8 16.6 PIO4/DMA2 33.3 Ultra DMA2	11.4/19.8 16.6 PIO4/DMA2 33.3 Ultra DMA2	14.5/26.1 16.6 PIO4/DMA2 66.6 Ultra DMA4
SIZE: (mm) H x W x D	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146	26.1 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	6/98	6/98	6/98	6/98	1/99
COMMENTS					

MANUFACTURER	FUJITSU	FUJITSU	FUJITSU	FUJITSU	FUJITSU
DRIVE	MPD3084AT (Picobird-13)	MPD3091AH (Picobird-13H)	MAA3182-FC Enterprise 18 (Allegro-4LE)	MAA3182-LV Enterprise 18 (Allegro-4LE)	MAA3182-SC/SP Enterprise 18 (Allegro-4)
DISK/TREND GROUP	5	5	6	6	6
PLATFORM	Desktop	Desktop	Server	Server	Server
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	GMR Thin Film	GMR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film
Interface	Ultra DMA/66	Ultra DMA/66	FC-AL	Ultra2 SCSI	Ultra SCSI
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 8,455	F: 9,134	F: 18,200	F: 18,200	F: 18,200
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	4	4	19	19	19
Tracks per surface	13033	12555	9040	9040	9040
Track density (TPI)	13750	13250	9620	9620	9620
Maximum linear density (BPI) (FCI)	243487	269951	159000	159000	159000
Areal density (Gb/square inch)	3.348	3.577	1.530	1.530	1.530
Recording code	16,17 EPR4ML	16,17 EPR4ML	PRML	PRML	PRML
Rotational speed (RPM)	5400	7200	7200	7200	7200
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	9.5 RD/10.5 WR	9.0 RD/10.0 WR	8 RD/9 WR	8 RD/9 WR	8 RD/9 WR
Average rotational delay (msec)	5.6	4.17	4.17	4.17	4.17
Average access time (msec)	15.1 RD/16.1 WR	13.17RD/14.17WR	12.17RD/13.17WR	12.17RD/13.17WR	12.17RD/13.17WR
Data transfer rate (MBytes/sec) Internal, min/max	14.5/26.1	21.4/34.6	12.3/19.5	12.3/19.5	12.3/19.5
External	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 66.6 Ultra DMA4	100.0	80.0 synch.	40.0 synch.
SIZE: (mm) H x W x D	26.1 x 101.6 x 146	26.1 x 101.6 x 146.0	41.3 x 101.6 x 146	41.3 x 101.6 x 146	41.3 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	1/99	4/99	1H98	1H98	11/97
COMMENTS					

MANUFACTURER	FUJITSU	FUJITSU	FUJITSU	FUJITSU	FUJITSU
DRIVE	MAE3182 (Allegro-5L)	MAG3182-FC (Allegro-5LE)	MAG3182-LV (Allegro-5LE)	MHG2102AT Mobile 10 (Hornet-11)	MPC3102AT Desktop 10 (Picobird-12)
DISK/TREND GROUP	6	6	6	6	6
PLATFORM	Server	Server	Server	Mobile	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM	OEM, DIST
MEDIA: Disk diameter	95 mm	84 mm	84 mm	65 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Glass	Aluminum
DRIVE: Heads	GMR Thin Film	GMR Thin Film	GMR Thin Film	GMR Thin Film	MR Thin Film
Interface	Ultra2 SCSI	FC-AL	Ultra2 SCSI	Ultra DMA/33	Ultra DMA/33
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 18,200	F: 18,200	F: 18,200	F: 10,000	F: 10,200
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	8	10	10	6	6
Tracks per surface	12010	10200	10200	8647	11467
Track density (TPI)	13250	13500	13500	18200	11800
Maximum linear density (BPI) (FCI)	275000	275000	275000	281800	210470
Areal density (Gb/square inch)	3.644	3.713	3.713	5.129	2.484
Recording code	16,17 EPR4ML	16,17 EPR4ML	16,17 EPR4ML	16,17 EPR4ML	16,17 EPRML
Rotational speed (RPM)	7200	10025	10025	4200	5400
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	7.0 RD/7.5 WR	5.0 RD/5.5 WR	5.0 RD/5.5 WR	13	10 RD/11 WR
Average rotational delay (msec)	4.17	2.99	2.99	7.14	5.6
Average access time (msec)	11.17RD/11.67WR	7.99 RD/8.49 WR	7.99 RD/8.49 WR	20.14	15.6 RD/16.6 WR
Data transfer rate (MBytes/sec) Internal, min/max	21.7/32.0	29.5/45.0	29.5/45.0	9.2/15.8	12.6/19.8
External	80.0 synch.	100.0	80.0 synch.	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2
SIZE: (mm) H x W x D	25.4 x 101.6 x 146.0	24.5 x 101.6 x 146	24.5 x 101.6 x 146	12.5 x 70 x 100	25.4 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	1Q99	2Q99	1Q99	2/99	
COMMENTS					

MANUFACTURER	FUJITSU	FUJITSU	FUJITSU	FUJITSU	FUJITSU
DRIVE	MPD3108AT (Picobird-13)	MPD3130AT (Picobird-13)	MPD3137AH (Picobird-13H)	MPD3173AT (Picobird-13)	MPD3182AH (Picobird-13H)
DISK/TREND GROUP	6	6	6	6	6
PLATFORM	Desktop	Desktop	Desktop	Desktop	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	GMR Thin Film	GMR Thin Film	GMR Thin Film	GMR Thin Film	GMR Thin Film
Interface	Ultra DMA/66	Ultra DMA/66	Ultra DMA/66	Ultra DMA/66	Ultra DMA/66
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 10,800	F: 13,021	F: 13,701	F: 17,302	F: 18,268
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	5	6	6	8	8
Tracks per surface	13033	13033	12555	13033	12555
Track density (TPI)	13750	13750	13250	13750	13250
Maximum linear density (BPI) (FCI)	243487	243487	269951	243487	269951
Areal density (Gb/square inch)	3.348	3.348	3.577	3.348	3.577
Recording code	16,17 EPR4ML	16,17 EPR4ML	16,17 EPR4ML	16,17 EPR4ML	16,17 EPR4ML
Rotational speed (RPM)	5400	5400	7200	5400	7200
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	9.5 RD/10.5 WR	9.5 RD/10.5 WR	9.0 RD/10.0 WR	9.5 RD/10.5 WR	9.0 RD/10.0 WR
Average rotational delay (msec)	5.6	5.6	4.17	5.6	4.17
Average access time (msec)	15.1 RD/16.1 WR	15.1 RD/16.1 WR	13.17RD/14.17WR	15.1 RD/16.1 WR	13.17RD/14.17WR
Data transfer rate (MBytes/sec) Internal, min/max	14.5/26.1	14.5/26.1	21.4/34.6	14.5/26.1	21.4/34.6
External	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 66.6 Ultra DMA4
SIZE: (mm) H x W x D	26.1 x 101.6 x 146	26.1 x 101.6 x 146	26.1 x 101.6 x 146.0	26.1 x 101.6 x 146	26.1 x 101.6 x 146.0
FIRST CUSTOMER SHIPMENT	1/99	1/99	4/99	2/99	4/99
COMMENTS					

MANUFACTURER	FUJITSU	FUJITSU	HALO DATA DEVICES	HITACHI	HITACHI
DRIVE	MAF3364-FC (Allegro-5E)	MAF3364-LV (Allegro-5E)	Halo Ultra (Preliminary)	DK226A-21U	DK226A-32
DISK/TREND GROUP	7	7	2	3	4
PLATFORM	Server	Server	Mobile	Mobile	Mobile
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM	OEM
MEDIA: Disk diameter	84 mm	84 mm	Approx. 1"	65 mm	65 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Glass	Glass	Glass
DRIVE: Heads	GMR Thin Film	GMR Thin Film	GMR Thin Film	MR Thin Film	MR Thin Film
Interface	FC-AL	Ultra2 SCSI	Compact Flash	Ultra DMA/33	IDE
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 36,400	F: 36,400	--	F: 2,160	F: 3,240
REMOVABLE	--	--	F: 265	--	--
Data surfaces per spindle	19	19	1	4	6
Tracks per surface	10200	10200		6255	6255
Track density (TPI)	13500	13500		11000	11000
Maximum linear density (BPI) (FCI)	275000	275000		183000	183000
Areal density (Gb/square inch)	3.713	3.713		2.013	2.013
Recording code	16,17 EPR4ML	16,17 EPR4ML		EPRML	8,9 EPRML
Rotational speed (RPM)	10025	10025	5400	4000	4000
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	5.7 RD/6.2 WR	5.7 RD/6.2 WR	14	12	12
Average rotational delay (msec)	2.99	2.99	5.6	7.5	7.5
Average access time (msec)	8.69 RD/9.19 WR	8.69 RD/9.19 WR	19.6	19.5	19.5
Data transfer rate (MBytes/sec) Internal, min/max	30.3/45.0	30.3/45.0	4.7/9.4	6.0-9.1	6.0-9.1
External	100.0	80.0 synch.		16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO Mode 4 16.6 DMA Mode 2
SIZE: (mm) H x W x D	41.3 x 101.6 x 146.0	41.3 x 101.6 x 146.0	3.3 x 36.4 x 42.8	12.7 x 70 x 100	12.7 x 70 x 100
FIRST CUSTOMER SHIPMENT	2Q99	2Q99		1/98	2Q97
COMMENTS			Compact Flash Type I.		

MANUFACTURER	HITACHI	HITACHI	HITACHI	HITACHI	HITACHI
DRIVE	DK226A-32U	DK227A-41	DK237A-32	DK238A-32	DK238A-43
DISK/TREND GROUP	4	4	4	4	4
PLATFORM	Mobile	Mobile	Mobile	Mobile	Mobile
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Disk diameter	65 mm	65 mm	65 mm	65 mm	65 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Glass	Glass	Glass	Glass	Glass
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	GMR Thin Film	GMR Thin Film
Interface	IDE	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 3,240	F: 4,090	F: 3,240	F: 3,245	F: 4,330
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	6	6	4	3	4
Tracks per surface	6255	6568	7470	8955	8955
Track density (TPI)	11000	12500	13000	15600	15600
Maximum linear density (BPI) (FCI)	183000	214900	220000	251800	251800
Areal density (Gb/square inch)	2.013	2.686	2.860	3.928	3.928
Recording code	8,9 EPRML	EPRML	EPRML	EPRML	EPRML
Rotational speed (RPM)	4000	4000	4000	4200	4200
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	12	12	12	12	12
Average rotational delay (msec)	7.5	7.5	7.5	7.14	7.14
Average access time (msec)	19.5	19.5	19.5	19.14	19.14
Data transfer rate (MBytes/sec) Internal, min/max	6.0-9.1	7.6-10.8	7.2-10.8	8.7-13.5	8.7-13.5
External	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2
SIZE: (mm) H x W x D	12.7 x 70 x 100	12.7 x 70 x 100	9.5 x 70 x 100	9.5 x 70 x 100	9.5 x 70 x 100
FIRST CUSTOMER SHIPMENT	2Q97	1/98	2/98		
COMMENTS					

MANUFACTURER	HITACHI	HITACHI	HITACHI	HITACHI	HITACHI
DRIVE	DK328H-43	DK227A-50	DK228A-65	DK239A-65	DK318H-91
DISK/TREND GROUP	4	5	5	5	5
PLATFORM	Server	Mobile	Mobile	Mobile	Server
MARKET	OEM, DIST	OEM	OEM	OEM	OEM, DIST
MEDIA: Disk diameter	95 mm	65 mm	65 mm	65 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Glass	Glass	Glass	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	GMR Thin Film	GMR Thin Film	MR Thin Film
Interface	Ultra SCSI	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33	Ultra SCSI
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 4,370	F: 5,020	F: 6,490	F: 6,490	F: 9,100
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	10	6	6	4	20
Tracks per surface	5890	7470	8968	11141	6104
Track density (TPI)	6200	13000	15600	19500	6450
Maximum linear density (BPI) (FCI)	131000	233200	250500	315300	131000
Areal density (Gb/square inch)	.812	3.032	3.908	6.148	.845
Recording code	8,9 PRML	EPRML	EPRML	MEEPRML	8,9 PRML
Rotational speed (RPM)	7200	4000	4200	4200	7200
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded		Embedded
Average positioning time (msec)	9	12	12	12	9
Average rotational delay (msec)	4.17	7.5	7.14	7.14	4.17
Average access time (msec)	13.17	19.5	19.14	19.14	13.17
Data transfer rate (MBytes/sec) Internal, min/max	9.4/15.6	7.6-11.0	8.6/13.4	10.0/16.3	9.4/15.6
External	40.0 synch. 20.0 asynch.	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	40.0 synch. 20.0 asynch.
SIZE: (mm) H x W x D	25.4 x 101.6 x 146	12.7 x 70 x 100	12.7 x 70 x 100	9.5 x 70 x 100	41.3 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	1/97	4/98	6/98	1Q99	1/97
COMMENTS					

MANUFACTURER	HITACHI	HITACHI	HITACHI	HITACHI	HITACHI
DRIVE	DK329H-91FC	DK329H-91LW	DK329H-91NS/WS	DK3E1T-91FC	DK3E1T-91LC DK3E1T-91LW
DISK/TREND GROUP	5	5	5	5	5
PLATFORM	Server	Server	Server	Server	Server
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM	OEM
MEDIA: Disk diameter	95 mm	95 mm	95 mm	65 mm	65 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film
Interface	FC-AL	Ultra2 SCSI	Ultra SCSI	FC-AL	Ultra2 SCSI
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 9,100	F: 9,100	F: 9,100	F: 9,200	F: 9,200
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	10	10	10	18	18
Tracks per surface					
Track density (TPI)	8600	8600	8600	10700	10700
Maximum linear density (BPI) (FCI)	169000	169000	169000	173300	173300
Areal density (Gb/square inch)	1.453	1.453	1.453	1.854	1.854
Recording code	EPRML	EPRML	EPRML	16,17 EPRML	16,17 EPRML
Rotational speed (RPM)	7200	7200	7200	12030	12030
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	7.5 RD	7.5 RD	7.5 RD	5 RD/6 WR	5 RD/6 WR
Average rotational delay (msec)	4.17	4.17	4.17	2.49	2.49
Average access time (msec)	11.67 RD	11.67 RD	11.67 RD	7.49 RD/8.49 WR	7.49 RD/8.49 WR
Data transfer rate (MBytes/sec) Internal, min/max External	13.5/21.8 100.0 synch.	13.5/21.8 80.0 synch.	13.5/21.8 40.0 synch.	18.6/27.3 100.0	18.6/27.3 80.0 synch.
SIZE: (mm) H x W x D	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146	41.3 x 101.6 x 146	41.3 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	1Q98	1Q98	1Q98	3Q98	3Q98
COMMENTS					

MANUFACTURER	HITACHI	HITACHI	HITACHI	HITACHI	HITACHI
DRIVE	DK3F2-9	DK229A-10	DK309-18	DK319H-18FC	DK319H-18LW
DISK/TREND GROUP	5	6	6	6	6
PLATFORM	Server	Mobile	Server	Server	Server
MARKET	Captive	OEM	Captive	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	65 mm	65 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Glass	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR heads	GMR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film
Interface	Ultra SCSI	Ultra DMA/33	SCSI	FC-AL	Ultra2 SCSI
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 9,230	F: 10,000	F: 18,460	F: 18,200	F: 18,200
REMOVABLE	--	--		--	--
Data surfaces per spindle		6		20	20
Tracks per surface		11141			
Track density (TPI)		19500		8600	8600
Maximum linear density (BPI) (FCI)		323000		169000	169000
Areal density (Gb/square inch)		6.299		1.453	1.453
Recording code		MEEPRML		EPRML	EPRML
Rotational speed (RPM)	12030	4200	6300	7200	7200
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	5.5 RD	12	11.5 RD	7.5 RD	7.5 RD
Average rotational delay (msec)	2.49	7.14	4.76	4.17	4.17
Average access time (msec)	7.99 RD	19.14	16.26 RD	11.67 RD	11.67 RD
Data transfer rate (MBytes/sec) Internal, min/max	18.6/27.5	10.3/16.6	9.9/15.2	13.5/21.8	13.5/21.8
External		16.6 PIO4/DMA2 33.3 Ultra DMA2		100.0 synch.	80.0 synch.
SIZE: (mm) H x W x D	72 x 114 x 245	12.7 x 70 x 100	72 x 114 x 245	41.3 x 101.6 x 146	41.3 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	3/99	1Q99	3/98	1Q98	1Q98
COMMENTS	HDD for H-6596 Mainframe Array		HDD for H-6596 Mainframe Array		

MANUFACTURER	HITACHI	HITACHI	HITACHI	HITACHI	HITACHI
DRIVE	DK319H-18NS/WS	DK32AH-18	DK32AH-18FC	DK3F2-15	DK30A-36
DISK/TREND GROUP	6	6	6	6	7
PLATFORM	Server	Server	Server	Server	Server
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	Captive	Captive
MEDIA: Disk diameter	95 mm	95 mm	95 mm	65 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR heads	MR heads	MR heads	MR heads
Interface	Ultra SCSI	Ultra2 SCSI	FC-AL	Ultra SCSI	Ultra SCSI
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 18,200	F: 18,400	F: 18,400	F: 15,390	F: 36,930
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	20	10	10		
Tracks per surface					
Track density (TPI)	8600	13000	13000		
Maximum linear density (BPI) (FCI)	169000	225000	225000		
Areal density (Gb/square inch)	1.453	2.925	2.925		
Recording code	EPRML	16,17 MEEPRML	16,17 MEEPRML		
Rotational speed (RPM)	7200	7208	7208	12030	6300
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	7.5 RD	6.8 RD	6.8 RD	5.5 RD	11.5 RD
Average rotational delay (msec)	4.17	4.16	4.16	2.49	4.76
Average access time (msec)	11.67 RD	10.96 RD	10.96 RD	7.99 RD	16.26 RD
Data transfer rate (MBytes/sec) Internal, min/max External	13.5/21.8 40.0 synch.	18.7/30.0 80.0 synch.	18.7/30.0 100	18.6/27.5	12.8/22.1
SIZE: (mm) H x W x D	41.3 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146	72 x 114 x 245	72 x 114 x 245
FIRST CUSTOMER SHIPMENT	1Q98	1/99	1/99	3/99	3/99
COMMENTS				HDD for H-6596 Mainframe Array	HDD for H-6596 Mainframe Array

MANUFACTURER	HITACHI	HITACHI	IBM	IBM	IBM
DRIVE	DK31AH-36	DK31AH-36FC	Microdrive 170 (Preliminary)	Microdrive 340 (Preliminary)	DCAS-32160 Ultrastar 2ES (Orion)
DISK/TREND GROUP	7	7	2	2	3
PLATFORM	Server	Server	Mobile	Mobile	Server
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	Approx. 1"	Approx. 1"	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Glass	Glass	Aluminum
DRIVE: Heads	MR heads	MR heads	GMR Thin Film	GMR Thin Film	MR Thin Film
Interface	Ultra2 SCSI	FC-AL	Compact Flash	Compact Flash	Ultra SCSI
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 36,800	F: 36,800	--	--	F: 2,160
REMOVABLE	--	--	F: 170	F: 340	--
Data surfaces per spindle	20	20	1	2	3
Tracks per surface					8210
Track density (TPI)	13000	13000			8600
Maximum linear density (BPI) (FCI)	225000	225000			134600
Areal density (Gb/square inch)	2.925	2.925			1.158
Recording code	16,17 MEEPRML	16,17 MEEPRML			PRML
Rotational speed (RPM)	7208	7208	4500	4500	5400
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	7.0 RD	7.0 RD	15	15	8.5 RD
Average rotational delay (msec)	4.16	4.16	6.7	6.7	5.6
Average access time (msec)	11.16 RD	11.16 RD	21.7	21.7	14.1 RD
Data transfer rate (MBytes/sec) Internal, min/max External	18.7/30.0 80.0 synch.	18.7/30.0 100	4.0-6.1	4.0-6.1	7.8/12.9 40.0 synch. 20.0 asynch.
SIZE: (mm) H x W x D	41.3 x 101.6 x 146	41.3 x 101.6 x 146	5.0 x 42.8 x 36.4	5.0 x 42.8 x 36.4	25.4 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	1/99	1/99	1999	1999	9/96
COMMENTS			Compact Flash Type II.	Compact Flash Type II.	

MANUFACTURER	IBM	IBM	IBM	IBM	IBM
DRIVE	DKLA-22160 Travelstar 4GN (Klondike)	DBCA-203240 Travelstar 6GN (Biscayne)	DBCA-204860 Travelstar 6GN (Biscayne)	DDRS-34560-U2S Ultrastar 9ES (Draco)	DDRS-34560-US Ultrastar 9ES (Draco)
DISK/TREND GROUP	3	4	4	4	4
PLATFORM	Mobile	Mobile	Mobile	Server	Server
MARKET	OEM, DIST	OEM	OEM	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	65 mm	65 mm	65 mm	95 mm	95 mm
Recording medium	Thin Film*	Thin Film*	Thin Film*	Thin Film	Thin Film
Substrate	Glass	Glass	Glass	Aluminum	Aluminum
DRIVE: Heads	GMR Thin Film	GMR Thin Film	GMR Thin Film	MR Thin Film	MR Thin Film
Interface	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33	Ultra2 SCSI	Ultra SCSI
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 2,160	F: 3,200	F: 4,800	F: 4,560	F: 4,560
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	2	2	3	5	5
Tracks per surface	9280	11648	11648	8420	8420
Track density (TPI)	16000	19900	19900	10000	10000
Maximum linear density (BPI) (FCI)	256400	286100	286100	156000	156000
Areal density (Gb/square inch)	4.102	5.693	5.693	1.560	1.560
Recording code	16,17 PRML	16,17 PRML	16,17 PRML	16,17 PRML	16,17 PRML
Rotational speed (RPM)	4200	4200	4200	7200	7200
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	13	13	13	7.5	7.5
Average rotational delay (msec)	7.1	7.1	7.1	4.17	4.17
Average access time (msec)	20.1	20.1	20.1	11.67	11.67
Data transfer rate (MBytes/sec) Internal, min/max	7.7-12.8	8.6/14.8	8.6/14.8	13.6/21.4	13.6/21.4
External	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	80.0	40.0
SIZE: (mm) H x W x D	9.5 x 70 x 100	9.5 x 70 x 100	9.5 x 70 x 100	25.4 x 101.6 x 146	25.4 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	7/98	12/98	12/98	1Q98	10/97
COMMENTS	*Untextured. Ramp loaded heads.	*Untextured. Ramp loaded heads.	*Untextured. Ramp loaded heads.		

