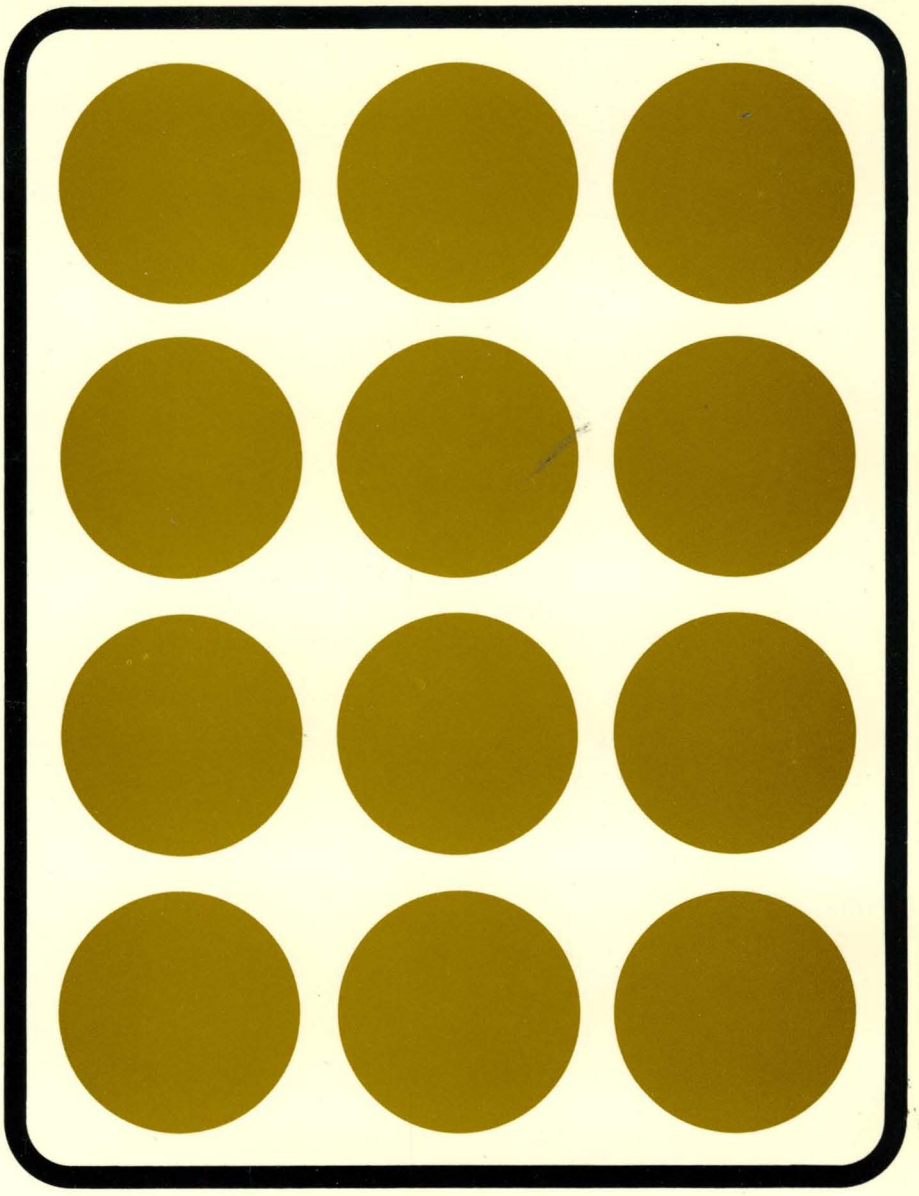
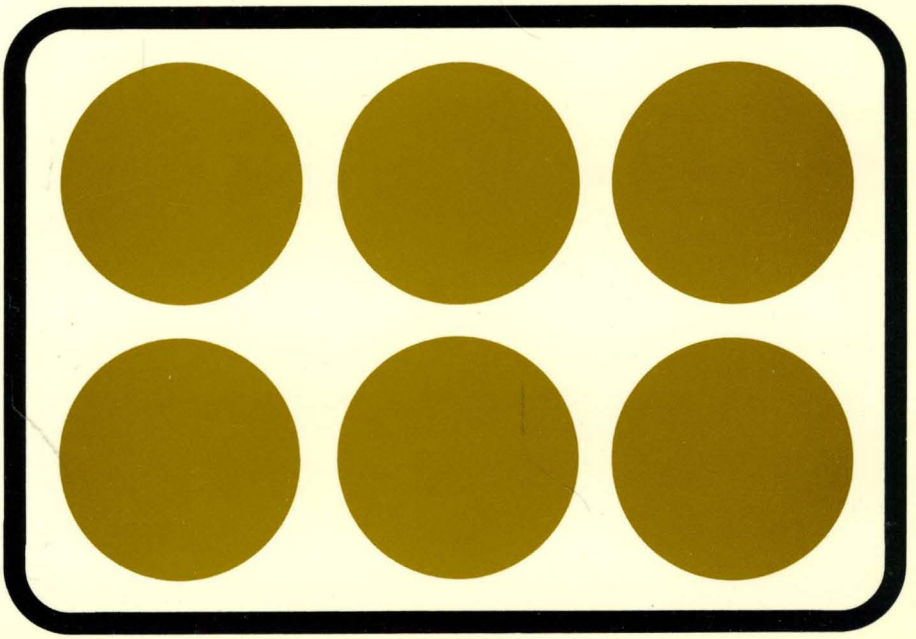