MANUFACTURER	IBM	IBM	IBM	IBM	IBM
DRIVE	DKLA-23240 Travelstar 4GN (Klondike)	DKLA-24320 Travelstar 4GN (Klondike)	DTTA-350320 Deskstar 16GP (Titan)	DTTA-350430 Deskstar 16GP (Titan)	DADA-25400 Travelstar 6GT (Acadia)
DISK/TREND GROUP	4	4	4	4	5
PLATFORM	Mobile	Mobile	Desktop	Desktop	Mobile
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM
MEDIA: Disk diameter	65 mm	65 mm	95 mm	95 mm	65 mm
Recording medium	Thin Film*	Thin Film*	Thin Film	Thin Film	Thin Film*
Substrate	Glass	Glass	Aluminum	Aluminum	Glass
DRIVE: Heads	GMR Thin Film	GMR Thin Film	GMR Thin Film	GMR Thin Film	GMR Thin Film
Interface	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 3,240	F: 4,320	F: 3,200	F: 4,300	F: 5,400
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	3	4	2	3	5
Tracks per surface	9280	9280	13085	13085	9280
Track density (TPI)	16000	16000	13700	13700	16000
Maximum linear density (BPI) (FCI)	256400	256400	196100	196100	256400
Areal density (Gb/square inch)	4.102	4.102	2.687	2.687	4.102
Recording code	16,17 PRML	16,17 PRML	PRML	PRML	16,17 PRML
Rotational speed (RPM)	4200	4200	5400	5400	4200
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	13	13	9.5 RD	9.5 RD	12
Average rotational delay (msec)	7.1	7.1	5.6	5.6	7.1
Average access time (msec)	20.1	20.1	15.1 RD	15.1 RD	19.1
Data transfer rate (MBytes/sec) Internal, min/max	7.7-12.8	7.7-12.8	--/20.5	--/20.5	7.7/12.8
External	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2
SIZE: (mm) H x W x D	9.5 x 70 x 100	9.5 x 70 x 100	25.4 x 101.6 x 146	25.4 x 101.6 x 146	12.5 x 70 x 100
FIRST CUSTOMER SHIPMENT	7/98	7/98	12/97	12/97	2/98
COMMENTS	*Untextured. Ramp loaded heads.	*Untextured. Ramp loaded heads.			*Untextured. Ramp loaded heads.

MANUFACTURER	IBM	IBM	IBM	IBM	IBM
DRIVE	DADA-26480 Travelstar 6GT (Acadia)	DBCA-206480 Travelstar 6GN (Biscayne)	DCXA-208100 Travelstar 10GT (Croix)	DDRS-39130-U2S Ultrastar 9ES (Draco)	DDRS-39130-US Ultrastar 9ES (Draco)
DISK/TREND GROUP	5	5	5	5	5
PLATFORM	Mobile	Mobile	Mobile	Server	Server
MARKET	OEM	OEM	OEM	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	65 mm	65 mm	65 mm	95 mm	95 mm
Recording medium	Thin Film*	Thin Film*	Thin Film*	Thin Film	Thin Film
Substrate	Glass	Glass	Glass	Aluminum	Aluminum
DRIVE: Heads	GMR Thin Film	GMR Thin Film	GMR Thin Film	MR Thin Film	MR Thin Film
Interface	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33	Ultra2 SCSI	Ultra SCSI
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 6,480	F: 6,400	F: 8,100	F: 9,130	F: 9,130
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	6	4	5	10	10
Tracks per surface	9280	11648	11968	8420	8420
Track density (TPI)	16000	19900	19900	10000	10000
Maximum linear density (BPI) (FCI)	256400	286100	283200	156000	156000
Areal density (Gb/square inch)	4.102	5.693	5.636	1.560	1.560
Recording code	16,17 PRML	16,17 PRML	16,17 PRML	16,17 PRML	16,17 PRML
Rotational speed (RPM)	4200	4200	4200	7200	7200
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	12	13	12	7.5	7.5
Average rotational delay (msec)	7.1	7.1	7.1	4.17	4.17
Average access time (msec)	19.1	20.1	19.1	11.67	11.67
Data transfer rate (MBytes/sec) Internal, min/max	7.7/12.8	8.6/14.8	8.6/14.8	13.6/21.4	13.6/21.4
External	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	80.0	40.0
SIZE: (mm) H x W x D	12.5 x 70 x 100	9.5 x 70 x 100	12.5 x 70 x 100	25.4 x 101.6 x 146	25.4 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	2/98	12/98	12/98	1Q98	10/97
COMMENTS	*Untextured. Ramp loaded heads.	*Untextured. Ramp loaded heads.	*Untextured. Ramp loaded heads.		

MANUFACTURER	IBM	IBM	IBM	IBM	IBM
DRIVE	DGHC-39110 Ultrastar 9LP (Sailfin)	DGHL-39110 Ultrastar 9LP (Sailfin)	DGHS-39110 Ultrastar 9LP (Sailfin)	DGHU-39110 Ultrastar 9LP (Sailfin)	DJNA-379100 Deskstar 22GPX (Janus)
DISK/TREND GROUP	5	5	5	5	5
PLATFORM	Server	Server	Server	Server	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	GMR Thin Film
Interface	SSA	FC-AL	Ultra SCSI	Ultra2 SCSI	Ultra DMA/66
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 9,110	F: 9,110	F: 9,110	F: 9,110	F: 9,100
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	10	10	10	10	4
Tracks per surface	8151	8151	8151	8151	15012
Track density (TPI)	8356	8356	8356	8356	15700
Maximum linear density (BPI) (FCI)	150000	150000	150000	150000	218600
Areal density (Gb/square inch)	1.253	1.253	1.253	1.253	3.432
Recording code	16,17 PRML	16,17 PRML	16,17 PRML	16,17 PRML	PRML
Rotational speed (RPM)	7200	7200	7200	7200	7200
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	6.5 RD	6.5 RD	6.5 RD	6.5 RD	9.0 RD
Average rotational delay (msec)	4.17	4.17	4.17	4.17	4.17
Average access time (msec)	10.67 RD	10.67 RD	10.67 RD	10.67 RD	13.17 RD
Data transfer rate (MBytes/sec) Internal, min/max	11.5/22.4	11.5/22.4	11.5/22.4	11.5/22.4	17.3/27.9
External	40.0	100.0	40.0	80.0	16.6 PIO4/DMA2 66.6 Ultra DMA4
SIZE: (mm) H x W x D	26 x 101.6 x 147	26 x 101.6 x 147	26 x 101.6 x 147	26 x 101.6 x 147	25.4 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	2Q98	2Q98	10/97	1Q98	12/98
COMMENTS					

MANUFACTURER	IBM	IBM	IBM	IBM	IBM
DRIVE	DMVC-09 Ultrastar 18LZX (Thornback)	DMVL-09 Ultrastar 18LZX (Thornback)	DMVS-09D/V Ultrastar 18LZX (Thornback)	DMVS-09X Ultrastar 18LZX (Thornback)	DNEF-309170 Ultrastar 18ES (Neptune)
DISK/TREND GROUP	5	5	5	5	5
PLATFORM	Server	Server	Server	Server	Server
MARKET	DIST, OEM	DIST, OEM	DIST, OEM	DIST, OEM	OEM, DIST
MEDIA: Disk diameter	84 mm	84 mm	84 mm	84 mm	95 mm
Recording medium	Thin Film*	Thin Film*	Thin Film*	Thin Film*	Thin Film
Substrate	Glass	Glass	Glass	Glass	Aluminum
DRIVE: Heads	GMR Thin Film	GMR Thin Film	GMR Thin Film	GMR Thin Film	GMR Thin Film
Interface	SSA	FC-AL	Ultra2 SCSI	SCSI Ultra2/160	FC-AL
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 9,100	F: 9,100	F: 9,100	F: 9,100	F: 9,100
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	5	5	5	5	5
Tracks per surface	11748	11748	11748	11748	11474
Track density (TPI)	13595	13595	13595	13595	13700
Maximum linear density (BPI) (FCI)	260000	260000	260000	260000	220000
Areal density (Gb/square inch)	3.535	3.535	3.535	3.535	3.014
Recording code	16,17 PRML	16,17 PRML	16,17 PRML	16,17 PRML	16,17 PRML
Rotational speed (RPM)	10000	10000	10000	10000	7200
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	4.9 RD	4.9 RD	4.9 RD	4.9 RD	7.0 RD
Average rotational delay (msec)	3.0	3.0	3.0	3.0	4.17
Average access time (msec)	7.9 RD	7.9 RD	7.9 RD	7.9 RD	11.17 RD
Data transfer rate (MBytes/sec) Internal, min/max External	23.3/44.3 160.0	23.3/44.3 100	23.3/44.3 80.0 synch.	23.3/44.3 160.0 synch.	19.9/30.5 100.0
SIZE: (mm) H x W x D	25.7 x 101.6 x 146.8	25.7 x 101.6 x 146.8	25.7 x 101.6 x 146.8	25.7 x 101.6 x 146.8	25.4 x 101.6 x 146.0
FIRST CUSTOMER SHIPMENT	4Q99	4Q99	5/99	3Q99	1Q98
COMMENTS	*Untextured. Ramp loaded heads.	*Untextured. Ramp loaded heads.	*Untextured. Ramp loaded heads.	*Untextured. Ramp loaded heads.	

MANUFACTURER	IBM	IBM	IBM	IBM	IBM
DRIVE	DNES-309170 Ultrastar 18ES (Neptune)	DRVC-30955C Ultrastar 9LZX (Mako)	DRVL-300955L Ultrastar 9LZX (Mako)	DRVS-309555S Ultrastar 9LZX (Mako)	DTTA-350640 Deskstar 16GP (Titan)
DISK/TREND GROUP	5	5	5	5	5
PLATFORM	Server	Server	Server	Server	Desktop
MARKET	OEM, DIST	DIST, OEM	DIST, OEM	DIST, OEM	OEM, DIST
MEDIA: Disk diameter	95 mm	84 mm	84 mm	84 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	GMR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	GMR Thin Film
Interface	Ultra2 SCSI	SSA	FC-AL	Ultra2 SCSI	Ultra DMA/33
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 9,100	F: 9,100	F: 9,100	F: 9,100	F: 6,400
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	5	10	10	10	4
Tracks per surface	11474	7052	7052	7052	13085
Track density (TPI)	13700	9240	9240	9240	13700
Maximum linear density (BPI) (FCI)	220000	219100	219100	219100	196100
Areal density (Gb/square inch)	3.014	2.024	2.024	2.024	2.687
Recording code	16,17 PRML	16,17 PRML	16,17 PRML	16,17 PRML	PRML
Rotational speed (RPM)	7200	10020	10020	10020	5400
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	7.0 RD	5.3 RD	5.3 RD	5.3 RD	9.5 RD
Average rotational delay (msec)	4.17	2.99	2.99	2.99	5.6
Average access time (msec)	11.17 RD	8.29 RD	8.29 RD	8.29 RD	15.1 RD
Data transfer rate (MBytes/sec) Internal, min/max External	19.9/30.5 80.0 synch.	23.4/30.5 40.0	23.4/30.5 100.0	23.4/30.5 80.0 synch.	--/20.5 16.6 PIO4/DMA2 33.3 Ultra DMA2
SIZE: (mm) H x W x D	25.4 x 101.6 x 146.0	25.7 x 101.6 x 146.8	25.7 x 101.6 x 146.8	25.7 x 101.6 x 146.8	25.4 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	1Q98	4Q98	4Q98	4Q98	12/97
COMMENTS					

MANUFACTURER	IBM	IBM	IBM	IBM	IBM
DRIVE	DTTA-350840 Deskstar 16GP (Titan)	DYLA-26480 Travelstar 8GS (Yellowstone)	DYLA-28100 Travelstar 8GS (Yellowstone)	DCXA-210000 Travelstar 10GT (Croix)	DCYA-214000 Travelstar 14GS (Cypress)
DISK/TREND GROUP	5	5	5	6	6
PLATFORM	Desktop	Mobile	Mobile	Mobile	Mobile
MARKET	OEM, DIST	OEM	OEM	OEM	OEM
MEDIA: Disk diameter	95 mm	65 mm	65 mm	65 mm	65 mm
Recording medium	Thin Film	Thin Film*	Thin Film*	Thin Film*	Thin Film*
Substrate	Aluminum	Glass	Glass	Glass	Glass
DRIVE: Heads	GMR Thin Film	MR Thin Film	MR Thin Film	GMR Thin Film	GMR Thin Film
Interface	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 8,400	F: 6,480	F: 8,100	F: 10,000	F: 14,100
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	5	8	10	6	10
Tracks per surface	13085	8320	8320	11968	11136
Track density (TPI)	13700	14000	14000	19900	19000
Maximum linear density (BPI) (FCI)	196100	221000	221000	283200	261900
Areal density (Gb/square inch)	2.687	3.094	3.094	5.636	4.976
Recording code	PRML	16,17 PRML	16,17 PRML	16,17 PRML	16,17 PRML
Rotational speed (RPM)	5400	4900	4900	4200	4900
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	9.5 RD	12 RD	12 RD	12	12
Average rotational delay (msec)	5.6	6.1	6.1	7.1	6.1
Average access time (msec)	15.1 RD	18.1 RD	18.1 RD	19.1	18.1
Data transfer rate (MBytes/sec) Internal, min/max External	--/20.5 16.6 PIO4/DMA2 33.3 Ultra DMA2	8.1/13.5 16.6 PIO4/DMA2 33.3 Ultra DMA2	8.1/13.5 16.6 PIO4/DMA2 33.3 Ultra DMA2	8.6/14.8 16.6 PIO4/DMA2 33.3 Ultra DMA2	9.6/15.7 16.6 PIO4/DMA2 33.3 Ultra DMA2
SIZE: (mm) H x W x D	25.4 x 101.6 x 146	17 x 70 x 100	17 x 70 x 100	12.5 x 70 x 100	17 x 70 x 100
FIRST CUSTOMER SHIPMENT	12/97	2/98	2/98	12/98	12/98
COMMENTS		*Untextured. Ramp loaded heads.	*Untextured. Ramp loaded heads.	*Untextured. Ramp loaded heads.	*Untextured. Ramp loaded heads.

MANUFACTURER	IBM	IBM	IBM	IBM	IBM
DRIVE	DGHC-318220 Ultrastar 18XP (Marlin)	DGHL-318220 Ultrastar 18XP (Marlin)	DGHS-318220 Ultrastar 18XP (Marlin)	DJNA-351010 Deskstar 25GP (Janus)	DJNA-351520 Deskstar 25GP (Janus)
DISK/TREND GROUP	6	6	6	6	6
PLATFORM	Server	Server	Server	Desktop	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	GMR Thin Film	GMR Thin Film
Interface	SSA	FC-AL	Ultra2 SCSI	Ultra DMA/66	Ultra DMA/66
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 18,220	F: 18,220	F: 18,220	F: 10,100	F: 15,200
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	20	20	20	4	6
Tracks per surface	8151	8151	8151	15302	15302
Track density (TPI)	8356	8356	8356	16000	16000
Maximum linear density (BPI) (FCI)	150000	150000	150000	233800	233800
Areal density (Gb/square inch)	1.253	1.253	1.253	3.741	3.741
Recording code	16,17 PRML	16,17 PRML	16,17 PRML	PRML	PRML
Rotational speed (RPM)	7200	7200	7200	5400	5400
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	7.5 RD	7.5 RD	7.5 RD	9.0 RD	9.0 RD
Average rotational delay (msec)	4.17	4.17	4.17	5.6	5.6
Average access time (msec)	11.67 RD	11.67 RD	11.67 RD	14.6 RD	14.6 RD
Data transfer rate (MBytes/sec) Internal, min/max External	11.5/22.4 40.0	11.5/22.4 100.0	11.5/22.4 80.0	13.7/24.5 16.6 PIO4/DMA2 66.6 Ultra DMA4	13.7/24.5 16.6 PIO4/DMA2 66.6 Ultra DMA4
SIZE: (mm) H x W x D	42 x 101.6 x 147	42 x 101.6 x 147	42 x 101.6 x 147	25.4 x 101.6 x 146	25.4 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	2Q98	2Q98	10/97	12/98	12/98
COMMENTS					

MANUFACTURER	IBM	IBM	IBM	IBM	IBM
DRIVE	DJNA-371350 Deskstar 22GPX (Janus)	DJNA-371800 Deskstar 22GXP (Janus)	DMVC-18 Ultrastar 18LZX (Stingray)	DMVL-18 Ultrastar 18LZX (Stingray)	DMVS-18D/V Ultrastar 18LZX (Stingray)
DISK/TREND GROUP	6	6	6	6	6
PLATFORM	Desktop	Desktop	Server	Server	Server
MARKET	OEM, DIST	OEM, DIST	DIST, OEM	DIST, OEM	DIST, OEM
MEDIA: Disk diameter	95 mm	95 mm	84 mm	84 mm	84 mm
Recording medium	Thin Film	Thin Film	Thin Film*	Thin Film*	Thin Film*
Substrate	Aluminum	Aluminum	Glass	Glass	Glass
DRIVE: Heads	GMR Thin Film	GMR Thin Film	GMR Thin Film	GMR Thin Film	GMR Thin Film
Interface	Ultra DMA/66	Ultra DMA/66	SSA	FC-AL	Ultra2 SCSI
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 13,500	F: 18,000	F: 18,300	F: 18,300	F: 18,300
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	6	8	10	10	10
Tracks per surface	15012	15012	11748	11748	11748
Track density (TPI)	15700	15700	13595	13595	13595
Maximum linear density (BPI) (FCI)	218600	218600	260000	260000	260000
Areal density (Gb/square inch)	3.432	3.432	3.535	3.535	3.535
Recording code	PRML	PRML	16,17 PRML	16,17 PRML	16,17 PRML
Rotational speed (RPM)	7200	7200	10000	10000	10000
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	9.0 RD	9.0 RD	4.9 RD	4.9 RD	4.9 RD
Average rotational delay (msec)	4.17	4.17	3.0	3.0	3.0
Average access time (msec)	13.17 RD		7.9 RD	7.9 RD	7.9 RD
Data transfer rate (MBytes/sec) Internal, min/max	17.3/27.9	17.3/27.9	23.3/44.3	23.3/44.3	23.3/44.3
External	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 66.6 Ultra DMA4	160.0	100	80.0 synch.
SIZE: (mm) H x W x D	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.7 x 101.6 x 146.8	25.7 x 101.6 x 146.8	25.7 x 101.6 x 146.8
FIRST CUSTOMER SHIPMENT	12/98	12/98	4Q99	4Q99	5/99
COMMENTS			*Untextured. Ramp loaded heads.	*Untextured. Ramp loaded heads.	*Untextured. Ramp loaded heads.

MANUFACTURER	IBM	IBM	IBM	IBM	IBM
DRIVE	DMVS-18X Ultrastar 18LZX (Stingray)	DNEF-318350 Ultrastar 18ES (Neptune)	DNES-318350 Ultrastar 18ES (Neptune)	DPTA-351500 Deskstar 37GP (Pluto)	DPTA-371360 Deskstar 34GXP (Pluto)
DISK/TREND GROUP	6	6	6	6	6
PLATFORM	Server	Server	Server	Desktop	Desktop
MARKET	DIST, OEM	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	84 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film*	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Glass	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	GMR Thin Film	GMR Thin Film	GMR Thin Film	GMR Thin Film	GMR Thin Film
Interface	SCSI Ultra2/160	FC-AL	Ultra2 SCSI	Ultra DMA/66	Ultra DMA/66
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 18,300	F: 18,200	F: 18,200	F: 15,000	F: 13,600
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	10	10	10	4	4
Tracks per surface	11748	11474	11474	17688	17494
Track density (TPI)	13595	13700	13700	18500	18300
Maximum linear density (BPI) (FCI)	260000	220000	220000	287000	282000
Areal density (Gb/square inch)	3.535	3.014	3.014	5.310	5.161
Recording code	16,17 PRML	16,17 PRML	16,17 PRML	PRML	PRML
Rotational speed (RPM)	10000	7200	7200	5400	7200
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	4.9 RD	7.0 RD	7.0 RD	9	9
Average rotational delay (msec)	3.0	4.17	4.17	5.6	4.17
Average access time (msec)	7.9 RD	11.17 RD	11.17 RD	14.6	13.17
Data transfer rate (MBytes/sec) Internal, min/max	23.3/44.3	19.9/30.5	19.9/30.5	--/31.0	--/35.5
External	160.0 synch.	100.0	80.0 synch.	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 66.6 Ultra DMA4
SIZE: (mm) H x W x D	25.7 x 101.6 x 146.8	25.4 x 101.6 x 146.0	25.4 x 101.6 x 146.0	25.4 x 101.6 x 146	25.4 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	3Q99	1Q98	1Q98	8/99	8/99
COMMENTS	*Untextured. Ramp loaded heads.				