1991 DISK/TREND® REPORT



OPTICAL DISK DRIVES

1991 DISK/TREND® REPORT

OPTICAL DISK DRIVES

July, 1991

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

Telephone: 415/961-6209
Facsimile: 415/969-2560
Telex: 171914

FOREWORD

The latter part of 1990 and early 1991 have been interesting, if not always pleasant. Despite economic slowdowns and war jitters, the optical recording industry made progress. The first 3.5" drives, new libraries, high(er) performance optical drives, hints of 2.5" drives to come, the entry of IBM and Hewlett-Packard as drive manufacturers, real multimedia products: It's finally starting to look like an industry.

There are still those nagging problems: Conflicting distribution channels, competing standards efforts, difficult media production, product proliferation, reliability questions, and the slow pace of system integration. All present challenges, and so does the next wave of drive component improvements, with better lasers, media, heads and other elements not too far in the offing.

And there are still the four 'P' problems: Performance, package, price, and profitability to be resolved before the optical storage industry can be fully competitive with magnetic recording technology.

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

We are always willing to help you at any time by providing additional information on the industry which we may have available. And, as always, we welcome and appreciate your suggestions for improvements in the DISK/TREND report.

James N. Porter

Robert H. Katzive

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF FIGURES

INTRODUCTION

1991 is the sixth year of publication for the DISK/TREND Report on optical disk drives and the second year of coverage for optical disk libraries. For those readers unfamiliar with DISK/TREND reports, a few useful points will help in interpreting the information presented.

* As with other DISK/TREND reports, this report concentrates upon disk drives and optical libraries used with computers, rather than upon media, controllers, or other related topics. Optical video disk drives and libraries for entertainment, optical tape drives, and optical card drives are not covered.

* Unit totals are given in spindles for drives, and in elevators for libraries. At present, all optical disk drives have one spindle.

* The values of any leased equipment are given on an 'if-sold' basis in all DISK/TREND estimates.

* Market share tables, usually included in DISK/TREND reports, are omitted for some sections of this report, because the 1990 market was too small for market share figures to be meaningful.

* This year's report divides optical disk drives into three groups and libraries into four groups:

    * Read-only optical disk drives
    * Read/write optical disk drives less than 1 gigabyte
    * Read/write optical disk drives more than 1 gigabyte

    * Read-only optical libraries
    * Read/write optical libraries, 1 - 39 cartridges
    * Read/write optical libraries, 40 - 69 cartridges
    * Read/write optical libraries, more than 70 cartridges

  The read/write groups include all equipment with the capability to both read and write data on an optical disk, regardless of whether individual drives are intended to operate primarily in a write-once mode, an erasable (rewritable) mode, or to have multifunction capabilities. However, rewritable drives and libraries using rewritable drives are specifically forecast in each product group section.

* Data contained in the tables of DISK/TREND reports is again being offered on floppy disks as an option to report subscribers. Instructions are included in the last section of the report.

SUMMARY: OPTICAL DISK DRIVES AND LIBRARIES

Industry size

1990 saw good overall revenue growth for both optical drives and libraries, but growth varied widely among product categories. However, all product groups showed positive revenue and shipment growth.

In 1990, 909,900 optical disk drives were shipped, up 29.2% over 1989. Shipments of optical libraries rose to 11,488 units, almost 69% of which were small read-only libraries. 1990 drive revenues reached $917.8 million, while optical library revenues rose to $102.3 million. (The library revenues do not include the revenues of associated drives, to avoid double counting.)

U.S. manufacturers captured 5.2% of worldwide optical disk drive revenues, a slight improvement over their previous year's 3.4% share. U.S. companies did better with libraries, as 47.6% of revenues went to U.S. firms in 1990. The U.S. share of drive unit shipments was only 1.4%, but it is expected to grow somewhat and reach 10% in 1994. Again, this is the result of U.S. non-participation in the CD-ROM market. U.S. firms held 18.5% of library unit shipments in 1990, a decrease from 1989 because of a large increase in read-only library shipments by non-U.S. suppliers.

In 1990, 44.1% of drive revenues were generated by sales in the United States, an increase from 38.3% in 1989. Sales to U.S. firms accounted for 54.2% of library revenues, a decrease from 65.3% in 1989 that reflects the impact of the 1990 recession in the U.S. In 1994, the U.S. market is expected to be a larger share, yielding 52.6% of a $3.6 billion drive market. The U.S. proportion of the library market is expected to recover and reach the 64% level in 1994.

IBM entered the optical storage arena as a manufacturer in 1991 with a 3.5" magneto-optic rewritable drive. IBM also remains a purchaser of 5.25" and 12" drives and libraries to integrate into its systems. Hewlett-Packard announced it will manufacture a 5.25" rewritable drive. As a result of these new market entries, U.S. manufacturers' share of the overall optical disk drive market is expected to increase.

The U.S. firms producing libraries continue to do well, as a result of aggressive new product development and because of their strengths in system integration and software support. Libraries are used mostly on multiuser systems, a technology well understood by many U.S. companies, and this has also helped the U.S. firms.

Non-U.S. firms have major strengths in optical drive component technology and have emerged as the major drive producers as a result. The U.S. has developed some capabilities at the component level, but will have difficulty in overcoming the Japanese lead in media, lasers, optical components, heads and mechanisms.

TABLE 1

CONSOLIDATED WORLDWIDE REVENUES

OPTICAL DISK DRIVES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1990		Forecast							
	Revenues		1991		1992		1993		1994	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	46.2	64.2	138.2	178.9	254.2	336.9	342.2	485.9
Other U.S. Captive	--	--	.4	.4	38.0	53.2	47.9	68.4	63.6	93.2
TOTAL U.S. CAPTIVE	--	--	46.6	64.6	176.2	232.1	302.1	405.3	405.8	579.1
PCM/Reseller	19.4	26.7	22.4	31.9	39.3	55.8	62.9	89.7	85.1	125.3
OEM/Integrator	20.8	21.5	34.5	40.2	58.5	74.4	83.3	110.2	117.6	153.3
TOTAL U.S. NON-CAPTIVE	40.2	48.2	56.9	72.1	97.8	130.2	146.2	199.9	202.7	278.6
TOTAL U.S. REVENUES	40.2	48.2	103.5	136.7	274.0	362.3	448.3	605.2	608.5	857.7
Non-U.S. Manufacturers										
Captive	29.9	332.6	71.0	487.4	134.4	659.8	159.9	790.9	226.4	1,031.3
PCM/Reseller	106.0	182.3	166.7	251.9	201.2	303.0	276.2	423.3	355.6	560.3
OEM/Integrator	229.0	354.7	289.7	470.8	432.4	679.9	581.7	940.5	729.2	1,202.3
TOTAL NON-U.S. REVENUES	364.9	869.6	527.4	1,210.1	768.0	1,642.7	1,017.8	2,154.7	1,311.2	2,793.9
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	405.1	917.8	630.9	1,346.8	1,042.0	2,005.0	1,466.1	2,759.9	1,919.7	3,651.6