MANUFACTURER	IBM	IBM	IBM	IBM	IBM
DRIVE	DRVC-3018510C Ultrastar 18ZX (Hammerhead)	DRVL-3018510L Ultrastar 18ZX (Hammerhead)	DRVS-3018510S Ultrastar 18ZX (Hammerhead)	DTTA-351010 Deskstar 16GP (Titan)	DTTA-351290 Deskstar 16GP (Titan)
DISK/TREND GROUP	6	6	6	6	6
PLATFORM	Server	Server	Server	Desktop	Desktop
MARKET	DIST, OEM	DIST, OEM	DIST, OEM	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	84 mm	84 mm	84 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	GMR Thin Film	GMR Thin Film
Interface	SSA	FC-AL	Ultra2 SCSI	Ultra DMA/33	Ultra DMA/33
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 18,200	F: 18,200	F: 18,200	F: 10,100	F: 12,900
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	20	20	20	6	8
Tracks per surface	7052	7052	7052	13085	13085
Track density (TPI)	9240	9240	9240	13700	13700
Maximum linear density (BPI) (FCI)	219100	219100	219100	196100	196100
Areal density (Gb/square inch)	2.024	2.024	2.024	2.687	2.687
Recording code	16,17 PRML	16,17 PRML	16,17 PRML	PRML	PRML
Rotational speed (RPM)	10020	10020	10020	5400	5400
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	5.3 RD	5.3 RD	5.3 RD	9.5 RD	9.5 RD
Average rotational delay (msec)	2.99	2.99	2.99	5.6	5.6
Average access time (msec)	8.29 RD	8.29 RD	8.29 RD	15.1 RD	15.1 RD
Data transfer rate (MBytes/sec) Internal, min/max	23.4/30.5	23.4/30.5	23.4/30.5	--/20.5	--/20.5
External	40.0	100.0	80.0 synch.	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2
SIZE: (mm) H x W x D	25.7 x 101.6 x 146.8	25.7 x 101.6 x 146.8	25.7 x 101.6 x 146.8	25.4 x 101.6 x 146	25.4 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	4Q98	4Q98	4Q98	12/97	12/97
COMMENTS					

MANUFACTURER	IBM	IBM	IBM	IBM	IBM
DRIVE	DTTA-351680 Deskstar 16GP (Titan)	DTTA-371010 Deskstar 14GXP (Titan)	DTTA-371290 Deskstar 14GXP (Titan)	DTTA-371440 Deskstar 14GXP (Titan)	DJNA-352030 Deskstar 25GP (Janus)
DISK/TREND GROUP	6	6	6	6	7
PLATFORM	Desktop	Desktop	Desktop	Desktop	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	GMR Thin Film	GMR Thin Film	GMR Thin Film	GMR Thin Film	GMR Thin Film
Interface	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33	Ultra DMA/66
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 16,800	F: 10,100	F: 12,900	F: 14,400	F: 20,300
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	10	7	8	10	8
Tracks per surface	13085	13085	13085	13085	15302
Track density (TPI)	13700	13700	13700	13700	16000
Maximum linear density (BPI) (FCI)	196100	178100	178100	178100	233800
Areal density (Gb/square inch)	2.687	2.440	2.440	2.440	3.741
Recording code	PRML	PRML	PRML	PRML	PRML
Rotational speed (RPM)	5400	7200	7200	7200	5400
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	9.5 RD	9.5 RD	9.5 RD	9.5 RD	9.0 RD
Average rotational delay (msec)	5.6	4.17	4.17	4.17	5.6
Average access time (msec)	15.1 RD	13.67 RD	13.67 RD	13.67 RD	
Data transfer rate (MBytes/sec) Internal, min/max	--/20.5	--/22.3	--/22.3	--/22.3	13.7/24.5
External	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 66.6 Ultra DMA4
SIZE: (mm) H x W x D	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	12/97	12/97	12/97	12/97	12/98
COMMENTS					

MANUFACTURER	IBM	IBM	IBM	IBM	IBM
DRIVE	DJNA-352500 Deskstar 25GP (Janus)	DJNA-372200 Deskstar 22GXP (Janus)	DMVC-36 Ultrastar 36ZX (Manta)	DMVL-36 Ultrastar 36ZX (Manta)	DMVS-36D/V Ultrastar 36ZX (Manta)
DISK/TREND GROUP	7	7	7	7	7
PLATFORM	Desktop	Desktop	Server	Server	Server
MARKET	OEM, DIST	OEM, DIST	DIST, OEM	DIST, OEM	DIST, OEM
MEDIA: Disk diameter	95 mm	95 mm	84 mm	84 mm	84 mm
Recording medium	Thin Film	Thin Film	Thin Film*	Thin Film*	Thin Film*
Substrate	Aluminum	Aluminum	Glass	Glass	Glass
DRIVE: Heads	GMR Thin Film	GMR Thin Film	GMR Thin Film	GMR Thin Film	GMR Thin Film
Interface	Ultra DMA/66	Ultra DMA/66	SSA	FC-AL	Ultra2 SCSI
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 25,000	F: 22,000	F: 36,700	F: 36,700	F: 36,700
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	10	10	20	20	20
Tracks per surface	15302	15012	11748	11748	11748
Track density (TPI)	16000	15700	13595	13595	13595
Maximum linear density (BPI) (FCI)	233800	218600	260000	260000	260000
Areal density (Gb/square inch)	3.741	3.432	3.535	3.535	3.535
Recording code	PRML	PRML	16,17 PRML	16,17 PRML	16,17 PRML
Rotational speed (RPM)	5400	7200	10000	10000	10000
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	9.0 RD	9.0 RD	5.4 RD	5.4 RD	5.4 RD
Average rotational delay (msec)	5.6	4.17	3.0	3.0	3.0
Average access time (msec)	14.6 RD	13.17	8.4 RD	8.4 RD	8.4 RD
Data transfer rate (MBytes/sec) Internal, min/max External	13.7/24.5 16.6 PIO4/DMA2 66.6 Ultra DMA4	17.3/27.9 16.6 PIO4/DMA2 66.6 Ultra DMA4	23.3/44.3 160.0	23.3/44.3 100	23.3/44.3 80.0 synch.
SIZE: (mm) H x W x D	25.4 x 101.6 x 146	25.4 x 101.6 x 146	41.5 x 101.6 x 146.8	41.5 x 101.6 x 146.8	41.5 x 101.6 x 146.8
FIRST CUSTOMER SHIPMENT	12/98	12/98	4Q99	4Q99	5/99
COMMENTS			*Untextured. Ramp loaded heads.	*Untextured. Ramp loaded heads.	*Untextured. Ramp loaded heads.

MANUFACTURER	IBM	IBM	IBM	IBM	IBM
DRIVE	DMVS-36X Ultrastar 36ZX (Manta)	DPTA-352250 Deskstar 37GP (Pluto)	DPTA-353000 Deskstar 37GP (Pluto)	DPTA-353750 Deskstar 37GP (Pluto)	DPTA-372050 Deskstar 34GXP (Pluto)
DISK/TREND GROUP	7	7	7	7	7
PLATFORM	Server	Desktop	Desktop	Desktop	Desktop
MARKET	DIST, OEM	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	84 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film*	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Glass	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	GMR Thin Film	GMR Thin Film	GMR Thin Film	GMR Thin Film	GMR Thin Film
Interface	SCSI Ultra2/160	Ultra DMA/66	Ultra DMA/66	Ultra DMA/66	Ultra DMA/66
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 36,700	F: 22,500	F: 30,000	F: 37,500	F: 20,500
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	20	6	8	10	6
Tracks per surface	11748	17688	17688	17688	17494
Track density (TPI)	13595	18500	18500	18500	18300
Maximum linear density (BPI) (FCI)	260000	287000	287000	287000	282000
Areal density (Gb/square inch)	3.535	5.310	5.310	5.310	5.161
Recording code	16,17 PRML	PRML	PRML	PRML	PRML
Rotational speed (RPM)	10000	5400	5400	5400	7200
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	5.4 RD	9	9	9	9
Average rotational delay (msec)	3.0	5.6	5.6	5.6	4.17
Average access time (msec)	8.4 RD	14.6	14.6	14.6	13.17
Data transfer rate (MBytes/sec) Internal, min/max	23.3/44.3	--/31.0	--/31.0	--/31.0	--/35.5
External	160.0 synch.	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 66.6 Ultra DMA4
SIZE: (mm) H x W x D	41.5 x 101.6 x 146.8	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	3Q99	8/99	8/99	8/99	8/99
COMMENTS	*Untextured. Ramp loaded heads.				

MANUFACTURER	IBM	IBM	IBM	IBM	IBM
DRIVE	DPTA-372730 Deskstar 34GXP (Pluto)	DPTA-373420 Deskstar 34GXP (Pluto)	DRHC-3036410C Ultrastar 36XP (Swordfish)	DRHL-3036410L Ultrastar 36XP (Swordfish)	DRHS-3036410S Ultrastar 36XP (Swordfish)
DISK/TREND GROUP	7	7	7	7	7
PLATFORM	Desktop	Desktop	Server	Server	Server
MARKET	OEM, DIST	OEM, DIST	DIST, OEM	DIST, OEM	DIST, OEM
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	GMR Thin Film	GMR Thin Film	NR Thin Film	NR Thin Film	NR Thin Film
Interface	Ultra DMA/66	Ultra DMA/66	SSA	FC-AL	Ultra2 SCSI
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 27,300	F: 34,200	F: 36,400	F: 36,400	F: 36,400
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	8	10	20	20	20
Tracks per surface	17494	17494	11494	11494	11494
Track density (TPI)	18300	18300	11550	11550	11550
Maximum linear density (BPI) (FCI)	282000	282000	238800	238800	238800
Areal density (Gb/square inch)	5.161	5.161	2.758	2.758	2.758
Recording code	PRML	PRML	16,17 PRML	16,17 PRML	16,17 PRML
Rotational speed (RPM)	7200	7200	7200	7200	7200
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	9	9	7.5 RD	7.5 RD	7.5 RD
Average rotational delay (msec)	4.17	4.17	4.17	4.17	4.17
Average access time (msec)	13.17	13.17	11.67 RD	11.67 RD	11.67 RD
Data transfer rate (MBytes/sec) Internal, min/max External	--/35.5 16.6 PIO4/DMA2 66.6 Ultra DMA4	--/35.5 16.6 PIO4/DMA2 66.6 Ultra DMA4	17.9/28.9 40.0 synch.	17.9/28.9 100.0	17.9/28.9 80.0 synch.
SIZE: (mm) H x W x D	25.4 x 101.6 x 146	25.4 x 101.6 x 146	41.0 x 101.9 x 147	41.0 x 101.9 x 147	41.0 x 101.9 x 147
FIRST CUSTOMER SHIPMENT	8/99	8/99	4Q98	4Q98	4Q98
COMMENTS					

MANUFACTURER	IOMEGA	IOMEGA	IOMEGA	IOMEGA	MAXTOR
DRIVE	Jaz 1 Internal	Jaz 1 Portable	Jaz 2 Internal	Jaz 2 Portable	90340D2 DiamondMax 3400
DISK/TREND GROUP	1	1	1	1	4
PLATFORM	Desktop	Desktop	Desktop	Desktop	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	Thin Film	Thin Film	Thin Film	Thin Film	MR Thin Film
Interface	SCSI-2	Ultra SCSI	Ultra SCSI	Ultra SCSI	Ultra DMA/33
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	--	--	--	--	F: 3,400
REMOVABLE	F: 540/1,070	F: 540/1,070	F: 1,070/2,002	F: 1,070/2,002	--
Data surfaces per spindle	4	4	4	4	2
Tracks per surface	4204	4204	6145	6145	11530
Track density (TPI)	4301	4301	6100	6100	11400
Maximum linear density (BPI) (FCI)	89178 66884	89178 66884	121330 91000	121330 91000	223000
Areal density (Gb/square inch)	.384	.384	.740	.740	2.542
Recording code	1,7 RLL	1,7 RLL	1,7 RLL	1,7 RLL	PRML
Rotational speed (RPM)	5400	5400	5400	5400	5400
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	10 RD/12 WR	10 RD/12 WR	10 RD/12 WR	10 RD/12 WR	9
Average rotational delay (msec)	5.6	5.6	5.6	5.6	5.6
Average access time (msec)	15.6 RD/17.6 WR	15.6 RD/17.6 WR	15.6 RD/17.6 WR	15.6 RD/17.6 WR	14.6
Data transfer rate (MBytes/sec) Internal, min/max External	3.5/6.7 10.0 synch. 5.0 asynch.	3.5/6.7 10.0 synch. 5.0 asynch.	4.9/8.7 20.0 synch. 5.0 asynch.	4.9/8.7 20.0 synch. 5.0 asynch.	--/18.6 16.6 PIO4/DMA2 33.3 Ultra DMA2
SIZE: (mm) H x W x D	25.4 x 101.6 x 149.9	38 x 135 x 203	25.4 x 101.6 x 149.9	38 x 135 x 203	25.9 x 102.1 x 146.6
FIRST CUSTOMER SHIPMENT	4Q95	4Q95	3/98	3/98	6/98
COMMENTS			Backward compatible with Jaz 1 GB disks.	Backward compatible with Jaz 1 GB disks.	

MANUFACTURER	MAXTOR	MAXTOR	MAXTOR	MAXTOR	MAXTOR
DRIVE	90432D2 DiamondMax 4320	90648D3 DiamondMax 4320	90650U2 DiamondMax 6800	90680D4 DiamondMax 3400	90750D3 DiamondMax Plus 5120
DISK/TREND GROUP	4	5	5	5	5
PLATFORM	Desktop	Desktop	Desktop	Desktop	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	GMR Thin Film	MR Thin Film	GMR Thin Film
Interface	Ultra DMA/33	Ultra DMA/33	Ultra DMA/66	Ultra DMA/33	Ultra DMA/66
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 4,320	F: 6,480	F: 6,500	F: 6,800	F: 7,680
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	2	3	2	4	3
Tracks per surface	13295	13295	17549	11530	14850
Track density (TPI)	13000	13000	17305	11400	14522
Maximum linear density (BPI) (FCI)	237000	237000	288000 306000	223000	255000 271000
Areal density (Gb/square inch)	3.081	3.081	4.984	2.542	3.703
Recording code	PRML	PRML	16,17 EPR4	PRML	PRML
Rotational speed (RPM)	5400	5400	5400	5400	7200
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	9	9	9	9	9
Average rotational delay (msec)	5.6	5.6	5.6	5.6	4.17
Average access time (msec)	14.6	14.6	14.6	14.6	13.17
Data transfer rate (MBytes/sec) Internal, min/max External	--/22.0 16.6 PIO4/DMA2 33.3 Ultra DMA2	--/22.0 16.6 PIO4/DMA2 33.3 Ultra DMA2	--/27.8 16.6 PIO4/DMA2 66.6 Ultra DMA4	--/18.6 16.6 PIO4/DMA2 33.3 Ultra DMA2	--/31.2 16.6 PIO4/DMA2 66.6 Ultra DMA4
SIZE: (mm) H x W x D	25.9 x 102.1 x 146.6	25.9 x 102.1 x 146.6	25.9 x 102.1 x 146.6	25.9 x 102.1 x 146.6	25.9 x 102.0 x 146.7
FIRST CUSTOMER SHIPMENT	10/98	10/98	6/99	6/98	3/99
COMMENTS					

MANUFACTURER	MAXTOR	MAXTOR	MAXTOR	MAXTOR	MAXTOR
DRIVE	90750D6 DiamondMax Plus 2500	90845D4 DiamondMax 4320	90845U3 DiamondMax 6800	91000D8 DiamondMax Plus 2500	91020U3 DiamondMax 6800
DISK/TREND GROUP	5	5	5	6	6
PLATFORM	Desktop	Desktop	Desktop	Desktop	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	GMR Thin Film	MR Thin Film	GMR Thin Film
Interface	Ultra DMA/33	Ultra DMA/33	Ultra DMA/66	Ultra DMA/33	Ultra DMA/66
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 7,500	F: 8,455	F: 8,455	F: 10,000	F: 10,209
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	6	4	3	8	3
Tracks per surface	10022	13295	17549	10022	17549
Track density (TPI)	9800	13000	17305	9800	17305
Maximum linear density (BPI) (FCI)	190000	237000	288000 306000	190000	288000 306000
Areal density (Gb/square inch)	1.862	3.081	4.984	1.862	4.984
Recording code	PRML	PRML	16,17 EPR4	PRML	16,17 EPR4
Rotational speed (RPM)	7200	5400	5400	7200	5400
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	9	9	9	9	9
Average rotational delay (msec)	4.17	5.6	5.6	4.17	5.6
Average access time (msec)	13.17	14.6	14.6	13.17	14.6
Data transfer rate (MBytes/sec) Internal, min/max External	--/21.9 16.6 PIO4/DMA2 33.3 Ultra DMA2	--/22.0 16.6 PIO4/DMA2 33.3 Ultra DMA2	--/27.8 16.6 PIO4/DMA2 66.6 Ultra DMA4	--/21.9 16.6 PIO4/DMA2 33.3 Ultra DMA2	--/27.8 16.6 PIO4/DMA2 66.6 Ultra DMA4
SIZE: (mm) H x W x D	25.9 x 102.1 x 146.6	25.9 x 102.1 x 146.6	25.9 x 102.1 x 146.6	25.9 x 102.1 x 146.6	25.9 x 102.1 x 146.6
FIRST CUSTOMER SHIPMENT	6/98	10/98	6/99	6/98	6/99
COMMENTS					

MANUFACTURER	MAXTOR	MAXTOR	MAXTOR	MAXTOR	MAXTOR
DRIVE	91080D5 DiamondMax 4320	91280D5 DiamondMax Plus 5120	91303D6 DiamondMax 4320	91360U4 DiamondMax 6800	91536D6 DiamondMax Plus 5120
DISK/TREND GROUP	6	6	6	6	6
PLATFORM	Desktop	Desktop	Desktop	Desktop	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	GMR Thin Film	MR Thin Film	GMR Thin Film	GMR Thin Film
Interface	Ultra DMA/33	Ultra DMA/66	Ultra DMA/33	Ultra DMA/66	Ultra DMA/66
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 10,800	F: 12,800	F: 13,030	F: 13,613	F: 15,360
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	5	5	6	4	6
Tracks per surface	13295	14850	13295	17549	14850
Track density (TPI)	13000	14522	13000	17305	14522
Maximum linear density (BPI) (FCI)	237000	255000 271000	237000	288000 306000	255000 271000
Areal density (Gb/square inch)	3.081	3.703	3.081	4.984	3.703
Recording code	PRML	PRML	PRML	16,17 EPR4	PRML
Rotational speed (RPM)	5400	7200	5400	5400	7200
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	9	9	9	9	9
Average rotational delay (msec)	4.17	4.17	5.6	5.6	4.17
Average access time (msec)	13.17	13.17	14.6	14.6	13.17
Data transfer rate (MBytes/sec) Internal, min/max External	--/31.2 16.6 PIO4/DMA2 66.6 Ultra DMA4	--/31.2 16.6 PIO4/DMA2 66.6 Ultra DMA4	--/22.0 16.6 PIO4/DMA2 33.3 Ultra DMA2	--/27.8 16.6 PIO4/DMA2 66.6 Ultra DMA4	--/31.2 16.6 PIO4/DMA2 66.6 Ultra DMA4
SIZE: (mm) H x W x D	25.9 x 102.0 x 146.7	25.9 x 102.0 x 146.7	25.9 x 102.1 x 146.6	25.9 x 102.1 x 146.6	25.9 x 102.0 x 146.7
FIRST CUSTOMER SHIPMENT	3/99	3/99	10/98	6/99	3/99
COMMENTS					

MANUFACTURER	MAXTOR	MAXTOR	MAXTOR	MAXTOR	MAXTOR
DRIVE	91700U5 DiamondMax 6800	91728D8 DiamondMax 4320	91792D7 DiamondMax Plus 5120	92040U6 DiamondMax 6800	92048D8 DiamondMax Plus 5120
DISK/TREND GROUP	6	6	6	7	7
PLATFORM	Desktop	Desktop	Desktop	Desktop	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	GMR Thin Film	MR Thin Film	GMR Thin Film	GMR Thin Film	GMR Thin Film
Interface	Ultra DMA/66	Ultra DMA/33	Ultra DMA/66	Ultra DMA/66	Ultra DMA/66
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 17,020	F: 17,280	F: 17,920	F: 20,419	F: 20,480
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	5	8	7	6	8
Tracks per surface	17549	13295	14850	17549	14850
Track density (TPI)	17305	13000	14522	17305	14522
Maximum linear density (BPI) (FCI)	288000 306000	237000	255000 271000	288000 306000	255000 271000
Areal density (Gb/square inch)	4.984	3.081	3.703	4.984	3.703
Recording code	16,17 EPR4	PRML	PRML	16,17 EPR4	PRML
Rotational speed (RPM)	5400	5400	7200	5400	7200
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	9	9	9	9	9
Average rotational delay (msec)	5.6	5.6	4.17	5.6	4.17
Average access time (msec)	14.6	14.6	13.17	14.6	13.17
Data transfer rate (MBytes/sec) Internal, min/max External	--/27.8 16.6 PIO4/DMA2 66.6 Ultra DMA4	--/22.0 16.6 PIO4/DMA2 33.3 Ultra DMA2	--/31.2 16.6 PIO4/DMA2 66.6 Ultra DMA4	--/27.8 16.6 PIO4/DMA2 66.6 Ultra DMA4	--/31.2 16.6 PIO4/DMA2 66.6 Ultra DMA4
SIZE: (mm) H x W x D	25.9 x 102.1 x 146.6	25.9 x 102.1 x 146.6	25.9 x 102.0 x 146.7	25.9 x 102.1 x 146.6	25.9 x 102.0 x 146.7
FIRST CUSTOMER SHIPMENT	6/99	10/98	3/99	6/99	3/99
COMMENTS					

MANUFACTURER	MAXTOR	NEC	NEC	NEC	NEC
DRIVE	92720U8 DiamondMax 6800	DCAS-32160	DCAS-34330	DTTA-350430	DTTA-350640
DISK/TREND GROUP	7	3	4	4	5
PLATFORM	Desktop	Server	Server	Desktop	Desktop
MARKET	OEM, DIST	Captive	Captive	Captive	Captive
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	GMR Thin Film	MR Thin Film	MR Thin Film	GMR Thin Film	GMR Thin Film
Interface	Ultra DMA/66	Ultra SCSI	Ultra SCSI	Ultra DMA/33	Ultra DMA/33
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 27,226	F: 2,160	F: 4,330	F: 4,300	F: 6,400
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	8	3	6	3	4
Tracks per surface	17549	8210	8210	13085	13085
Track density (TPI)	17305	8600	8600	13700	13700
Maximum linear density (BPI) (FCI)	288000 306000	134600	134600	196100	196100
Areal density (Gb/square inch)	4.984	1.158	1.158	2.687	2.687
Recording code	16,17 EPR4	PRML	PRML	PRML	PRML
Rotational speed (RPM)	5400	5400	5400	5400	5400
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	9	8.5 RD	8.5 RD	9.5 RD	9.5 RD
Average rotational delay (msec)	5.6	5.6	5.6	5.6	5.6
Average access time (msec)	14.6	14.1 RD	14.1 RD	15.1 RD	15.1 RD
Data transfer rate (MBytes/sec) Internal, min/max	--/27.8	7.8/12.9	7.8/12.9	--/20.5	--/20.5
External	16.6 PIO4/DMA2 66.6 Ultra DMA4	40.0 synch. 20.0 asynch.	40.0 synch. 20.0 asynch.	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2
SIZE: (mm) H x W x D	25.9 x 102.1 x 146.6	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	6/99	1998	1998	1998	1998
COMMENTS					

MANUFACTURER	NEC	NEC	NEC	NEC	PCS, INC.
DRIVE	DTTA-350840	DJNA-351010	DJNA-351520	DTTA-351010	8170E Viper 170E (Integral Peripherals)
DISK/TREND GROUP	5	6	6	6	2
PLATFORM	Desktop	Desktop	Desktop	Desktop	Mobile
MARKET	Captive	Captive	Captive	Captive	OEM
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	48 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film*
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	
DRIVE: Heads	GMR Thin Film	GMR Thin Film	GMR Thin Film	GMR Thin Film	Thin Film
Interface	Ultra DMA/33	Ultra DMA/66	Ultra DMA/66	Ultra DMA/33	PCMCIA-ATA
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 8,400	F: 10,100	F: 15,200	F: 10,100	--
REMOVABLE	--	--	--	--	F: 170.8
Data surfaces per spindle	5	4	6	6	2
Tracks per surface	13085	15302	15302	13085	2000
Track density (TPI)	13700	16000	16000	13700	5100
Maximum linear density (BPI) (FCI)	196100	233800	233800	196100	123600 92700
Areal density (Gb/square inch)	2.687	3.741	3.741	2.687	.630
Recording code	PRML	PRML	PRML	PRML	1,7 PRML
Rotational speed (RPM)	5400	5400	5400	5400	4500
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	9.5 RD	9.0 RD	9.0 RD	9.5 RD	12
Average rotational delay (msec)	5.6	5.6	5.6	5.6	6.7
Average access time (msec)	15.1 RD	14.6	14.6	15.1 RD	18.7
Data transfer rate (MBytes/sec) Internal, min/max	--/20.5	--/24.5	--/24.5	--/20.5	--/5.7
External	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.0
SIZE: (mm) H x W x D	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146	10.5 x 54 x 85.6
FIRST CUSTOMER SHIPMENT	1998	1998	1998	1998	7/94
COMMENTS					PCMCIA Type III Ramp loaded heads. *Untextured disks.

MANUFACTURER	PCS, INC.	QUANTUM	QUANTUM	QUANTUM	QUANTUM
DRIVE	8340PA Viper 340 (Integral Peripherals)	QM302500EL-A Fireball EL	QM303200EX-A Fireball EX	QM304300CR-A Fireball CR	QM304550TD-FC Atlas III
DISK/TREND GROUP	2	3	4	4	4
PLATFORM	Mobile	Desktop	Desktop	Desktop	Server
MARKET	OEM	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	48 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film*	Thin Film	Thin Film	Thin Film	Thin Film
Substrate		Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film
Interface	PCMCIA-ATA	Ultra DMA/33	Ultra DMA/33	Ultra DMA/66	FC-AL
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	--	F: 2,564	F: 3,228	F: 4,320	F: 4,550
REMOVABLE	F: 341.1	--	--	--	--
Data surfaces per spindle	4	2	2	2	5
Tracks per surface	2000		11550	12515	8000
Track density (TPI)	5100	10000	12000	13000	8900
Maximum linear density (BPI) (FCI)	123600 92700	194684	222118	260000	175000 186000
Areal density (Gb/square inch)	.630	1.947	2.665	3.380	1.558
Recording code	1,7 PRML	EPRML	EPRML	16,17 PRML	16,17 PRML
Rotational speed (RPM)	4500	5400	5400	5400	7200
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	12	9.5	9.5	9.5 RD/11.0 WR	7.5 RD
Average rotational delay (msec)	6.7	5.6	5.6	5.6	4.17
Average access time (msec)	18.7	15.1	15.1	15.1 RD/16.6 WR	11.67 RD
Data transfer rate (MBytes/sec) Internal, min/max External	--/5.7 16.0	--/20.3 16.6 PIO4/DMA2 33.3 Ultra DMA2	--/23.4 16.6 PIO4/DMA2 33.3 Ultra DMA2	19.1/23.6 16.6 PIO4/DMA2 66.6 Ultra DMA4	13.8/22.5 200.0
SIZE: (mm) H x W x D	10.5 x 54 x 85.6	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1
FIRST CUSTOMER SHIPMENT	7/94	5/98	7/98	1Q99	1Q98
COMMENTS	PCMCIA Type III Ramp loaded heads. *Untextured disks.				

MANUFACTURER	QUANTUM	QUANTUM	QUANTUM	QUANTUM	QUANTUM
DRIVE	QM304550TD-SXX Atlas III	QM34550PX-SXX Viking II	QM305100EL-A Fireball EL	QM305100EX-A Fireball EX	QM306400CR-A Fireball CR
DISK/TREND GROUP	4	4	5	5	5
PLATFORM	Server	Server	Desktop	Desktop	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film
Interface	SCSI Ultra 2	SCSI Ultra 2	Ultra DMA/33	Ultra DMA/33	Ultra DMA/66
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 4,550	F: 4,550	F: 5,130	F: 5,130	F: 6,480
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	5	5	4	3	3
Tracks per surface	8000	8338		11550	12515
Track density (TPI)	8900	8500	10000	12000	13000
Maximum linear density (BPI) (FCI)	175000 186000	158000	194684	222118	260000
Areal density (Gb/square inch)	1.558	1.343	1.947	2.665	3.380
Recording code	16,17 PRML	16,17 PRML	EPRML	EPRML	16,17 PRML
Rotational speed (RPM)	7200	7200	5400	5400	5400
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	7.5 RD	8	9.5	9.5	9.5 RD/11.0 WR
Average rotational delay (msec)	4.17	4.17	5.6	5.6	5.6
Average access time (msec)	11.67 RD	12.17	15.1	15.1	15.1 RD/16.6 WR
Data transfer rate (MBytes/sec) Internal, min/max	13.8/22.5	12.3/21.3	--/20.3	--/23.4	19.1/23.6
External	80.0 synch.	80.0 synch.	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 66.6 Ultra DMA4
SIZE: (mm) H x W x D	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1
FIRST CUSTOMER SHIPMENT	1Q98	1Q98	5/98	7/98	1Q99
COMMENTS					

MANUFACTURER	QUANTUM	QUANTUM	QUANTUM	QUANTUM	QUANTUM
DRIVE	QM306400EX-A Fireball EX	QM307600EL-A Fireball EL	QM308400CR-A Fireball CR	QM309100KN-LW QM309100KN-SCA Atlas IV	QM309100TD-SXX Atlas III
DISK/TREND GROUP	5	5	5	5	5
PLATFORM	Desktop	Desktop	Desktop	Server	Server
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film
Interface	Ultra DMA/33	Ultra DMA/33	Ultra DMA/66	SCSI Ultra2/160	SCSI Ultra 2
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 6,448	F: 7,696	F: 8,640	F: 9,100	F: 9,100
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	4	6	4	4	10
Tracks per surface	11550		12515	13846	8000
Track density (TPI)	12000	10000	13000	13700	8900
Maximum linear density (BPI) (FCI)	222118	194684	260000	249000	175000 186000
Areal density (Gb/square inch)	2.665	1.947	3.380	3.411	1.558
Recording code	EPRML	EPRML	16,17 PRML	24,25 PRML	16,17 PRML
Rotational speed (RPM)	5400	5400	5400	7200	7200
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	9.5	9.5	9.5 RD/11.0 WR	6.9 RD	7.5 RD
Average rotational delay (msec)	5.6	5.6	5.6	4.17	4.17
Average access time (msec)	15.1	15.1	15.1 RD/16.6 WR	11.07	11.67 RD
Data transfer rate (MBytes/sec) Internal, min/max External	--/23.4 16.6 PIO4/DMA2 33.3 Ultra DMA2	--/20.3 16.6 PIO4/DMA2 33.3 Ultra DMA2	19.1/23.6 16.6 PIO4/DMA2 66.6 Ultra DMA4	18.9/32.1 160 synch.	13.8/22.5 80.0 synch.
SIZE: (mm) H x W x D	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1
FIRST CUSTOMER SHIPMENT	7/98	5/98	1Q99	5/99	1Q98
COMMENTS					

MANUFACTURER	QUANTUM	QUANTUM	QUANTUM	QUANTUM	QUANTUM
DRIVE	QM309100TN-FC Atlas 10K	QM309100TN-LW QM309100TN-SCA Atlas 10K	QM30911TD-FC Atlas III	QM36400CX-A Fireball CX	QM39100PX-SXX Viking II
DISK/TREND GROUP	5	5	5	5	5
PLATFORM	Server	Server	Server	Desktop	Server
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	84 mm	84 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	GMR Thin Film	MR Thin Film
Interface	FC-AL	SCSI Ultra2/160	FC-AL	Ultra DMA/66	SCSI Ultra2
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 9,100	F: 9,100	F: 9,100	F: 6,448	F: 9,100
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	6	6	10	2	10
Tracks per surface	10458	10458	8000		8338
Track density (TPI)	13600	13600	8900		8500
Maximum linear density (BPI) (FCI)	254000	254000	175000 186000		158000
Areal density (Gb/square inch)	3.454	3.454	1.558		1.343
Recording code	24,25 PRML	24,25 PRML	16,17 PRML		16,17 PRML
Rotational speed (RPM)	10000	10000	7200	5400	7200
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	5.0	5.0	7.5 RD	9.5	8
Average rotational delay (msec)	3.0	3.0	4.17	5.6	4.17
Average access time (msec)	8.0	8.0	11.67 RD	15.1	12.17
Data transfer rate (MBytes/sec) Internal, min/max	26.9/39.4	26.9/39.4	13.8/22.5	--/30.1	12.3/21.3
External	100	160 synch.	200.0	16.6 PIO4/DMA2 66.6 Ultra DMA4	80.0 synch.
SIZE: (mm) H x W x D	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1
FIRST CUSTOMER SHIPMENT	3Q99	5/99	1Q98	4/99	1Q98
COMMENTS					

MANUFACTURER	QUANTUM	QUANTUM	QUANTUM	QUANTUM	QUANTUM
DRIVE	QM506400TS Bigfoot TS	QM508400TS Bigfoot TS	QMP06400KA-A Fireball Plus KA	QMP09100KA-A Fireball Plus KA	QM310200CX-A Fireball CX
DISK/TREND GROUP	5	5	5	5	6
PLATFORM	Desktop	Desktop	Desktop	Desktop	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	130 mm	130 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	GMR Thin Film
Interface	Ultra DMA/33	Ultra DMA/33	Ultra DMA/66	Ultra DMA/66	Ultra DMA/66
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 6,418	F: 8,455	F: 6,400	F: 9,100	F: 10,275
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	2	3	3	4	3
Tracks per surface	15449	15495	13889	13889	
Track density (TPI)	12000	12000	13700	13700	
Maximum linear density (BPI) (FCI)	205458 218299	205458 218299	241000	241000	
Areal density (Gb/square inch)	2.465	2.465	3.302	3.302	
Recording code	16,17 PRML	16,17 PRML	16,17 PRML	16,17 PRML	
Rotational speed (RPM)	4000	4000	7200	7200	5400
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	10.5	10.5	8.5	8.5	9.5
Average rotational delay (msec)	7.5	7.5	4.17	4.17	5.6
Average access time (msec)	18.0	18.0	12.67	12.67	15.1
Data transfer rate (MBytes/sec) Internal, min/max External	12.6/21.0 16.6 PIO4/DMA2 33.3 Ultra DMA2	12.6/21.0 16.6 PIO4/DMA2 33.3 Ultra DMA2	--/29.4 16.6 PIO4/DMA2 66.6 Ultra DMA4	--/29.4 16.6 PIO4/DMA2 66.6 Ultra DMA4	--/30.1 16.6 PIO4/DMA2 66.6 Ultra DMA4
SIZE: (mm) H x W x D	25.4 x 146.1 x 203.2	25.4 x 146.1 x 203.2	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1
FIRST CUSTOMER SHIPMENT	10/98	10/98	1Q99	1Q99	4/99
COMMENTS					

MANUFACTURER	QUANTUM	QUANTUM	QUANTUM	QUANTUM	QUANTUM
DRIVE	QM310200EL-A Fireball EL	QM310200EX-A Fireball EX	QM312700CR-A Fireball CR	QM312700EX-A Fireball EX	QM313000CX-A Fireball CX
DISK/TREND GROUP	6	6	6	6	6
PLATFORM	Desktop	Desktop	Desktop	Desktop	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	GMR Thin Film
Interface	Ultra DMA/33	Ultra DMA/33	Ultra DMA/66	Ultra DMA/33	Ultra DMA/66
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 10,262	F: 10,262	F: 12,960	F: 12,720	F: 13,020
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	8	6	6	8	4
Tracks per surface		11550	12515	11550	
Track density (TPI)	10000	12000	13000	12000	
Maximum linear density (BPI) (FCI)	194684	222118	260000	222118	
Areal density (Gb/square inch)	1.947	2.665	3.380	2.665	
Recording code	EPRML	EPRML	16,17 PRML	EPRML	
Rotational speed (RPM)	5400	5400	5400	5400	5400
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	9.5	9.5	9.5 RD/11.0 WR	9.5	9.5
Average rotational delay (msec)	5.6	5.6	5.6	5.6	5.6
Average access time (msec)	15.1	15.1	15.1 RD/16.6 WR	15.1	15.1
Data transfer rate (MBytes/sec) Internal, min/max	--/20.3	--/23.4	19.1/23.6	--/23.4	--/30.1
External	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 66.6 Ultra DMA4
SIZE: (mm) H x W x D	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1
FIRST CUSTOMER SHIPMENT	5/98	7/98	1Q99	7/98	4/99
COMMENTS					

MANUFACTURER	QUANTUM	QUANTUM	QUANTUM	QUANTUM	QUANTUM
DRIVE	QM318200KN-LW QM318200KN-SCA Atlas IV	QM318200TD-FC Atlas III	QM318200TD-SXX Atlas III	QM318200TN-FC Atlas 10K	QM318200TN-LW QM318200TN-SCA Atlas 10K
DISK/TREND GROUP	6	6	6	6	6
PLATFORM	Server	Server	Server	Server	Server
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	84 mm	84 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film
Interface	SCSI Ultra2/160	FC-AL	SCSI Ultra2	FC-AL	SCSI Ultra2/160
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 18,200	F: 18,200	F: 18,200	F: 18,200	F: 18,200
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	8	20	20	12	12
Tracks per surface	13846	8000	8000	10458	10458
Track density (TPI)	13700	8900	8900	13600	13600
Maximum linear density (BPI) (FCI)	249000	175000 186000	175000 186000	254000	254000
Areal density (Gb/square inch)	3.411	1.558	1.558	3.454	3.454
Recording code	24,25 PRML	16,17 PRML	16,17 PRML	24,25 PRML	24,25 PRML
Rotational speed (RPM)	7200	7200	7200	10000	10000
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	6.9 RD	7.5 RD	7.5 RD	5.0	5.0
Average rotational delay (msec)	4.17	4.17	4.17	3.0	3.0
Average access time (msec)	11.07	11.67 RD	11.67 RD	8.0	8.0
Data transfer rate (MBytes/sec) Internal, min/max External	18.9/32.1 160 synch.	13.8/22.5 200.0	13.8/22.5 80.0 synch.	26.9/39.4 160 synch.	26.9/39.4 160 synch.
SIZE: (mm) H x W x D	25.4 x 101.6 x 146.1	41.3 x 101.6 x 146.1	41.3 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1
FIRST CUSTOMER SHIPMENT	5/99	1Q98	1Q98	3Q99	5/99
COMMENTS					

MANUFACTURER	QUANTUM	QUANTUM	QUANTUM	QUANTUM	QUANTUM
DRIVE	QM512700TS Bigfoot TS	QM519200TS Bigfoot TS	QMP13600KA-A Fireball Plus KA	QMP18200KA-A Fireball Plus KA	QM320400CX-A Fireball CX
DISK/TREND GROUP	6	6	6	6	7
PLATFORM	Desktop	Desktop	Desktop	Desktop	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	130 mm	130 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	GMR Thin Film
Interface	Ultra DMA/33	Ultra DMA/33	Ultra DMA/66	Ultra DMA/66	Ultra DMA/66
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 12,720	F: 19,292	F: 13,600	F: 18,200	F: 20,553
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	4	6	6	8	6
Tracks per surface	15449	15449	13889	13889	
Track density (TPI)	12000	12000	13700	13700	
Maximum linear density (BPI) (FCI)	205458 218299	205458 218299	241000	241000	
Areal density (Gb/square inch)	2.465	2.465	3.302	3.302	
Recording code	16,17 PRML	16,17 PRML	16,17 PRML	16,17 PRML	
Rotational speed (RPM)	4000	4000	7200	7200	5400
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	10.5	11.5	8.5	8.5	9.5
Average rotational delay (msec)	7.5	7.5	4.17	4.17	5.6
Average access time (msec)	18.0	19.0	12.67	12.67	15.1
Data transfer rate (MBytes/sec) Internal, min/max External	12.6/21.0 16.6 PIO4/DMA2 33.3 Ultra DMA2	12.6/21.0 16.6 PIO4/DMA2 33.3 Ultra DMA2	--/29.4 16.6 PIO4/DMA2 66.6 Ultra DMA4	--/29.4 16.6 PIO4/DMA2 66.6 Ultra DMA4	--/30.1 16.6 PIO4/DMA2 66.6 Ultra DMA4
SIZE: (mm) H x W x D	25.4 x 146.1 x 203.2	25.4 x 146.1 x 203.2	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1
FIRST CUSTOMER SHIPMENT	10/98	10/98	1Q99	1Q99	4/99
COMMENTS					

MANUFACTURER	QUANTUM	QUANTUM	QUANTUM	RAYMOND ENGINEERING	RAYMOND ENGINEERING
DRIVE	QM336400TN-LW QM336400TN-SCA Atlas 10K	QM336400KN-LW QM336400KN-SCA Atlas IV	QM336400TN-FC Atlas 10K	84300	8440
DISK/TREND GROUP	7	7	7	2	2
PLATFORM	Server	Server	Server	Server	Server
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM	OEM
MEDIA: Disk diameter	84 mm	95 mm	84 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	Thin Film	Ferrite
Interface	SCSI Ultra2/160	SCSI Ultra2/160	FC-AL	SCSI	SCSI
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 36,400	F: 36,400	F: 36,400	--	--
REMOVABLE	--	--	--	F: 306	F: 40.55
Data surfaces per spindle	24	16	24	9	8
Tracks per surface	10458	13846	10458	1231	450
Track density (TPI)	13600	13700	13600	2075	850
Maximum linear density (BPI) (FCI)	254000	249000	254000	46227 30818	17000 17000
Areal density (Gb/square inch)	3.454	3.411	3.454	.096	.014
Recording code	24,25 PRML	24,25 PRML	24,25 PRML	2,7 RLL	MFM
Rotational speed (RPM)	10000	7200	10000	3688	3637
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Dedicated Surf.	Embedded
Average positioning time (msec)	5.5	7.9 RD	5.5	25	115
Average rotational delay (msec)	3.0	4.17	3.0	8.1	8.3
Average access time (msec)	8.5	12.07	8.5	33.1	123.3
Data transfer rate (MBytes/sec) Internal, min/max	26.9/39.4	18.9/32.1	26.9/39.4		
External	160 synch.	160 synch.	100	1.2	0.4
SIZE: (mm) H x W x D	41.4 x 101.6 x 146.1	41.4 x 101.6 x 146.1	41.4 x 101.6 x 146.1	58.4 x 106.7 x 188	58.4 x 106.7 x 188
FIRST CUSTOMER SHIPMENT	2Q99	2Q99	3Q99	1991	1987
COMMENTS				Mil-Spec ruggedized drive and electronics assembly. Removable disk drive cartridge	Mil-Spec ruggedized drive and electronics assembly. Removable disk drive cartridge