TABLE 2

CONSOLIDATED WORLDWIDE REVENUES

OPTICAL LIBRARIES

REVENUE SUMMARY

	LIBRARY REVENUES, BY SHIPMENT DESTINATION (M)									
	1990		Forecast							
	Revenues		1991		1992		1993		1994	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	16.0	24.5	19.2	29.0	31.4	46.8	42.2	62.3	50.1	74.1
TOTAL U.S. CAPTIVE	16.0	24.5	19.2	29.0	31.4	46.8	42.2	62.3	50.1	74.1
PCM/Reseller	2.7	3.4	5.2	6.7	16.5	22.4	20.4	27.5	23.5	31.9
OEM/Integrator	21.8	27.9	40.8	53.5	55.9	71.8	62.5	82.3	65.5	88.2
TOTAL U.S. NON-CAPTIVE	24.5	31.3	46.0	60.2	72.4	94.2	82.9	109.8	89.0	120.1
TOTAL U.S. REVENUES	40.5	55.8	65.2	89.2	103.8	141.0	125.1	172.1	139.1	194.2
Non-U.S. Manufacturers										
Captive	.2	15.4	.5	16.3	.6	16.1	.6	16.6	.5	16.5
PCM/Reseller	3.5	8.7	6.9	15.2	9.2	20.2	10.4	22.8	11.9	24.5
OEM/Integrator	11.2	22.4	23.3	40.4	33.8	55.5	42.9	69.0	50.2	78.6
TOTAL NON-U.S. REVENUES	14.9	46.5	30.7	71.9	43.6	91.8	53.9	108.4	62.6	119.6
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	55.4	102.3	95.9	161.1	147.4	232.8	179.0	280.5	201.7	313.8