MANUFACTURER	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS
DRIVE	SV0322A SpinPoint V3200	SV0432A SpinPoint V4300	SV0432D SpinPoint V4300	WN34324U SpinPoint	SP0914D SpinPoint P4500
DISK/TREND GROUP	4	4	4	4	5
PLATFORM	Desktop	Desktop	Desktop	Desktop	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	Thin Film	MR Thin Film
Interface	Ultra DMA/33	Ultra DMA/33	Ultra DMA/66	SCSI	Ultra DMA/66
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 3,200	F: 4,311	F: 4,311	F: 4,320	F: 9,100
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	2	2	2	6	4
Tracks per surface	10100	12257	12257	7050	
Track density (TPI)	10300	12500	12500		13000
Maximum linear density (BPI) (FCI)	230000 245000	260000 276000	256000		260000
Areal density (Gb/square inch)	2.369	3.250	3.200		3.380
Recording code	16,17 EPR4	16,17 EPR4	16,17 EPR4	8,9 PRML	16,17 EPR4
Rotational speed (RPM)	5400	5400	5400	5400	7200
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	10 RD/11 WR	9.5 RD/10.5 WR	9.5 RD/10.5 WR	11	8.5
Average rotational delay (msec)	5.6	5.6	5.6	5.6	4.17
Average access time (msec)	15.6 RD/11.6 WR	15.1 RD/16.1 WR	15.1 RD/16.1 WR	16.6	12.67
Data transfer rate (MBytes/sec) Internal, min/max	--/21.6	15.5/25.0	15.5/25.0		--/33.8
External	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 66.6 Ultra DMA4	20.0 synch. 7.0 asynch.	16.6 PIO4/DMA2 66.6 Ultra DMA4
SIZE: (mm) H x W x D	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1
FIRST CUSTOMER SHIPMENT	6/98	10/98	4/99		4/99
COMMENTS					

MANUFACTURER	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS
DRIVE	SV0642D SpinPoint V6800	SV0643A SpinPoint V4300	SV0643D SpinPoint V4300	SV0644A SpinPoint V3200	SV0844A SpinPoint V4300
DISK/TREND GROUP	5	5	5	5	5
PLATFORM	Desktop	Desktop	Desktop	Desktop	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	GMR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film
Interface	Ultra DMA/66	Ultra DMA/33	Ultra DMA/66	Ultra DMA/33	Ultra DMA/33
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 6,400	F: 6,448	F: 6,448	F: 6,400	F: 8,455
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	2	3	3	4	4
Tracks per surface		12257	12257	10100	12257
Track density (TPI)	16500	12500	12500	10300	12500
Maximum linear density (BPI) (FCI)	300000	260000 276000	256000	230000 245000	260000 276000
Areal density (Gb/square inch)	4.950	3.250	3.200	2.369	3.250
Recording code	16,17 EPR4	16,17 EPR4	16,17 EPR4	16,17 EPR4	16,17 EPR4
Rotational speed (RPM)	5400	5400	5400	5400	5400
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)		9.5 RD/10.5 WR	9.5 RD/10.5 WR	10 RD/11 WR	9.5 RD/10.5 WR
Average rotational delay (msec)	5.6	5.6	5.6	5.6	5.6
Average access time (msec)		15.1 RD/16.1 WR	15.1 RD/16.1 WR	15.6 RD/11.6 WR	15.1 RD/16.1 WR
Data transfer rate (MBytes/sec) Internal, min/max	--/31.3	15.5/25.0	15.5/25.0	--/21.6	15.5/25.0
External	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2
SIZE: (mm) H x W x D	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1
FIRST CUSTOMER SHIPMENT	6/99		4/99	6/98	10/98
COMMENTS					

MANUFACTURER	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS
DRIVE	SV0844D SpinPoint V4300	SP1364D SpinPoint P6800	SP1366D SpinPoint P4500	SP1828D SpinPoint P4500	SV1003D SpinPoint V6800
DISK/TREND GROUP	5	6	6	6	6
PLATFORM	Desktop	Desktop	Desktop	Desktop	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	GMR Thin Film	MR Thin Film	MR Thin Film	GMR Thin Film
Interface	Ultra DMA/66	Ultra DMA/66	Ultra DMA/66	Ultra DMA/66	Ultra DMA/66
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 8,455	F: 13,600	F: 13,650	F: 18,200	F: 10,000
REMOVABLE	--		--	--	--
Data surfaces per spindle	4	4	6	8	3
Tracks per surface	12257				
Track density (TPI)	12500	16500	13000	13000	16500
Maximum linear density (BPI) (FCI)	256000	300000	260000	260000	300000
Areal density (Gb/square inch)	3.200	4.950	3.380	3.380	4.950
Recording code	16,17 EPR4	16,17 EPR4	16,17 EPR4	16,17 EPR4	16,17 EPR4
Rotational speed (RPM)	5400	7200	7200	7200	5400
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	9.5 RD/10.5 WR	8	8.5	8.5	
Average rotational delay (msec)	5.6	4.17	4.17	4.17	5.6
Average access time (msec)	15.1 RD/16.1 WR	12.17	12.67	12.67	
Data transfer rate (MBytes/sec) Internal, min/max	15.5/25.0	--/40.6	--/33.8	--/33.8	--/31.3
External	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 66.6 Ultra DMA4
SIZE: (mm) H x W x D	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1
FIRST CUSTOMER SHIPMENT	4/99	7/99	4/99	4/99	6/99
COMMENTS					

MANUFACTURER	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS
DRIVE	SV1296A SpinPoint V4300	SV1296D SpinPoint V4300	SV1344D SpinPoint V6800	SP2046D SpinPoint P6800	SP2728D SpinPoint P6800
DISK/TREND GROUP	6	6	6	7	7
PLATFORM	Desktop	Desktop	Desktop	Desktop	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	GMR Thin Film	GMR Thin Film	GMR Thin Film
Interface	Ultra DMA/33	Ultra DMA/66	Ultra DMA/66	Ultra DMA/66	Ultra DMA/66
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 12,922	F: 12,922	F: 13,400	F: 20,400	F: 27,200
REMOVABLE	--	--	--		
Data surfaces per spindle	6	6	4	6	8
Tracks per surface	12257	12257			
Track density (TPI)	12500	12500	16500	16500	16500
Maximum linear density (BPI) (FCI)	260000 276000	256000	300000	300000	300000
Areal density (Gb/square inch)	3.250	3.200	4.950	4.950	4.950
Recording code	16,17 EPR4	16,17 EPR4	16,17 EPR4	16,17 EPR4	16,17 EPR4
Rotational speed (RPM)	5400	5400	5400	7200	7200
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	9.5 RD/10.5 WR	9.5 RD/10.5 WR		8	8
Average rotational delay (msec)	5.6	5.6	5.6	4.17	4.17
Average access time (msec)	15.1 RD/16.1 WR	15.1 RD/16.1 WR		12.17	12.17
Data transfer rate (MBytes/sec) Internal, min/max	15.5/25.0	15.5/25.0	--/31.3	--/40.6	--/40.6
External	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 66.6 Ultra DMA4
SIZE: (mm) H x W x D	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1
FIRST CUSTOMER SHIPMENT	10/98	4/99	6/99	7/99	7/99
COMMENTS					

MANUFACTURER	SAMSUNG ELECTRONICS	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY
DRIVE	SV2016D SpinPoint V6800	ST33210A Medalist 3210	ST34310A Medalist 4310	ST34311A U4	ST34312A Medalist 4312
DISK/TREND GROUP	7	4	4	4	4
PLATFORM	Desktop	Desktop	Desktop	Desktop	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	GMR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film
Interface	Ultra DMA/66	Ultra DMA/33	Ultra DMA/33	Ultra DMA/66	Ultra DMA/66
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 20,100	F: 3,249	F: 4,300	F: 4,300	F: 4,300
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	6	2	2	2	2
Tracks per surface					
Track density (TPI)	16500	12000	13405	13100	13405
Maximum linear density (BPI) (FCI)	300000	210000	234000	241000	239000
Areal density (Gb/square inch)	4.950	2.520	3.137	3.157	3.204
Recording code	16,17 EPR4	16,17 EPRML	16,17 EPR4	16,17 EPRML	16,17 EPRML
Rotational speed (RPM)	5400	5400	5400	5400	5400
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)		9.5	9 RD	10.5 RD/11.5 WR	9 RD/10.5 WR
Average rotational delay (msec)	5.6	5.6	5.6	5.6	5.6
Average access time (msec)		15.1	14.6 RD	16.1 RD/17.1 WR	14.6 RD/16.1 WR
Data transfer rate (MBytes/sec) Internal, min/max	--/31.3	--/21.4	--/23.5	--/25.8	--/23.5
External	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 66.6 Ultra DMA4
SIZE: (mm) H x W x D	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 147.0	26.1 x 102.0 x 147.0	26.1 x 101.9 x 147.0
FIRST CUSTOMER SHIPMENT	6/99	11/98	1Q99	4/99	4/99
COMMENTS					

MANUFACTURER	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY
DRIVE	ST34323A U2	ST34502FC Cheetah 4LP	ST34502LC ST34502LW Cheetah 4LP	ST34573DC ST34573W ST34573WC ST34573WD Barracuda 9LP	ST34573LC ST34573LW Barracuda 9LP
DISK/TREND GROUP	4	4	4	4	4
PLATFORM	Desktop	Server	Server	Server	Server
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	84 mm	84 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film
Interface	Ultra DMA/33	FC-AL	Ultra SCSI-2	Ultra SCSI	Ultra SCSI-2
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 4,311	F: 4,500	F: 4,500	F: 4,550	F: 4,550
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	4	6	6	5	5
Tracks per surface		6472	6472		
Track density (TPI)	8897	8966	8966	8250	8250
Maximum linear density (BPI) (FCI)	165000	181000	181000	180000	180000
Areal density (Gb/square inch)	1.468	1.623	1.623	1.485	1.485
Recording code	16,17 PRML	8,9 PR4	8,9 PR4	16,17 EPR4	16,17 EPR4
Rotational speed (RPM)	4500	10025	10025	7200	7200
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	12 RD/14 WR	5.2 RD/6.0 WR	5.2 RD/6.0 WR	7.1 RD/7.8 WR	7.1 RD/7.8 WR
Average rotational delay (msec)	6.7	2.99	2.99	4.17	4.17
Average access time (msec)	18.7 RD/20.7 WR	8.19 RD/8.99 WR	8.19 RD/8.99 WR	11.27RD/11.97WR	11.27RD/11.97WR
Data transfer rate (MBytes/sec) Internal, min/max	--/15.8	19.4/28.4	19.4/28.4	15.0/23.8	15.0/23.8
External	16.6 PIO4/DMA2 33.3 Ultra DMA2	100.0	80.0	40.0 synch.	80.0 synch.
SIZE: (mm) H x W x D	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146	25.4 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	2098	3/98	3/98	12/97	12/97
COMMENTS					

MANUFACTURER	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY
DRIVE	ST34573N Barracuda 9LP	ST36421A U4	ST36422A Medalist 6422	ST36810A Barracuda ATA	ST38420A Medalist 8420
DISK/TREND GROUP	4	5	5	5	5
PLATFORM	Server	Desktop	Desktop	Desktop	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	GMR Thin Film	MR Thin Film
Interface	SCSI-2	Ultra DMA/66	Ultra DMA/33	Ultra DMA/66	Ultra DMA/33
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 4,550	F: 6,400	F: 6,400	F: 6,833	F: 8,400
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	5	3	4	2	4
Tracks per surface					
Track density (TPI)	8250	13100	12000	16700	13405
Maximum linear density (BPI) (FCI)	180000	241000	210000	305000	234000
Areal density (Gb/square inch)	1.485	3.157	2.520	5.094	3.137
Recording code	16,17 EPR4	16,17 EPRML	16,17 EPRML	16,17 EPRML	16,17 EPR4
Rotational speed (RPM)	7200	5400	5400	7200	5400
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	7.1 RD/7.8 WR	10.5 RD/11.5 WR	9.5	8.6 RD	9 RD
Average rotational delay (msec)	4.17	5.6	5.6	4.17	5.6
Average access time (msec)	11.27RD/11.97WR	16.1 RD/17.1 WR	15.1	12.77 RD	14.6 RD
Data transfer rate (MBytes/sec) Internal, min/max	15.0/23.8	--/25.8	--/21.4	--/40.4	--/23.5
External	20.0 synch.	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 33.3 Ultra DMA2
SIZE: (mm) H x W x D	25.4 x 101.6 x 146	26.1 x 102.0 x 147.0	25.4 x 101.6 x 146.1	26.1 x 101.9 x 147.0	25.4 x 101.6 x 147.0
FIRST CUSTOMER SHIPMENT	12/97	4/99	11/98	7/99	1Q99
COMMENTS					

MANUFACTURER	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY
DRIVE	ST38421A U4	ST38422A Medalist 8422	ST39102FC Cheetah 9LP	ST39102LC ST39102LW Cheetah 9LP	ST39103FC Cheetah 18LP
DISK/TREND GROUP	5	5	5	5	5
PLATFORM	Desktop	Desktop	Server	Server	Server
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	84 mm	84 mm	84 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film
Interface	Ultra DMA/66	Ultra DMA/66	FC-AL	Ultra SCSI-2	FC-AL
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 8,400	F: 8,400	F: 9,100	F: 9,100	F: 9,100
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	4	4	12	12	6
Tracks per surface			6472	6472	9772
Track density (TPI)	13100	13405	8966	8966	12580
Maximum linear density (BPI) (FCI)	241000	239000	181000	181000	243000
Areal density (Gb/square inch)	3.157	3.204	1.623	1.623	3.057
Recording code	16,17 EPRML	16,17 EPRML	8,9 PR4	8,9 PR4	PRML
Rotational speed (RPM)	5400	5400	10025	10025	10016
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	10.5 RD/11.5 WR	9 RD/10.5 WR	5.2 RD/6.0 WR	5.2 RD/6.0 WR	5.2 RD/6.0 WR
Average rotational delay (msec)	5.6	5.6	2.99	2.99	2.99
Average access time (msec)	16.1 RD/17.1 WR	14.6 RD/16.1 WR	8.19 RD/8.99 WR	8.19 RD/8.99 WR	8.19 RD/8.99 WR
Data transfer rate (MBytes/sec) Internal, min/max	--/25.8	--/23.5	19.4/28.4	19.4/28.4	18.3/28.0
External	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 66.6 Ultra DMA4	100.0	80.0	100.0
SIZE: (mm) H x W x D	26.1 x 102.0 x 147.0	26.1 x 101.9 x 147.0	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1
FIRST CUSTOMER SHIPMENT	4/99	4/99	3/98	3/98	2/99
COMMENTS					

MANUFACTURER	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY
DRIVE	ST39103LW ST39103LC Cheetah 18LP	ST39140N ST39140W ST39140WC MedalistPro 9.1	ST39173FC Barracuda 9LP	ST39173LC ST39173LW Barracuda 9LP	ST39173N Barracuda 9LP
DISK/TREND GROUP	5	5	5	5	5
PLATFORM	Server	Server	Server	Server	Server
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	84 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film
Interface	Ultra2 SCSI	Ultra SCSI	FC-AL	Ultra SCSI-2	SCSI-2
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 9,100	F: 9,100	F: 9,100	F: 9,100	F: 9,100
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	6	8	10	10	10
Tracks per surface	9772	9006	7501	7501	7501
Track density (TPI)	12580	9570	8250	8250	8250
Maximum linear density (BPI) (FCI)	243000	179200	180000	180000	180000
Areal density (Gb/square inch)	3.057	1.715	1.485	1.485	1.485
Recording code	PRML	16,17 EPRML	16,17 EPR4	16,17 EPR4	16,17 EPR4
Rotational speed (RPM)	10016	7200	7200	7200	7200
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	5.2 RD/6.0 WR	8.5 RD/9.5 WR	7.1 RD/7.8 WR	7.1 RD/7.8 WR	7.1 RD/7.8 WR
Average rotational delay (msec)	2.99	4.17	4.17	4.17	4.17
Average access time (msec)	8.19 RD/8.99 WR	12.67RD/13.67WR	11.27RD/11.97WR	11.27RD/11.97WR	11.27RD/11.97WR
Data transfer rate (MBytes/sec) Internal, min/max External	18.3/28.0 80.0 synch.	15.5/24.2 40.0 synch.	15.0/23.8 100.0 synch.	15.0/23.8 80.0 synch.	15.0/23.8 20.0 synch.
SIZE: (mm) H x W x D	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	2/99	1098	12/97	12/97	12/97
COMMENTS					

MANUFACTURER	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY
DRIVE	ST39173W ST39173WC ST39173WD Barracuda 9LP	ST39175LW ST39175LC Barracuda 18LP	ST118202FC Cheetah 18	ST118202LC ST118202LW Cheetah 18	ST118273DC ST118273W ST118273WC ST118273WD Barracuda 18
DISK/TREND GROUP	5	5	6	6	6
PLATFORM	Server	Server	Server	Server	Server
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	84 mm	84 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film
Interface	Ultra SCSI	Ultra2 SCSI	FC-AL	Ultra SCSI-2	Ultra SCSI
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 9,100	F: 9,100	F: 18,200	F: 18,200	F: 18,210
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	10	5	24	24	20
Tracks per surface	7501	11737	6476	6476	7501
Track density (TPI)	8250	12600	8250	8250	8250
Maximum linear density (BPI) (FCI)	180000	230000	184000	184000	180000
Areal density (Gb/square inch)	1.485	2.898	1.518	1.518	1.485
Recording code	16,17 EPR4	PRML	8,9 PR4	8,9 PR4	16,17 EPR4
Rotational speed (RPM)	7200	7200	10025	10025	7200
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	7.1 RD/7.8 WR	6.9 RD/7.4 WR	5.7 RD/6.5 WR	5.7 RD/6.5 WR	7.6 RD/8.3 WR
Average rotational delay (msec)	4.17	4.17	2.99	2.99	4.17
Average access time (msec)	11.27RD/11.97WR	11.07RD/11.57WR	8.69 RD/9.48 WR	8.69 RD/9.48 WR	11.77RD/12.47WR
Data transfer rate (MBytes/sec) Internal, min/max External	15.0/23.8 40.0 synch.	12.9/22.5 80.0 synch.	19.4/28.4 100.0	19.4/28.4 80.0	15.0/23.8 40.0 synch.
SIZE: (mm) H x W x D	25.4 x 101.6 x 146	25.4 x 101.6 x 145.8	41.3 x 101.6 x 146.1	41.3 x 101.6 x 146.1	41.1 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	12/97	11/98	3/98	3/98	12/97
COMMENTS					

MANUFACTURER	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY
DRIVE	ST118273FC Barracuda 18	ST118273LC ST118273LW Barracuda 18	ST310220A Barracuda ATA	ST310230A Medalist 10230	ST310232A Medalist 10232
DISK/TREND GROUP	6	6	6	6	6
PLATFORM	Server	Server	Desktop	Desktop	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	GMR Thin Film	MR Thin Film	MR Thin Film
Interface	FC-AL	Ultra SCSI-2	Ultra DMA/66	Ultra DMA/33	Ultra DMA/33
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 18,210	F: 18,210	F: 10,242	F: 10,200	F: 10,200
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	20	20	3	6	6
Tracks per surface	7501	7501			
Track density (TPI)	8250	8250	16700	12000	13405
Maximum linear density (BPI) (FCI)	180000	180000	305000	210000	239000
Areal density (Gb/square inch)	1.485	1.485	5.094	2.520	3.204
Recording code	16,17 EPR4	16,17 EPR4	16,17 EPRML	16,17 EPRML	16,17 EPRML
Rotational speed (RPM)	7200	7200	7200	5400	5400
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	7.6 RD/8.3 WR	7.6 RD/8.3 WR	8.6 RD	9.5	9 RD/10.5 WR
Average rotational delay (msec)	4.17	4.17	4.17	5.6	5.6
Average access time (msec)	11.77RD/12.47WR	11.77RD/12.47WR	12.77 RD	15.1	14.6 RD/16.1 WR
Data transfer rate (MBytes/sec) Internal, min/max	15.0/23.8	15.0/23.8	--/40.4	--/21.4	--/23.5
External	100.0 synch.	80.0 synch.	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2
SIZE: (mm) H x W x D	41.1 x 101.6 x 146	41.1 x 101.6 x 146	26.1 x 101.9 x 147.0	25.4 x 101.6 x 146.1	26.1 x 101.9 x 147.0
FIRST CUSTOMER SHIPMENT	12/97	12/97	7/99	11/98	1Q99
COMMENTS					

MANUFACTURER	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY
DRIVE	ST313030A Medalist 13030	ST313032A Medalist 13032	ST313620A Barracuda ATA	ST313640A Medalist 13640	ST317240A Medalist 17240
DISK/TREND GROUP	6	6	6	6	6
PLATFORM	Desktop	Desktop	Desktop	Desktop	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	GMR Thin Film	MR Thin Film	MR Thin Film
Interface	Ultra DMA/33	Ultra DMA/66	Ultra DMA/66	Ultra DMA/33	Ultra DMA/33
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 13,022	F: 13,000	F: 13,666	F: 13,600	F: 17,200
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	6	6	4	8	8
Tracks per surface					
Track density (TPI)	13405	13405	16700	12000	13405
Maximum linear density (BPI) (FCI)	234000	239000	305000	210000	234000
Areal density (Gb/square inch)	3.137	3.204	5.094	2.520	3.137
Recording code	16,17 EPR4	16,17 EPRML	16,17 EPRML	16,17 EPRML	16,17 EPR4
Rotational speed (RPM)	5400	5400	7200	5400	5400
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	9 RD	9 RD/10.5 WR	8.6 RD	9.5	9 RD
Average rotational delay (msec)	5.6	5.6	4.17	5.6	5.6
Average access time (msec)	14.6 RD	14.6 RD/16.1 WR	12.77 RD	15.1	14.6 RD
Data transfer rate (MBytes/sec) Internal, min/max	--/21.4	--/23.5	--/40.4	--/21.4	--/23.5
External	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2
SIZE: (mm) H x W x D	25.4 x 101.6 x 147.0	26.1 x 101.9 x 147.0	26.1 x 101.9 x 147.0	25.4 x 101.6 x 146.1	25.4 x 101.6 x 147.0
FIRST CUSTOMER SHIPMENT	1Q99	4/99	7/99	11/98	1Q99
COMMENTS					

MANUFACTURER	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY
DRIVE	ST317242A Medalist 17242	ST318203FC Cheetah 18LP	ST318203LW ST318203LC Cheetah 18LP	ST318275FC Barracuda 18LP	ST318275LW ST318275LC Barracuda 18LP
DISK/TREND GROUP	6	6	6	6	6
PLATFORM	Desktop	Server	Server	Server	Server
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	84 mm	84 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film
Interface	Ultra DMA/66	FC-AL	Ultra2 SCSI	FC-AL	Ultra2 SCSI
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 17,200	F: 18,200	F: 18,200	F: 18,200	F: 18,200
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	8	12	12	10	10
Tracks per surface		9772	9772	11737	11737
Track density (TPI)	13405	12580	12580	12600	12600
Maximum linear density (BPI) (FCI)	239000	243000	243000	230000	230000
Areal density (Gb/square inch)	3.204	3.057	3.057	2.898	2.898
Recording code	16,17 EPRML	PRML	PRML	PRML	PRML
Rotational speed (RPM)	5400	10016	10016	7200	7200
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	9 RD/10.5 WR	5.2 RD/6.0 WR	5.2 RD/6.0 WR	6.9 RD/7.4 WR	6.9 RD/7.4 WR
Average rotational delay (msec)	5.6	2.99	2.99	4.17	4.17
Average access time (msec)	14.6 RD/16.1 WR	8.19 RD/8.99 WR	8.19 RD/8.99 WR	11.07RD/11.57WR	11.07RD/11.57WR
Data transfer rate (MBytes/sec) Internal, min/max	--/23.5	18.3/28.0	18.3/28.0	12.9/22.5	12.9/22.5
External	16.6 PI04/DMA2 66.6 Ultra DMA4	100.0	80.0 synch.	100.0	80.0 synch.
SIZE: (mm) H x W x D	26.1 x 101.9 x 147.0	25.4 x 101.6 x 146.1	25.4 x 101.6 x 146.1	25.4 x 101.6 x 145.8	25.4 x 101.6 x 145.8
FIRST CUSTOMER SHIPMENT	4/99	2/99	2/99	11/98	11/98
COMMENTS					

MANUFACTURER	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY
DRIVE	ST136403FC Cheetah 36	ST136403LW ST136403LC Cheetah 36	ST136475FC Barracuda 36	ST136475LW ST136475LC Barracuda 36	ST320430A Barracuda ATA
DISK/TREND GROUP	7	7	7	7	7
PLATFORM	Server	Server	Server	Server	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	84 mm	84 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	GMR Thin Film
Interface	FC-AL	Ultra2 SCSI	FC-AL	Ultra2 SCSI	Ultra DMA/66
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 36,400	F: 36,400	F: 36,400	F: 36,400	F: 20,500
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	24	24	20	20	6
Tracks per surface	9772	9772	11737	11737	
Track density (TPI)	12580	12580	12600	12600	16700
Maximum linear density (BPI) (FCI)	243000	243000	230000	230000	305000
Areal density (Gb/square inch)	3.057	3.057	2.898	2.898	5.094
Recording code	PRML	PRML	PRML	PRML	16,17 EPRML
Rotational speed (RPM)	10016	10016	7200	7200	7200
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	5.7 RD/6.5 WR	5.7 RD/6.5 WR	7.4 RD/8.2 WR	7.4 RD/8.2 WR	8.6 RD
Average rotational delay (msec)	2.99	2.99	4.17	4.17	4.17
Average access time (msec)	8.69 RD/9.49 WR	8.69 RD/9.49 WR	11.57RD/12.37WR	11.57RD/12.37WR	12.77 RD
Data transfer rate (MBytes/sec)					
Internal, min/max	18.3/28.0	18.3/28.0	12.9/22.5	12.9/22.5	--/40.4
External	100.0	80.0 synch.	100.0	80.0 synch.	16.6 PIO4/DMA2 66.6 Ultra DMA4
SIZE: (mm) H x W x D	41.3 x 101.6 x 146.1	41.3 x 101.6 x 146.1	41.1 x 101.6 x 146	41.1 x 101.6 x 146	26.1 x 101.9 x 147.0
FIRST CUSTOMER SHIPMENT	2/99	2/99	11/98	11/98	7/99
COMMENTS					

MANUFACTURER	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	SEAGATE TECHNOLOGY	TOSHIBA	TOSHIBA
DRIVE	ST328040A Barracuda ATA	ST150176FC Barracuda 50	ST150176LW ST150176LC Barracuda 50	MK-1403MAV	MK-1608MAT
DISK/TREND GROUP	7	8	8	2	2
PLATFORM	Desktop	Server	Server	Mobile	Mobile
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM	OEM
MEDIA: Disk diameter	95 mm	95 mm	95 mm	65 mm	65 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Glass	Glass
DRIVE: Heads	GMR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film
Interface	Ultra DMA/66	FC-AL	Ultra2 SCSI	IDE	Ultra DMA/33
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 28,520	F: 50,100	F: 50,100	F: 1,440	F: 1,620
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	8	22	22	4	2
Tracks per surface		12024	12024	5160	6250
Track density (TPI)	16700	12900	12900	8763	
Maximum linear density (BPI) (FCI)	305000	250000	250000	149100	
Areal density (Gb/square inch)	5.094	3.225	3.225	1.307	
Recording code	16,17 EPRML	PRML	PRML	PRML	16,17 EPR4ML
Rotational speed (RPM)	7200	7184	7184	4200	4200
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	8.6 RD	7.4 RD/8.2 WR	7.4 RD/8.2 WR	13	13
Average rotational delay (msec)	4.17	4.18	4.18	7.14	7.14
Average access time (msec)	12.77 RD	11.58RD/12.38WR	11.58RD/12.38WR	20.14	20.14
Data transfer rate (MBytes/sec) Internal, min/max	--/40.4	14.9/25.7	14.9/25.7	--/8.7	--/12.9
External	16.6 PIO4/DMA2 66.6 Ultra DMA4	100.0	80.0 synch.	16.6 PIO Mode 4 16.6 DMA Mode 2	16.6 PIO4/DMA2 33.3 Ultra DMA2
SIZE: (mm) H x W x D	26.1 x 101.9 x 147.0	41.1 x 101.6 x 146	41.1 x 101.6 x 146	12.5 x 70 x 100	8.45 x 70 x 100
FIRST CUSTOMER SHIPMENT	7/99	3/99	3/99	4Q96	2Q98
COMMENTS					

MANUFACTURER	TOSHIBA	TOSHIBA	TOSHIBA	TOSHIBA	TOSHIBA
DRIVE	MK-2104MAV	MK-2105MAT	MK-2109MAT	MK-2110MAF	MK-2110MAT
DISK/TREND GROUP	3	3	3	3	3
PLATFORM	Mobile	Mobile	Mobile	Mobile	Mobile
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Disk diameter	65 mm	65 mm	65 mm	65 mm	65 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Glass	Glass	Glass	Glass	Glass
DRIVE: Heads	MR Thin Film	MR Thin Film	GMR Thin Film	MR Thin Film	MR Thin Film
Interface	IDE	IDE	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 2,160	F: 2,160	F: 2,160	F: 2,160	F: 2,160
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	4	4	2	2	2
Tracks per surface	6250	5850	8880	8910	8910
Track density (TPI)	10533	9868	14900	15090	15090
Maximum linear density (BPI) (FCI)	174300	201000	241000	246000	246000
Areal density (Gb/square inch)	1.836	1.983	3.591	3.712	3.712
Recording code	PRML	EPR4ML	16,17 EPR4ML	16,18 EEPR4ML	16,17 EPR4ML
Rotational speed (RPM)	4200	4200	4200	4200	4200
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	13	13	13	13	13
Average rotational delay (msec)	7.14	7.14	7.14	7.14	7.14
Average access time (msec)	20.14	20.14	20.14	20.14	20.14
Data transfer rate (MBytes/sec) Internal, min/max	--/10.1	6.6/11.0	--/13.8	8.4/13.7	--/13.7
External	16.6 PIO Mode 4 16.6 DMA Mode 2	16.6 PIO Mode 4 16.6 DMA Mode 2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2
SIZE: (mm) H x W x D	12.5 x 70 x 100	8.45 x 70 x 100	8.45 x 70 x 100	6.35 x 70 x 100	8.45 x 70 x 100
FIRST CUSTOMER SHIPMENT	11/97	1Q98	2Q98	2Q98	3Q98
COMMENTS					

MANUFACTURER	TOSHIBA	TOSHIBA	TOSHIBA	TOSHIBA	TOSHIBA
DRIVE	MK-3209MAT	MK-3212MAT	MK-4006MAV	MK-4309MAT	MK-4310MAT
DISK/TREND GROUP	4	4	4	4	4
PLATFORM	Mobile	Mobile	Mobile	Mobile	Mobile
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Disk diameter	65 mm	65 mm	65 mm	65 mm	65 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Glass	Glass	Glass	Glass	Glass
DRIVE: Heads	GMR Thin Film	MR Thin Film	MR Thin Film	GMR Thin Film	MR Thin Film
Interface	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 3,250	F: 3,250	F: 4,090	F: 4,320	F: 4,320
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	3	2	6	4	4
Tracks per surface	8880	10800	6600	8880	8910
Track density (TPI)	14900	19000	10871	14900	15087
Maximum linear density (BPI) (FCI)	241000	307000	213000	241000	243000
Areal density (Gb/square inch)	3.591	5.833	2.316	3.591	3.666
Recording code	16,17 EPR4ML	16,18 EEPR4ML	EPR4ML	16,17 EPR4ML	EPR4ML
Rotational speed (RPM)	4200	4200	4200	4200	4200
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	13	13	13	13	13
Average rotational delay (msec)	7.14	7.14	7.14	7.14	7.14
Average access time (msec)	20.14	20.14	20.14	20.14	20.14
Data transfer rate (MBytes/sec) Internal, min/max	--/13.8	--/16.9	--/11.5	8.3/13.8	8.3/13.6
External	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2
SIZE: (mm) H x W x D	8.45 x 70 x 100	8.45 x 70 x 100	12.5 x 70 x 100	8.45 x 70 x 100	8.45 x 70 x 100
FIRST CUSTOMER SHIPMENT	3Q98	1Q99	1Q98	2Q98	2Q98
COMMENTS					

MANUFACTURER	TOSHIBA	TOSHIBA	TOSHIBA	TOSHIBA	WESTERN DIGITAL
DRIVE	MK-6409MAV	MK-6411MAT	MK-6412MAT	MK-1011GAV	WDAC14300 Caviar
DISK/TREND GROUP	5	5	5	6	4
PLATFORM	Mobile	Mobile	Mobile	Mobile	Desktop
MARKET	OEM	OEM	OEM	OEM	OEM, DIST
MEDIA: Disk diameter	65 mm	65 mm	65 mm	65 mm	95 mm
Recording medium	Thin Film	Thin Film*	Thin Film	Thin Film*	Thin Film
Substrate	Glass	Glass	Glass	Glass	Aluminum
DRIVE: Heads	GMR Thin Film	GMR Thin Film	MR Thin Film	GMR Thin Film	MR Thin Film
Interface	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33	Ultra DMA/33	Ultra DMA/66
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 6,490	F: 6,490	F: 6,490	F: 10,050	F: 4,311
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	6	4	4	6	2
Tracks per surface	8960	10290	10800	10500	
Track density (TPI)	14900	17500	19000	17500	14340
Maximum linear density (BPI) (FCI)	246000	330000	307000	330000	218000 232000
Areal density (Gb/square inch)	3.665	5.775	5.833	5.775	3.126
Recording code	16,17 EPR4ML	16,17 EPR4ML	16,18 EEPR4ML	16,18 EEPR4ML	PRML
Rotational speed (RPM)	4200	4200	4200	4200	5400
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	13	13	13	13	9.5 RD
Average rotational delay (msec)	7.14	7.14	7.14	7.14	5.6
Average access time (msec)	20.14	20.14	20.14	20.14	15.1 RD
Data transfer rate (MBytes/sec) Internal, min/max	8.4/14.0	10.8/19.2	--/16.9	11.1/19.8	--/20.2
External	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 33.3 Ultra DMA2	16.6 PIO4/DMA2 66.6 Ultra DMA4
SIZE: (mm) H x W x D	12.5 x 70 x 100	8.45 x 70 x 100	8.45 x 70 x 100	12.5 x 70 x 100	25.4 x 101.6 x 146.0
FIRST CUSTOMER SHIPMENT	2Q98	4Q98	1Q99	2/99	10/98
COMMENTS		*Untextured. Ramp loaded heads.		*Untextured. Ramp loaded heads.	

MANUFACTURER	WESTERN DIGITAL	WESTERN DIGITAL	WESTERN DIGITAL	WESTERN DIGITAL	WESTERN DIGITAL
DRIVE	WDE4550 WDE4550AV	WD64AA Caviar	WD68AB Expert	WDAC28400 Caviar	WDAC29100 Expert
DISK/TREND GROUP	4	5	5	5	5
PLATFORM	Server	Desktop	Desktop	Desktop	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	GMR Thin Film	GMR Thin Film	MR Thin Film	GMR Thin Film
Interface	Ultra 2 SCSI	Ultra DMA/66	Ultra DMA/66	Ultra DMA/66	Ultra DMA/66
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 4,550	F: 6,448	F: 6,838	F: 8,455	F: 9,115
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	6	2	2	4	4
Tracks per surface	6504				
Track density (TPI)	7500	17836	18300	14340	15700
Maximum linear density (BPI) (FCI)	160000	307000	285000	218000 232000	220130
Areal density (Gb/square inch)	1.200	5.476	5.216	3.126	3.456
Recording code	PRML			PRML	PRML
Rotational speed (RPM)	7200	5400	7200	5400	7200
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	7.8 RD	9.5	9	9.5 RD	8.5 RD
Average rotational delay (msec)	4.17	5.6	4.17	5.6	4.17
Average access time (msec)	11.97 RD	15.1	13.17	15.1 RD	12.67 RD
Data transfer rate (MBytes/sec) Internal, min/max	9.0/21.5	--/29.2	--/36.3	--/20.2	--/27.9
External	80.0 synch.	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 66.6 Ultra DMA4
SIZE: (mm) H x W x D	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146.0	25.4 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	7/98	7/99	3Q99	10/98	1/99
COMMENTS					

MANUFACTURER	WESTERN DIGITAL	WESTERN DIGITAL	WESTERN DIGITAL	WESTERN DIGITAL	WESTERN DIGITAL
DRIVE	WDE9100 WDE9100AV Enterprise	WDE9150 WDE9150AV Enterprise	WDE9180 WDE9180AV Enterprise	WD102AA Caviar	WD136AA Caviar
DISK/TREND GROUP	5	5	5	6	6
PLATFORM	Server	Server	Server	Desktop	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	MR Thin Film	GMR Thin Film	MR Thin Film	GMR Thin Film	GMR Thin Film
Interface	Ultra 2 SCSI	Ultra 2 SCSI	Ultra 2 SCSI	Ultra DMA/66	Ultra DMA/66
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 9,100	F: 9,150	F: 9,180	F: 10,262	F: 13,601
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	12	4	6	3	4
Tracks per surface	6504	13614	10600		
Track density (TPI)	7500	13500	10750	17836	17836
Maximum linear density (BPI) (FCI)	160000	239420	208000	307000	307000
Areal density (Gb/square inch)	1.200	3.232	2.236	5.476	5.476
Recording code	PRML	EPRML	EPRML		
Rotational speed (RPM)	7200	10036	7200	5400	5400
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	7.8 RD	5.2 RD	6.9 RD	9.5	9.5
Average rotational delay (msec)	4.17	2.99	4.17	5.6	5.6
Average access time (msec)	11.97 RD	8.19	11.07	15.1	15.1
Data transfer rate (MBytes/sec) Internal, min/max	9.0/21.5	25.6/45.0	18.4/30.8	--/29.2	--/29.2
External	80.0 synch.	80.0 synch.	80.0 synch.	16.6 PIO4/DMA2 66.6 Ultra DMA4	16.6 PIO4/DMA2 66.6 Ultra DMA4
SIZE: (mm) H x W x D	25.4 x 101.6 x 146	25.4 x 4.0 x 5.75	25.4 x 101.6 x 146.0	25.4 x 101.6 x 146	25.4 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	7/98	2Q99	1/99	7/99	7/99
COMMENTS					

MANUFACTURER	WESTERN DIGITAL	WESTERN DIGITAL	WESTERN DIGITAL	WESTERN DIGITAL	WESTERN DIGITAL
DRIVE	WD136AB Expert	WD172AA Caviar	WDAC210200 Caviar	WDAC310200 Caviar	WDAC313000 Caviar
DISK/TREND GROUP	6	6	6	6	6
PLATFORM	Desktop	Desktop	Desktop	Desktop	Desktop
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	GMR Thin Film	GMR Thin Film	GMR Thin Film	MR Thin Film	MR Thin Film
Interface	Ultra DMA/66	Ultra DMA/66	Ultra DMA/66	Ultra DMA/66	Ultra DMA/66
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 13,676	F: 17,247	F: 10,262	F: 10,262	F: 13,020
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	4	5	4	5	6
Tracks per surface					
Track density (TPI)	18300	17836	16000	14340	14340
Maximum linear density (BPI) (FCI)	285000	307000	236520	218000 232000	218000 232000
Areal density (Gb/square inch)	5.216	5.476	3.784	3.126	3.126
Recording code			PRML	PRML	PRML
Rotational speed (RPM)	7200	5400	5400	5400	5400
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	9	9.5	8.5 RD	9.5 RD	9.5 RD
Average rotational delay (msec)	4.17	5.6	5.6	5.6	5.6
Average access time (msec)	13.17	15.1	14.1 RD	15.1 RD	15.1 RD
Data transfer rate (MBytes/sec) Internal, min/max External	--/36.3 16.6 PIO4/DMA2 66.6 Ultra DMA4	--/29.2 16.6 PIO4/DMA2 66.6 Ultra DMA4	--/24.3 16.6 PIO4/DMA2 66.6 Ultra DMA4	--/20.2 16.6 PIO4/DMA2 66.6 Ultra DMA4	--/20.2 16.6 PIO4/DMA2 66.6 Ultra DMA4
SIZE: (mm) H x W x D	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146.0	25.4 x 101.6 x 146.0
FIRST CUSTOMER SHIPMENT	3Q99	7/99	1/99	10/98	10/98
COMMENTS					

MANUFACTURER	WESTERN DIGITAL	WESTERN DIGITAL	WESTERN DIGITAL	WESTERN DIGITAL	WESTERN DIGITAL
DRIVE	WDAC313500 Expert	WDAC315300 Caviar	WDAC418000 Expert	WDE18300 WDE18300AV Enterprise	WDE18310 WDE18310AV Enterprise
DISK/TREND GROUP	6	6	6	6	6
PLATFORM	Desktop	Desktop	Desktop	Server	Server
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
DRIVE: Heads	GMR Thin Film	GMR Thin Film	GMR Thin Film	MR Thin Film	GMR Thin Film
Interface	Ultra DMA/66	Ultra DMA/66	Ultra DMA/66	Ultra 2 SCSI	Ultra 2 SCSI
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 13,578	F: 15,377	F: 18,042	F: 18,300	F: 18,300
REMOVABLE	--	--	--	--	--
Data surfaces per spindle	6	6	8	12	8
Tracks per surface				10600	13614
Track density (TPI)	15700	16000	15700	10750	13500
Maximum linear density (BPI) (FCI)	220130	236520	220130	208000	239420
Areal density (Gb/square inch)	3.456	3.784	3.456	2.236	3.232
Recording code	PRML	PRML	PRML	EPRML	EPRML
Rotational speed (RPM)	7200	5400	7200	7200	10036
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	8.5 RD	8.5 RD	8.5 RD	6.9 RD	5.2 RD
Average rotational delay (msec)	4.17	5.6	4.17	4.17	2.99
Average access time (msec)	12.67 RD	14.1 RD	12.67 RD	11.07	8.19
Data transfer rate (MBytes/sec) Internal, min/max External	--/27.9 16.6 PIO4/DMA2 66.6 Ultra DMA4	--/24.3 16.6 PIO4/DMA2 66.6 Ultra DMA4	--/27.9 16.6 PIO4/DMA2 66.6 Ultra DMA4	18.4/30.8 80.0 synch.	25.6/45.0 80.0 synch.
SIZE: (mm) H x W x D	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146.0	25.4 x 4.0 x 5.75
FIRST CUSTOMER SHIPMENT	1/99	1/99	1/99	1/99	2099
COMMENTS					

MANUFACTURER	WESTERN DIGITAL	WESTERN DIGITAL	WESTERN DIGITAL	WESTERN DIGITAL	
DRIVE	WD204AB Expert	WD205AA Caviar	WD272AB Expert	WDAC420400 Caviar	
DISK/TREND GROUP	7	7	7	7	
PLATFORM	Desktop	Desktop	Desktop	Desktop	
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	
Substrate	Aluminum	Aluminum	Aluminum	Aluminum	
DRIVE: Heads	GMR Thin Film	GMR Thin Film	GMR Thin Film	GMR Thin Film	
Interface	Ultra DMA/66	Ultra DMA/66	Ultra DMA/66	Ultra DMA/66	
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	F: 20,515	F: 20,520	F: 27,353	F: 20,416	
REMOVABLE	--	--	--	--	
Data surfaces per spindle	6	6	8	8	
Tracks per surface					
Track density (TPI)	18300	17836	18300	16000	
Maximum linear density (BPI) (FCI)	285000	307000	285000	236520	
Areal density (Gb/square inch)	5.216	5.476	5.216	3.784	
Recording code				PRML	
Rotational speed (RPM)	7200	5400	7200	5400	
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	
Servo type	Embedded	Embedded	Embedded	Embedded	
Average positioning time (msec)	9	9.5	9	8.5 RD	
Average rotational delay (msec)	4.17	5.6	4.17	5.6	
Average access time (msec)	13.17	15.1	13.17	14.1 RD	
Data transfer rate (MBytes/sec) Internal, min/max External	--/36.3 16.6 PIO4/DMA2 66.6 Ultra DMA4	--/29.2 16.6 PIO4/DMA2 66.6 Ultra DMA4	--/36.3 16.6 PIO4/DMA2 66.6 Ultra DMA4	--/24.3 16.6 PIO4/DMA2 66.6 Ultra DMA4	
SIZE: (mm) H x W x D	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146	25.4 x 101.6 x 146	
FIRST CUSTOMER SHIPMENT	3Q99	7/99	3Q99	1/99	
COMMENTS					

MANUFACTURER PROFILES

1999 DISK/TREND REPORT

MANUFACTURER PROFILES

All manufacturers now producing moving head rigid magnetic disk drives, or which have indicated specific plans to enter the market, are listed in this section. The heading "1998 disk sales" refers only to the DISK/TREND estimate of moving head rigid disk drive sales for the calendar year -- no sales of other drive types are included, nor are sales of parts or other related products such as controllers. "1998 total net sales" covers the fiscal year ending December 31, 1998, for each firm unless noted otherwise, or for the parent company if the disk drive manufacturer is a subsidiary that does not report financial data separately.