Figure 1

CHANGING PRODUCT MIX
Worldwide Optical Disk Drive Revenue

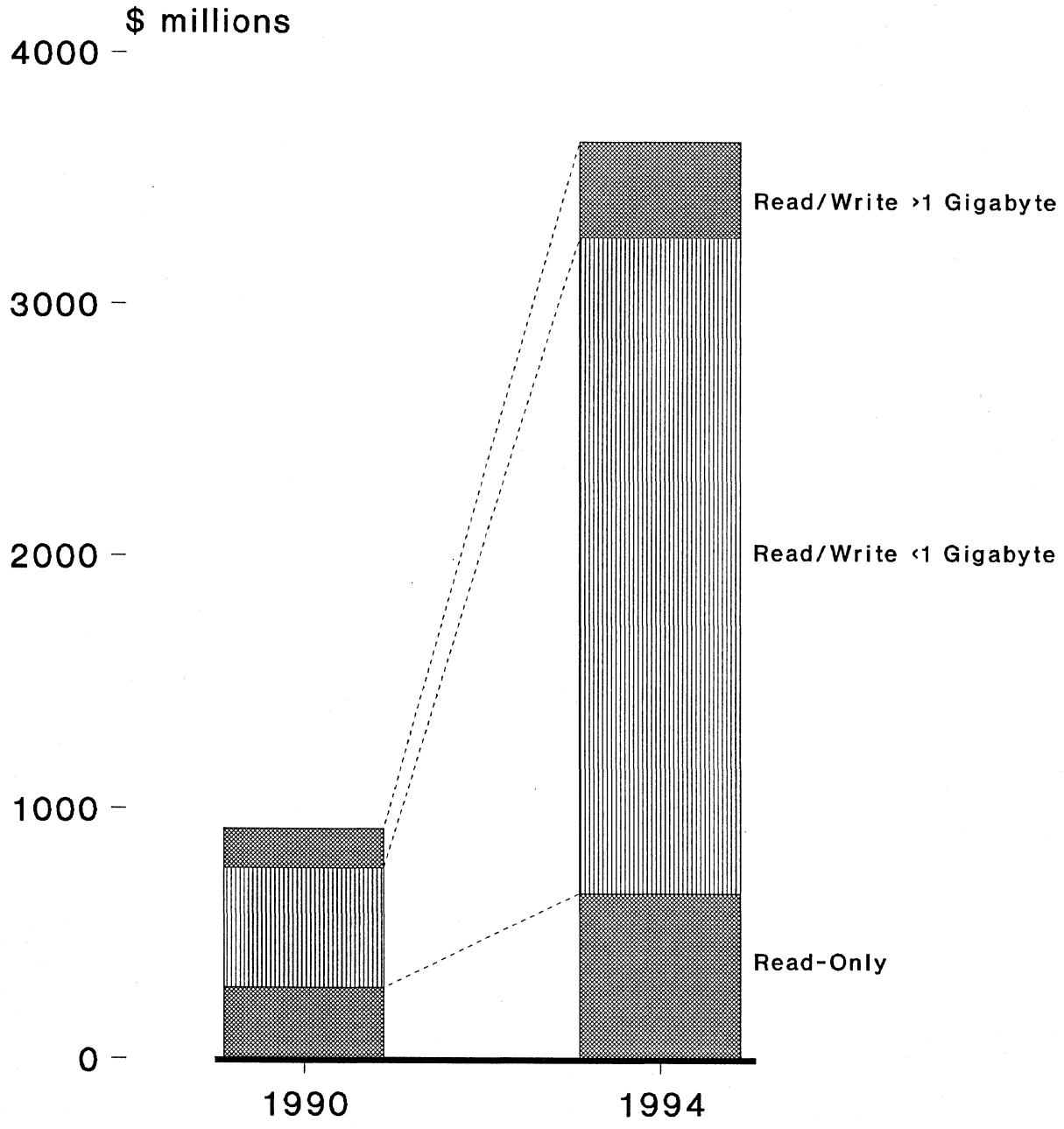
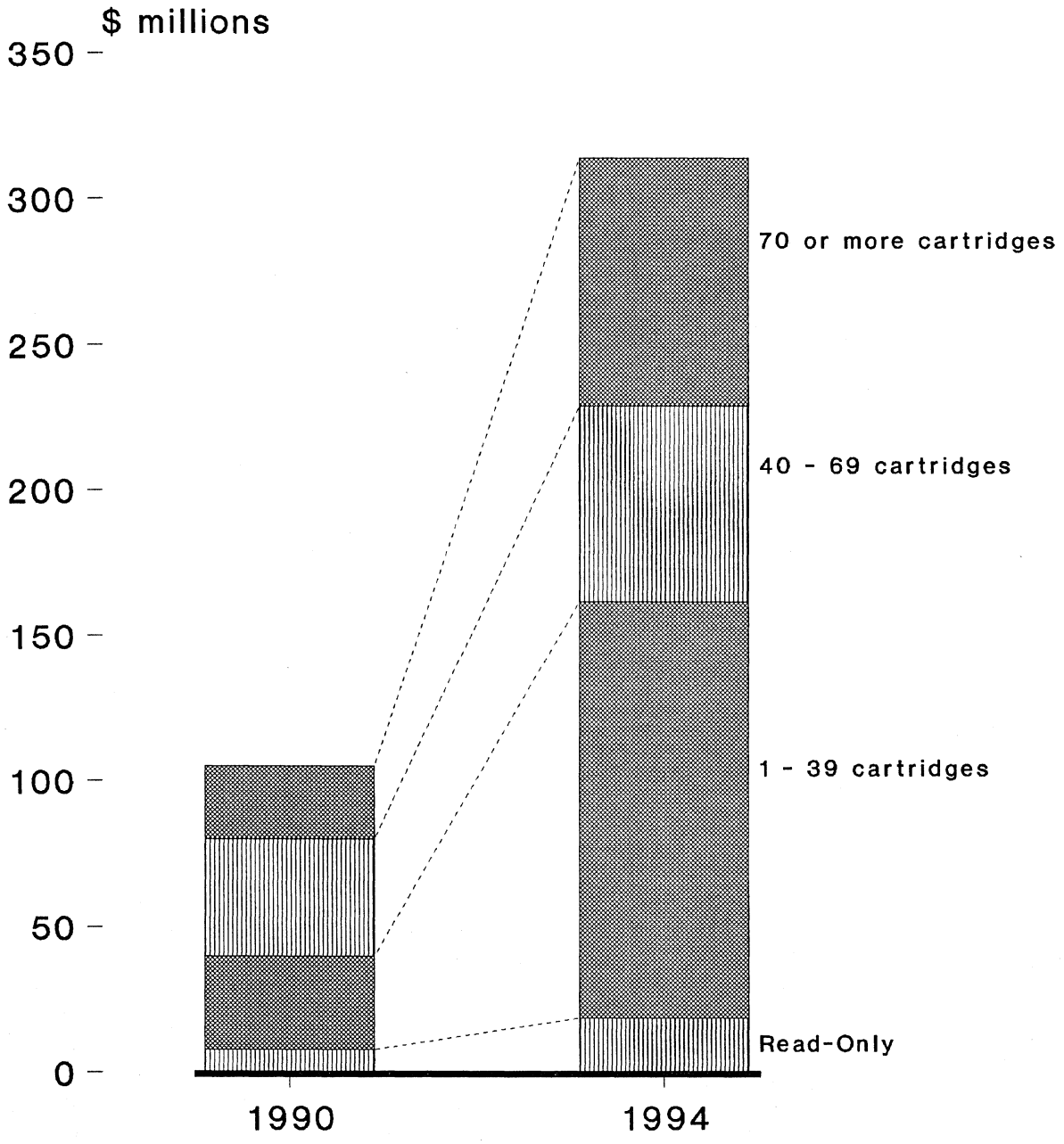