Exchange rates

The exchange rates used in converting the financial data of non-U.S. manufacturers to dollars is given below. The average exchange rates for 1998 are used, as reported by the U.S. Federal Reserve Bulletin, and rounded to three significant figures.

Country	Currency	Currency units per U.S. dollar
Japan	Yen	131.0
South Korea	Won	1,400.4
United Kingdom	Pound	0.6

Use caution in making year to year comparisons of sales revenue and income figures, as they are significantly impacted by exchange rate changes.

U.S. Manufacturers

AVATAR PERIPHERALS, INC.
1455 McCarthy Boulevard
Milpitas, CA 95035

Avatar was founded as Avatar Systems in 1991 by John Bizjak, a veteran of several pioneering disk drive programs, to develop high capacity disk cartridge drives. The company started production of an 85 megabyte 2.5" disk cartridge drive in mid-1993, using glass disks, and intended for portable and desktop applications. After management changes in 1994, emphasis was placed on 170 megabyte drive models primarily for OEM markets. After more management changes in 1996 and a name change to Avatar Peripherals, emphasis was placed on 250 megabyte drive models targeted at distribution markets. Drive development centered in Milpitas, using a manufacturing facility established in Thailand in 1995. By early 1999, it had become clear that the emphasis on distribution markets was not paying off, and Avatar's operations were closed down.

BELFORT MEMORY INTERNATIONAL
170 Knowles Drive
Los Gatos, CA 95030

The company now known as Belfort Memory International is the latest reincarnation of high-end 5.25" drive designs originally undertaken at Priam, later purchased from the bankruptcy court by Orca, then subsequently purchased from the Orca bankruptcy by a combination of disk drive industry veterans and European investors. The disk drives were assembled in small quantities in Germany during 1993, and a deal was later struck to conduct manufacturing operations in the inactive Bull plant in Belfort, France. BMI's California operation designed a 1.08 gigabyte 5.25" drive to be sold at low prices for personal computer applications, and manufacturing started at Belfort in early 1996.

It was a difficult start-up, but not due to conventional product design or manufacturing problems. As the production line started, a variety of French bureaucrats and prosecutors descended on the scene, apparently prompted by a tangled web of French politics. Before the episode was finished, a BMI executive and two local officials were held in jail for weeks, training for plant personnel was disrupted, a protest march was held in Belfort over the potential for lost jobs, and both BMI suppliers and customers were concerned over the strange situation. In late Spring, 1997, everyone was released from jail, with various charges of fraud, failure to file paperwork and improper money transfers still pending, although the prosecutor didn't seem to have much of a case. In the middle of this chaos, disk drive production actually commenced at Belfort, although at low levels, before French bureaucracy and lack of financing forced the closing of the plant. Back in California, BMI designed 3 and 5 gigabyte 5.25" desktop drives and made arrangements for contract manufacturing in China which got underway in 1997, with 4 and 8 gigabyte models added in 1999.

CASTLEWOOD SYSTEMS
5000 Hopyard Road, Suite 330
Pleasanton, CA 94588

Castlewood Systems was founded in September, 1996, by Syed Iftikar, former founder and CEO of SyQuest Technology, and announced a 2.16 gigabyte 3.5" disk cartridge drive using a single disk cartridge at the 1997 Fall Comdex show. Castlewood has arranged with two Malaysian companies to manufacture the drives on a contract basis, and a similar arrangement for disk cartridges has been made with a Taiwan firm. Volume deliveries were started in early 1999.

CONNER TECHNOLOGY, INC.
P.O. Box 53115
Carmel, CA 93921

It is widely known in the disk drive industry that Finis Conner, co-founder and CEO of Conner Peripherals, has been actively organizing a new disk drive company to enter the desktop drive market with drives targeted at very low cost personal computers. Conner Technology has established an administrative and marketing headquarters in San Jose, set up engineering in Colorado and has arranged for contract drive manufacturing in China. It is expected that the new company's first products will be available in mid-1999. Conner Peripherals started production in early 1987, achieved the highest first year sales revenue of any company in the history of the United States, established growth records before a series of problems caused a $445 million loss in 1993, and was acquired by Seagate Technology in early 1996. With the Seagate acquisition, Finis Conner's financial package included a two year no competition agreement, which expired in February, 1998.

HALO DATA DEVICES
1971 North Capital Avenue, Suite A
San Jose, CA

Founded in March of 1998, Halo is developing a 3.3 millimeter low profile rigid disk drives based on technology acquired from the now-defunct ThinSpin LLC. The drive is intended to fit within the form factor of a CompactFlash card. Target specifications are 265 megabyte capacity, 5,400 RPM rotation rate and a 4.5-9 megabyte per second data transfer rate. Like the CompactFlash card, it will operate at 3.3 volts, but may draw about .25 amperes at spin-up.

INTEGRAL PERIPHERALS
5775 Flatiron Parkway
Boulder, CO 80301

Integral Peripherals was founded in September, 1990, by engineering and management personnel who previously pioneered early 2.5" drives at PrairieTek. The company was the first to design and manufacture 1.8" disk drives. Its initial product was a 20 megabyte drive, first produced in the second half of 1991, and for which the available market was minimal. Integral had somewhat better luck with a 42 megabyte model placed in production in early 1992, and a succession of higher capacity models which followed. Integral's 1.8" drives used ramp loaded heads, and were designed to high operating shock and vibration specifications, with low power requirements, in anticipation of wide usage in subnotebook computers and other mobile computer applications.

Integral pioneered in utilizing untextured disks in higher capacity models, a technique made possible by using the ramp loading head method to avoid parking heads on the disk surface. Integral began its high volume manufacturing in Singapore in mid-1992, moved into a new plant in 1995 and added 1.8" drives with up to 340 megabytes all in PC Card Type III format, with a 510 megabyte model announced but never produced. In 1995, Integral added 2.5" drives as the beginning of a new product family, the result of a design contract with Samsung Electronics to provide designs for 2.5" drives, with both companies entitled to manufacture the drives involved.

After finding a cool market reception for latecomers to the 2.5" disk drive business, Integral switched to 3" drives in 1997. The combination of the limited market available for 1.8" drives, the firm's expenditures to develop and initiate production of 2.5" and 3" drives, and the withdrawal from the market of other announced 3" drive producers finally became too big a burden on Integral's finances, and the company entered U.S. Chapter 11 bankruptcy proceedings in March, 1998. The firm's management made an attempt to secure new financing and complete the design for a higher capacity 3" mobile disk drive, but to no avail. Hambrecht & Quist acquired Integral's assets from bankruptcy and established a new company named Mobile Storage Technology, Inc., which is designing a new family of 3" drives for the mobile computer market.

INTERNATIONAL BUSINESS MACHINES CORPORATION
Route 22
Armonk, NY 10504

1998 disk sales: $8,161,900,000
1998 total net sales: $81,667,000,000 Net income: $6,328,000,000

IBM shipped the world's first moving head disk drive in 1956, and the company has provided a large share of the industry's advanced technology during the following 43 years. Until the end of the 1970's, most of IBM's product designs were routinely copied by the rest of the industry. However, the advent of

personal computers and engineering workstations intensified the development race and inspired the appearance of dozens of new disk drive manufacturers intent upon producing smaller drives, using new interfaces and exploring new marketing approaches.

After a flurry of activity during the first half of the 1980's resulted in various 14", 8", 5.25" and 3.5" drives without much distinction, IBM since 1989 has introduced a series of drives which place it in the first tier of midrange and low-end disk drive manufacturers, as well as maintaining its traditional leadership in high-end disk drives. For personal computers and notebook computers, several generations of drives developed at the Fujisawa plant have set the industry's benchmarks for small diameter disk drive areal density, with 1" high 3.5" desktop drives offering up to 37.5 gigabytes on 5 platters and 2.5" mobile drives with up to 14.1 gigabytes on 5 platters. Older generations of server drives have been replaced by IBM's current 3.5" series of 7,200 RPM models with up to 36.4 gigabytes capacity and a 3" series of 10,000 RPM models with capacities up to 36.7 gigabytes. IBM is expected to continue to aggressively develop drives appropriate for strong product lines in mobile, desktop and server drive markets.

After 20 years of operating as the General Products Division, IBM's data storage activities went through a series of reorganizations in the early 1990's, and emerged as the Storage Systems Division, with headquarters in San Jose. IBM disk drives are manufactured at a combination of its own plants and in contract manufacturers' facilities, in the United States, Europe and Asia. The original San Jose facility has served as the design center for high-end 3.5" server drives, with production at a factory opened in recent years in Singapore, already doubled in size in 1997. Fujisawa (Japan) transferred its manufacturing activities for 3.5" desktop and 2.5" mobile drives to a contract manufacturing organization in Thailand, and in 1997 IBM added a new plant of its own in Thailand to make 2.5" drives. A new disk drive manufacturing plant has been established in Hungary for desktop drives. The Havant (U.K.) plant has been spun off in an employee buy out under the Xyratex name (see European manufacturers section). In May, 1999, IBM Storage Systems Division announced that development programs for server drives would be transferred to Fujisawa.

IBM's first significant OEM sales of disk drives were made in 1984, when the firm began selling the 3380 to both Siemens and Honeywell. Some low-end 3.5" drives with Microchannel interfaces were also sold to European system manufacturers who chose to offer personal computer models with the Microchannel bus. For disk drives broadly sold on an OEM basis, IBM has transitioned through several phases and reorganizations. Server, desktop and mobile drives are now sold widely through OEM and distributor channels. In 1997, IBM established a buy-and-sell relationship with NEC in which IBM sells complete desktop drive designs and sets of components, as necessary, which NEC then uses to manufacture disk drives equivalent to specific IBM models. Some of the drives are produced for IBM on a contract manufacturing basis and others are utilized by NEC for its own programs. In 1998, IBM and Western Digital announced a deal in which Western Digital will buy GMR heads and other critical components for

desktop drives from IBM, which can then be used in manufacturing drives equivalent to IBM models or in Western Digital designs.

IOMEGA CORPORATION
1821 West Iomega Way
Roy, UT 84067

1998 disk sales: $175,900,000
1998 total net sales: $1,694,385,000 Net income: ($54,222,000)

Iomega, founded in 1980, was successful in establishing production capability for its unique 8" flexible disk drive, which maintained control of head/disk contact with the Bernoulli effect. The product was originally intended as an OEM drive, but Iomega had much better luck with subsystems sold in the personal computer add-on market. The original 8" drives for the IBM PC market provided most of the company's revenue growth until displaced by the 5.25" models in production from 1987 to 1996. But time passes on, and the Bernoulli drive product line is now out of production, and Iomega moved on to new products with much larger markets.

Attempting to broaden its product coverage, Iomega licensed the Insite Peripherals "floptical" drive and media. Iomega's 20 megabyte "floptical" drive was introduced in 1992, but was discontinued in 1994 after only limited sales success. That venture convinced Iomega's management that a comparable drive with higher capacity and the right price could be a success. The result was the 100 megabyte "Zip" 3.5" floppy drive, which began shipments in early 1995, and has found a much broader market, due to its unique combination of 100 megabyte disk capacity and initial $199 drive retail price, since reduced.

The 1 gigabyte two platter "Jaz" drive, which first shipped in late 1995, marked Iomega's entry into the rigid cartridge disk drive market. The Jaz was produced for Iomega under contract by Sequel until the Autumn of 1996, then Iomega moved manufacturing to its own factory in Penang, which was purchased in 1996 from Quantum, when that company discontinued internal manufacturing of high-end rigid disk drives. The 2 gigabyte Jaz 2 drive started shipments in the first quarter of 1998.

JTS CORPORATION
166 Baypoint Parkway
San Jose, CA 95134

1997 disk sales: $142,000,000
1997 total net sales: $145,900,000 (FY ending 2/2/98) Net income: ($130,600,000)

Kalok was founded in 1987 to participate in the market for 20 and 40 megabyte 3.5" drives, designed for very low manufacturing cost. Unable to obtain

adequate funding from U.S. venture capital sources, the firm negotiated a manufacturing and inventory financing arrangement with Oriental Precision Company of South Korea. OPC started manufacturing Kalok drives in mid-1988 with substantial shipment levels, but dropped out of the game a few years later after being acquired. In order to broaden its production base, Kalok in 1989 also established a plant in the Philippines, the first hard disk drive producer to do so. In late 1991, Kalok sold its Philippines factory to Xebec Co. Ltd., a Japanese firm, and subsequently sold its entire stepping motor drive product line to Xebec, retaining only the design for a .5" high 3.5" drive family. After a series of management changes and a Chapter 11 filing, Kalok began actively selling a removable version of the .5" high drive.

In February, 1994, Kalok was reorganized as JTS with investment from Jugi Tandon, one of the disk drive industry's pioneers in developing high volume disk drive manufacturing for both floppy and rigid disk drives. The JTS program centered on 3.5" desktop drives for the personal computer market, following an abortive attempt to start a significant 3" drive challenge to the 2.5" mobile drive dominance for notebook computer applications. Manufacturing was at a plant at Madras, India, at a facility originally controlled by the Tandon family. In early 1996, JTS was merged with Atari, becoming a publicly traded corporation, with JTS the successor company, and with complete concentration on the disk drive product lines. JTS found it difficult to keep up with the disk drive industry's hectic pace of product development and continuous parts count reduction. Operations were closed in mid-1998, and Chapter 11 bankruptcy was subsequently filed.

MAXTOR CORPORATION
510 Cottonwood Drive
Milpitas, CA 95035

1998 disk sales: $2,408,200,000
1998 total net sales: $2,408,528,000 Net income: $31,173,000

Maxtor startled its competitors in 1982 by announcing a family of 5.25" drives with up to 140 megabyte capacity. These drives went into production in mid-1983, later joined by 190 megabyte drives in 1984 and the industry's first 380 megabyte drives in 1985. Maxtor became the first company to find space in the standard 5.25" form factor for eight disks, and thus was able to achieve high capacities while maintaining the standard Seagate transfer rate of five megabits per second -- a strategy which proved successful with OEMs wishing to use standard ST412 controllers. In preparation for the ten megabit per second transfer rate required by the 380 megabyte drive, Maxtor became the industry leader in establishing the ESDI interface standard, which at the time was widely used for high performance 5.25" drives.

Starting with the departure of several key employees in 1987, there was a continuing succession of management changes which, combined with the

numerous internal changes which followed, disrupted Maxtor's ability to continue the pioneering product development activities upon which most of the company's growth was based. In 1990, Maxtor acquired the MiniScribe product line and manufacturing facilities, providing the firm with a 1" high 3.5" drive product line and a 2.5" drive that was ready to be announced. After a strong initiative to secure leadership in 1.8" PCMCIA disk drives found a much smaller available market than anticipated, Maxtor discontinued the 1.8" drives in 1995. All of Maxtor's current revenues are derived from 3.5" drives sold for personal computer applications.

In 1994, Maxtor improved its financial status when Hyundai invested heavily in the company, acquiring approximately 40% of the firm, and in 1995 Maxtor transferred all of its manufacturing facilities to Hyundai. In November, 1995, Maxtor's board of directors agreed to a Hyundai offer to acquire the remainder of the outstanding Maxtor shares. Following shareholder approval early in 1996, Maxtor became a wholly owned subsidiary of Hyundai Electronics America, in turn a subsidiary of Hyundai Electronics Industries Company, Ltd. When the epidemic of Asian economic problems started to seriously affect major Korean conglomerates, the Hyundai group liquidated several investments in U.S. technology companies, and with two public offerings of Maxtor's stock, the company again became a publicly traded U.S. company in 1998.

The Maxtor headquarters has been relocated to Milpitas, but product development remains in Longmont, Colorado, with manufacturing in Singapore. The results so far of the numerous changes at Maxtor have been an overhaul of the company's management, resign of the Singapore factory, rapid updating of the desktop drive product line, plans to enter the server drive market, and sharply increased sales. In early 1999, the company announced that it would delay a planned manufacturing startup in China, and instead acquired an additional facility in Singapore which will be used to expand production.

MOBILE STORAGE TECHNOLOGY, INC.
5775 Flatiron Parkway
Boulder, CO 80301

After Integral Peripherals filed Chapter 11 bankruptcy in March, 1998, the firm's assets were later purchased by a Hambrecht & Quist venture capital fund, H&Q Asia Pacific, Ltd., and were included in a newly formed company, Mobile Storage Technology, Inc. Mobile Storage is now headed by John Squires, the cofounder of Conner Peripherals, and is concentrating on development of 3" drives for mobile applications. The company has not yet announced when it expects to start shipments or what arrangements it will make for manufacturing.

PERIPHERAL COMPUTER SUPPORT, INC.
44131 Nobel Drive
Fremont, CA 94538

PCS, Inc., is an established supplier of service management and limited production for disk drives and other computer peripherals. The company maintains facilities in California, Asia and Europe, and in mid-1998 acquired the Singapore facility in which Integral Peripherals had previously manufactured disk drives. Calluna Technology has announced a deal with PCS to provide contract manufacturing services for the Calluna Type II PC Card drive. PCS has also been licensed to manufacture and sell the 1.8" drives manufactured by Integral Peripherals before that firm filed bankruptcy and is expected to also arrange for manufacturing of disk cartridge drives no longer in production.

QUANTUM CORPORATION
500 McCarthy Boulevard
Milpitas, CA 95035

1998 disk sales: $3,717,200,000
1999 total net sales: $4,902,056,000 (FY ending 3/31/99) Net income: ($29,535,000)

Quantum's original product strategy was to manufacture an upgrade to the Shugart Associates 8" Winchester drives. The Quantum plan worked well, and 5.25" drives with capacities up to 40 megabytes were added in 1983, becoming the company's major product. As the Quantum full-size 40 megabyte 5.25" drives peaked, the firm announced half high OEM 5.25" drives with up to 80 megabytes, but shipment was late, and Quantum's sales growth flattened out. In 1985, the company established the Plus Development subsidiary to pioneer development and marketing of the Plus Hardcard, an innovative plug-in card for the IBM personal computer aftermarket, combining a 3.5" Winchester and all controller electronics on a single add-in card. Manufacturing was contracted out to Matsushita-Kotobuki Electronics.

Quantum was able to reestablish growth in OEM drive shipments in 1987, through successful implementation of an emergency plan to quickly develop an OEM 3.5" drive using the Hardcard design and tooling, with manufacturing by Matsushita-Kotobuki Electronics. While Quantum has designed all of its drives, manufacturing of current models is done by MKE, in factories located in Japan, Singapore and Ireland.

In August, 1993, Quantum formed a separate operating group to manage the development, production and marketing of the high-end 3.5" drives then manufactured at Milpitas. Quantum purchased Digital Equipment's OEM storage products business in 1994, adding Digital's lines of high capacity disk drives and tape drives to its product portfolio. Along with the products came major design and manufacturing facilities in the U.S. and Southeast Asia, plus approximately

5,000 employees, providing Quantum with a major management challenge to digest all of the new resources without losing momentum. After more than a year of trying to integrate the Digital disk drive products with its existing high-end disk drive operation, it closed out its high-end disk drive manufacturing operations and turned over production to MKE. MKE now manufactures all of Quantum's desktop and server disk drives.

RAYMOND ENGINEERING (Subsidiary of Kaman)
217 Smith Street
Middletown, CT 06457

Raymond Engineering was founded in 1938 as a specialty electromechanical components supplier, and is today a subsidiary of Kaman, a large military electronics contractor. The Memory Systems Division of Raymond Engineering provides ruggedized and mil-spec data storage subsystems, using some disk drives which are internally manufactured, plus repackaged disk and tape drive mechanisms and flash memory based subsystems.

SEAGATE TECHNOLOGY
920 Disc Drive
Scotts Valley, CA 95066

1998 disk sales: $5,942,900,000
1998 total net sales: $6,819,000,000 (FY ending 7/3/98) Net income: ($530,000,000)

In 1981, Seagate shipped two thirds of the 5.25" drives produced worldwide, with 35,000 units -- and another de facto standard was created. Seagate took the lead in moving production for its high volume drives offshore to secure lower manufacturing costs. But the world changed for Seagate in mid-1984, with a sharp reduction in sales to its largest customer, IBM -- and an up-and-down buying pattern which continued in 1985. Through tough management, Seagate stayed profitable, rebuilt its revenues, and starting in 1986 became the worldwide leader in OEM disk drive revenues.

After 1985, a major part of Seagate's growth came from the personal computer aftermarket. Seagate prospered in the PC aftermarket, but IBM led a growing movement by personal computer manufacturers to "bundle" hard disk drives with PC systems at the factory instead of giving dealers an easy opportunity to upgrade with independent disk drives. The effect of this bundling, plus Seagate's late arrival in the 3.5" marketplace, dampened Seagate's growth rate in the late 1980's.

In October, 1989, Seagate completed an agreement with Control Data to acquire Imprimis Technology in a deal valued at $450 million. There was little overlap between the Seagate's line of desktop PC drives and Imprimis' server drives, or between Seagate's predominantly aftermarket distribution and Impri-

mis' predominantly OEM sales. In late 1991, the company made key changes in executive management in an attempt to reassert product leadership and was successful in establishing an aggressive product development program.

The new Seagate maintained a vigorous pace of product development and market leadership with the 5.25" and 3.5" server drives developed at the Oklahoma and Minneapolis operations. 3.5" drives advanced from 5,400, to 7,200, to 10,000 RPM models offering capacities now ranging up to 50 gigabytes. The Elite 5.25" drive series was successfully extended to 9 gigabyte, then to 23 gigabytes, and finally to 47 gigabytes in late 1997, before finally being displaced in 1999 by the firm's high-end 3.5" server drives. The company pioneered in using 3" drives in advanced 10,000 RPM drives, to reduce vibration problems and cut power requirements.

During the 1993 disk drive price wars, Seagate, alone among the major independent drive producers, maintained consistent profitability as a result of the firm's strength in high end drives and a notable disinclination to price below levels returning a reasonable gross margin. During 1994, Seagate began diversifying into additional markets, acquiring several firms specializing in storage related software, and the company established a major program to become a major factor in the storage management software market. In mid-1997, it acquired Quinta, a start-up company using new technology approaches to develop high capacity, high performance optical disk drives, in a deal priced at a minimum of $230 million.

In September, 1995, Seagate announced an agreement to acquire Conner Peripherals. The acquisition was consummated in early 1996, providing Seagate with major expansions in several areas, including internal disk media manufacturing, low end 3.5" drives for desktop personal computer markets, and a tape drive product line derived from the Conner 1992 acquisition of Archive. As with many acquisitions, smooth integration of the Conner Peripherals operation proved difficult to accomplish, and the next year Seagate was hit with a wave of effective new competitors in the server drive sector, the company's largest area of sales revenue, combined with enhanced competition in desktop drive markets from Asian drive manufacturers. Seagate responded in Fall, 1997, with major revisions in management organization and accelerated product development efforts, followed in mid-1998 by a change in executive management.

SYQUEST TECHNOLOGY
47071 Bayside Parkway
Fremont, CA 94538

1998 disk sales: $87,300,000

SyQuest was started in early 1982 to make rigid disk drives using 3.9" (100 mm) plated disks, in both fixed and removable disk cartridge configurations, but after several years of production 3.9" disks were displaced by industry standard sizes. The firm began shipping 5.25" disk cartridge drives with formatted capaci-

ty of 44 megabytes and embedded SCSI controllers in 1988, achieving significant success in the Macintosh add-on market, and with its 5.25" disk cartridges, eventually becoming the dominant "prepress" interchange standard for graphics and desktop publishing. In 1989, SyQuest began manufacturing in Singapore.

In the 1990's, SyQuest increased the capacity of its 5.25" cartridge disk drive series to 88 megabytes, then to 200 megabytes. A 3.5" disk cartridge drive program resulted in first shipments of 105 and 270 megabyte models in 1993. SyQuest also manufactures the disk cartridges for the drives, and cartridges account for about half of the firm's revenue. A unique 1.8" drive was announced in 1995, utilizing a disk cartridge designed to be removable from a PC Card Type III disk drive, but the project was stopped in early 1996.

The EZ135, a 135 megabyte drive marketed as a counter to the high capacity floppy Iomega "Zip" drive, began shipping in mid-1995, but the product was a major financial drain and production was stopped in mid-1996. SyQuest suffered financial difficulties starting in mid-1995, as the result of costs which were higher than expected for the EZ135, combined with significant penetration of traditional SyQuest markets by both the Iomega Zip drive and the Jaz rigid disk cartridge drive series.

As the result of the company's continuing financial losses, a major management reorganization was undertaken, 60% of the company's employees were laid off, and the company's activities were refocused on new products. The 230 megabyte EZFlyer 3.5" drive replaced the money losing EZ135. The two platter 1.5 gigabyte SyJet 3.5" disk cartridge drive went into production in early 1997 and the single platter 1 gigabyte SparQ 3.5" disk cartridge drive started production at the end of 1997, both with the mission to reclaim the high-end disk cartridge market from the Iomega Jaz.

Despite intense market development programs, aggressive pricing and expanded production facilities, SyQuest wasn't able to turn the business around, and most of its operations were closed down in November, 1998. During the subsequent bankruptcy proceedings, Iomega purchased all of SyQuest's intellectual property, U.S. fixed assets and inventory for $9.1 million, and the remaining service and warranty business is continuing under the name SYQT, Inc.

WESTERN DIGITAL CORPORATION
8105 Irvine Center Drive
Irvine, CA 92718

1998 disk sales: $2,871,900,000
1998 total net sales: $3,541,500,000 (FY ending 6/27/98) Net income: ($290,200,000)

Western Digital, at the time a major supplier of controllers and specialized semiconductor components, entered the rigid disk drive market by purchasing

the rigid disk drive operations of Tandon at the end of 1987. The firm has maintained a disk drive development facility in San Jose for several years to develop desktop drives for the personal computer market. The company has aggressively moved from heavy dependence on aftermarket distribution with the original product line purchased from Tandon to a primary emphasis on OEM sales. WD's early development and shipment of a two platter 340 megabyte 3.5" drive in the first half of 1992 boosted the firm's share of the personal computer disk drive market, and impacted the product development plans of most competitors.

Western Digital continued a program of aggressive development for its Caviar 3.5" desktop drive product line, but by 1997 found itself falling behind competition in product development by delaying too long in its movement to using magnetoresistive heads. The company reassigned all available engineering talent to emergency programs to utilize MR heads as soon as possible, and WD's program for development of 3" mobile drives was stopped. In mid-1998, WD made a deal with IBM to become a customer for GMR heads and other necessary components, with the objective to start production of 3.5" desktop drives in the first half of 1999 using GMR heads, in order to reestablish a fully competitive product line.

Western Digital has also undertaken a major expansion program to build a significant position in the 3.5" server drive market, with a high-end development facility in Rochester, Minnesota, and production in Singapore. The company started production in the second half of 1996 with its initial server product line of 2.17 and 4.36 gigabyte 1 " high 3.5" drives, using inductive thin film heads, to facilitate the initial production ramp. The company has so far stayed with 1" high 3.5" server drives, and transitioning to MR heads with 7,200 RPM drives offering up to 18.3 gigabytes, and to GMR heads with 10,000 RPM drives, also with 18.3 gigabytes.

Asian Manufacturers

(All fiscal years end in March, 1999, unless otherwise noted. All companies are in Japan unless otherwise noted.)

FUJITSU LTD.
6-1, Marunouchi 2-chome
Chiyoda-ku, Tokyo 100

1998 disk sales: $3,021,900,000
1999 total net sales: $40,022,793,000 Net income: ($104,107,000)

Fujitsu derives about 66% of its sales from the computer industry and is known as the leading manufacturer of computers for the Japanese domestic market. Fujitsu is also a major exporter to the worldwide computer market. Since 1982, the company has been among the leaders in worldwide disk drive revenues, and skillfully managed a transition from older removable magnetic disk drives to a product line consisting mainly of fixed disk drives in all capacity ranges and in several disk diameters. Fujitsu is a leading producer of 3.5" optical drives and 3.5" optical libraries. Over 90% of Fujitsu's rigid drive production is currently done outside Japan, in Thailand and the Philippines. Fujitsu, which had 44% ownership in Amdahl, increased its holdings to 100% in 1997.

Fujitsu has marketed most of its captive drives in OEM versions also, using industry standard interfaces, and is a serious contender in the market for OEM rigid disk drives. Fujitsu is also a participant in the enterprise systems plug compatible disk drive market through products sold by Amdahl. Particularly effective in the OEM market during the 1980's was the series of high performance 8" 48/84/168/337/690/824/1000/2000/2600 megabyte drives. Development of new 5.25" drives was halted in mid-1994 in favor of 3.5" drive development. Fujitsu now has an extensive product line of 3.5" desktop and server drives, combined with 2.5" mobile drives, and during the past year has been able to significantly increase its share of worldwide disk drive sales.

HITACHI, LTD.
4-6 Kanda-Surugadai
Chiyoda-ku, Tokyo 101

1998 disk sales: $629,400,000
1999 total net sales: $60,895,984,000 Net income: ($2,586,214,000)

Hitachi remains Japan's largest manufacturer of electrical and electronic equipment and a major manufacturer of computer systems. 54% of the company's sales are in equipment for information systems. The firm currently makes a wide range of fixed disk drives for both captive and noncaptive markets.

In addition to significant OEM sales of smaller capacity fixed disk drives, Hitachi also sells data storage subsystems in the IBM compatible mainframe and midrange market through Hitachi Data Systems (formerly National Advanced

Systems, before acquisition by Hitachi), and in 1983 started selling PCM drives for distribution in the European PCM market through BASF, and currently through Comparex. Hitachi was the first independent disk drive supplier to ship a double capacity drive equivalent to the IBM 3380E, and was an early supplier of 3380K equivalent drives. In recent years Hitachi used a 6.5" drive series for IBM plug compatible drive subsystems, including a 3390-9 equivalent subsystem, before transitioning to high capacity 3.5" drives. The company's 3.5" drive activities are concentrated on server drives, currently extending to 36.9 gigabytes. Hitachi's current rigid disk drive products are manufactured in plants in Japan and the Philippines.

In 1993, MiniStor and Hitachi announced agreements under which MiniStor licensed Hitachi to utilize the firm's 1.8" drive technology. The two companies then jointly developed a family of 2.5" disk drives, and subsequent development by Hitachi has extended the 2.5" series to become a major market participant, on two occasions producing drives with the industry's highest areal density, with current mobile drives up to 10 gigabytes in capacity. Hitachi has also used 2.5" disks in a server drive which operates at 12,000 RPM, currently the industry's highest motor speed. Plans for 1.8" drives terminated after MiniStor went out of business.

MATSUSHITA-KOTOBUKI ELECTRONICS INDUSTRIES, LTD.
2-2-10, Kotobuki-machi
Takamatsu City 760

1998 total net sales: $5,987,498,000 (FY ending 3/31/98) Net income: $165,954,000

During the 1980's, Matsushita-Kotobuki Electronics concentrated on production of VCRs on an OEM basis for a number of U.S. consumer electronics manufacturers and distributors, as well as for sale under the Matsushita "Panasonic" brand name. In more recent years MKE became the largest producer of CD-ROM drives, which are sold mostly through other Matsushita group companies, and has undertaken a manufacturing program for 120 megabyte 3.5" LS-120 "super disk" floppy drives.

In 1985, Plus Development established a contract manufacturing arrangement with MKE for the Hardcard, which evolved into a manufacturing program for the highly successful 3.5" OEM drives offered by Plus' parent company, Quantum Corporation. MKE has the rights to sell the Quantum drives under license in the Japanese domestic OEM market, and activated a marketing program in 1989, but with limited results. MKE produces rigid disk drives in Japan and in a Singapore facility, and established a subsidiary in Ireland to manufacture Quantum products for the European market. In early 1996, Quantum turned over the balance of its disk drive production to MKE, including high end drives previously manufactured in California and in plants acquired with the purchase of the Digital Equipment disk drive product line.

NEC CORPORATION
5-33-1, Shiba
Minato-ku, Tokyo 108

1998 total net sales: $40,471,692,000 (FY ending 3/31/98) Net income: $341,057,000

NEC has defined its product area as communications and computers, with computer products currently accounting for about 39% of the firm's total revenues. In recent years, disk drive production has involved a variety of disk drives, from large to small configurations, for both captive and OEM markets. Disk drives produced in recent years have included 9", 5.25", 3.5", 2.5" and 1.8" disk diameters. All except 3.5" desktop drives have been phased out, with remaining products targeted to take advantage of NEC's leadership position in the Japanese personal computer market. In 1997 NEC and IBM agreed on an arrangement in which NEC will manufacture IBM desktop drive designs for use by NEC, and the company will also produce the drives on a contract manufacturing basis for IBM. NEC was the first of the major Japanese drive producers to produce small form factor rigid disk drives offshore, with the establishment of a factory in the Philippines, and the firm has added a new Philippines plant in which the IBM drive models are being manufactured.

SAMSUNG ELECTRONICS CO., LTD.
7, Soonwha-dong
Chung-ku
Seoul, South Korea

1998 disk sales: $1,077,800,000
1997 total net sales: $19,420,865,000 (FY ending 12/31/97) Net income: $129,896,000

Samsung Electronics, founded in 1969, is Korea's largest electronics company, producing a variety of consumer, industrial and computer products. The firm is the leading supplier of DRAM chips and is becoming increasingly visible in the rigid disk drive market. Samsung made a minority investment in Comport, a 1987 U.S. startup, and manufactured Comport's 3.5" line of disk drives until Comport went out of business. Samsung's production of disk drives is currently entirely in 1" high 3.5" desktop models targeted for the higher capacity range used with personal computers, extending up to 27.2 gigabytes, and has achieved substantial sales growth in the last few years. Samsung arranged for development of 2.5" drives by Integral Peripherals, with production start originally planned for 1996, but did not subsequently enter the 2.5" mobile drive market. Samsung maintains an R&D center for disk drive design in San Jose.

TOSHIBA CORPORATION
1-1-1 Shibaura
Minato-ku, Tokyo 105

1998 disk sales: $1,848,700,000
1999 total net sales: $40,464,900,000 Net income: ($106,076,000)

Toshiba is a major factor in consumer electric and electronic products, plus a wide range of industrial electronic products and heavy electric power equipment. The company also has a leading position in the Japanese office computer market, and about two thirds of sales revenues are derived from computing and communications products.

Rigid disk drive production at Toshiba has a history of more than two decades including 14", 8", 5.25", 3.5" and 2.5" disk diameters. Toshiba's presence in the U.S. OEM rigid disk drive market was enhanced when it acquired the OEM disk drive operations of Memorex from Burroughs, and Toshiba continued to expand its U.S. operations, establishing a design center in Southern California. Toshiba then dropped most of its 5.25" drives in order to concentrate on 3.5" and smaller form factors. In 1992, the company established a San Jose factory to manufacture high-end 3.5" drives originally developed at its design center in Southern California, but after it became clear that the firm's product designs would be eclipsed by the industry leaders, it phased out the 3.5" San Jose program.

Toshiba has established a very successful 2.5" disk drive series, as a result of an aggressive development program which provided a significant share of the industry's product leadership in 2.5" drives in the 1990's. Active in both the noncaptive market for 2.5" mobile drives and in Toshiba's requirement for captive drives used in notebook computers, the company's 2.5" product line now extends to 10 gigabytes with GMR head drives. Toshiba has pioneered in the production of very thin 2.5" drives, with models as thin as 6.35 millimeters. Like many other Japanese companies, Toshiba is shifting its rigid drive production offshore, with a factory in the Philippines.

European Manufacturers

CALLUNA TECHNOLOGY LTD.
Blackwood Road, Eastfield
Glenrothes, Fife KY7 4NP
Scotland

1998 total net sales: $10,804,918 (FY ending 3/31/98) Net income:($10,155,737)

Calluna Technology was founded to design and manufacture 1.8" drives in Glenrothes. The founders were all veterans of Rodime, the pioneer manufacturer of 3.5" drives, and many were previously with the Burroughs disk drive manufacturing facility in Glenrothes. Calluna occupied a new industrial building early in 1992 and started production of disk drives in the PCMCIA Type III PC Card format in mid-1993.

The PC Card drive product line has since been expanded, and currently includes drives with capacities up to 1,040 megabytes and an announced Type II 260 megabyte drive currently planned for production in mid-1999. In March, 1999, Calluna announced that the Type II drive will be produced in Singapore under a contract manufacturing arrangement with PCS, Inc., a California headquartered supplier of disk drive service and manufacturing programs. Production of a 520 megabyte drive was initiated in 1997, utilizing a contract manufacturing arrangement with Xyratex, the firm which resulted from a management buyout of IBM's facilities at Havant, U.K., but other contract manufacturing arrangements are expected to be made, since Xyratex plans to cease contract manufacturing of disk drives. With the end of 1.8" disk drive production by Integral Peripherals, Calluna is the only surviving 1.8" drive manufacturer.

NOMAI
188, rue de la Liberte -- B.P. 141
50301 AVRANCHES cedex
France

Nomai entered the data storage market in 1992 as a manufacturer and marketer of rigid disk drive cartridges compatible with SyQuest 5.25" drives. After a flurry of legal actions by SyQuest were settled, Nomai was successful in setting up extensive distribution for the disk cartridge product line, including the temporary enlistment of Iomega as a reseller. In 1995, the company announced the development of 3.5" rigid disk cartridge drives, with initial shipments starting at the end of 1995. The basic 540 megabyte drive design was done in Scotland by Myrica (U.K.) Limited, a design firm staffed with Rodime graduates, with technology assistance from universities in the U.K. and France. The 540 megabyte drive and a later 750 megabyte model were manufactured by Xyratex at Havant in the U.K.

During the 1997-98 period legal claims and counterclaims between Nomai and Iomega appeared in the courtrooms of several countries, as Nomai entered the market for Zip compatible 3.5" floppy disk cartridges. Iomega cleared up the legal problems by buying control of Nomai and installing its own management. Subsequently, Nomai withdrew from the rigid disk cartridge drive business.

RODIME LTD.
Nasmyth Road
Southfield Industrial Estates
Glenrothes, Fife KY6 2SD
Scotland

After being formed in late 1980 by key personnel from the Burroughs facility in Glenrothes, Rodime met its schedule for shipments in 1981, and until 1986 continued to achieve a healthy growth rate. With the decline of its older 5.25" models, Rodime's sales increasingly relied on shipments of 3.5" drives, which it was the first to ship in 1983. The company had difficulty in keeping up with the industry's short product life cycles, and in early 1989 top management was completely overhauled as Rodime came perilously near bankruptcy. New financing was obtained, but Rodime never returned to profitability. In mid-1991 Rodime announced that it would file for bankruptcy and cease manufacturing of drives.

Rodime surprised the industry by obtaining patent coverage on the form factor of a 3.5" drive -- claiming no new technology, only a reduction in size. The firm then sued MiniScribe and Conner Peripherals for patent infringement. When IBM announced the PS/2 family, which used 3.5" drives, it sued Rodime to invalidate the patent, and Rodime bravely met the challenge by countersuing IBM for patent infringement. MiniScribe opted out of the legal proceedings by taking a license.

In the meantime, after extensive patent office preliminaries, the affair began a long tour of the U.S. federal court system which ended when IBM and Conner took licenses. Although several other companies have signed up for Rodime licenses, legal proceedings have lingered on. Appeals court rulings in 1995 and 1996 appear to have weakened the Rodime negotiating position, but Rodime continues to argue that other patent claims are still valid.

XYRATEX (Havant International Ltd.)
P.O. Box 6, Langstone Road
Havant, Hampshire PO9 1SA
United Kingdom

Xyratex was created in December, 1994, as the result of a management buy-out of IBM's Havant facilities. Xyratex, the firm's brand name at the time of the

buyout, became the company's new name. Products include flexible circuits, storage subsystems (including disk drive arrays), test systems and networking equipment. Disk drives have been produced under contract, at various times, for a number of clients, including IBM, Western Digital, Calluna, JTS and Nomai.

Although "new", the company is of significant size, occupying about 600,000 square feet of space and employing about 2,000 people. In past years, the Havant facility has operated at disk drive manufacturing levels which in some years exceeded two million small disk drives per year, but the company now is emphasizing other business activities and it is expected that disk drive manufacturing will be phased out.

DISK/TREND ON DISK

1999 DISK/TREND REPORT

DISK/TREND ON DISK

Introduction

DISK/TREND ON DISK is a licensed set of floppy disks available for separate purchase that contain the statistical tables and specification tables from the annual DISK/TREND Reports. The statistical tables are provided in text format usable on IBM-compatible computers running under MS-DOS, PC-DOS, or Microsoft Windows. Specification tables are provided in the form of an Excel spreadsheet file.

User instructions for 1999 DISK/TREND on Disk are included on the diskettes in the form of web browser readable files, and can also be found on the DISK/TREND web site at www.disktrend.com/dtod/dtod.htm. To see the instructions on the diskette, set the browser to: file://A:/index.htm. If you are using other than the "A" drive as your floppy disk, then use the appropriate drive letter.

If you are using DISK/TREND on Disk files for years earlier than 1999, please refer to the DISK/TREND Report for the appropriate year and product type for instructions.

A file translation program, DataImport, is available from DISK/TREND to assist in converting the data supplied to the formats of several popular spreadsheets. One copy of DataImport is provided at no extra charge to DISK/TREND subscribers who purchase DISK/TREND on DISK for the first time. Upgrades to DataImport for users with the earlier AutoImport conversion software are available at a special price: Please contact DISK/TREND for details.

DataImport
Use of DataImport is subject to license terms and conditions of Spalding Software, Inc. 154 Technology Parkway, Suite 250, Norcross, GA 30092

Trademarks
IBM, PC-DOS, Lotus and Lotus 1-2-3 are trademarks of International Business Machines Corporation. Excel and MS-DOS are trademarks of Microsoft Corporation. AutoImport is a trademark of White Crane Systems, Inc. DataImport is a trademark of Spalding Software, Inc.