Figure 2

CHANGING PRODUCT MIX
Worldwide Optical Library Revenue



Marketing channels

The marketing channels used by optical drive and library manufacturers are defined in this report as captive, PCM/Reseller, and OEM/integrator. Captive drives and libraries are sold as part of systems also manufactured by the same company. The PCM/Reseller channel includes drives and libraries used in add-on subsystems for use with computer systems of all types and sizes, plus aftermarket distribution through wholesalers, dealers and other resellers. The PCM/Reseller channel also includes drive or library sales directly from the manufacturer to government or large end user 'house accounts'. The OEM/Integrator channel includes drives and libraries sold to system manufacturers to be used as part of computer systems, plus sales to system integrators and value-added resellers which assemble complete systems.

As of mid-1991, there are 10 U.S. producers of optical drives. One of these, Optimem, has announced that it is halting production in 1991. There are 25 Asian manufacturers, and two European manufacturers, the same as in 1990. The U.S. and Asian manufacturer counts for libraries have not changed, but the number of European manufacturers has risen to 5.

OEM/Integrator optical disk drive revenues accounted for 41% of the worldwide total of $917.8 million in 1990, followed by captive revenues at 36.2%. PCM/Reseller revenues were 22.8%. In 1993, of the $2.798 billion total revenues expected for optical disk drives, the OEM/Integrator share will decline slightly to 37.2%. PCM/Reseller revenue is projected to decline to 18.8%, while captive revenues, responding to IBM and Hewlett-Packard market entry as manufacturers, are forecasted to grow to 44% of 1994 revenues.

1990 library revenues of $102.3 million were split 49.2% from

OEM/Integrators, 39% from captive sales, and 11.8% from the PCM/Reseller channel. In 1994, library revenues of $313.8 million are expected to be divided 53.2% to OEM/Integrators, 28.9% to captive sales, and 17.9% through PCM/Resellers. Because of the complex system integration and support requirements of libraries, only the simplest types will be offered through the reseller channel.

Projected revenues for both drives and libraries include allowance for IBM 5.25" optical disk drives, judged to have a high probability of introduction in the 1991/1992 time frame, but do not include any allowance for IBM-manufactured libraries because IBM's intentions regarding libraries are much less clear.

Revenues in this report are based on the price of the drive or library the first time it is sold to an unaffiliated buyer, at captive end user, PCM/Reseller or OEM/Integrator levels. Drive prices are based on disk drives alone, without controllers or other accessories, and leased drives are valued at the price they would command if actually sold. Library prices are for the library only and do not include the disk drives or external controllers.

TABLE 3

CONSOLIDATED WORLDWIDE REVENUES
OPTICAL DISK DRIVES
MARKET CLASS REVIEW

REVENUE SUMMARY

WORLDWIDE REVENUES BY MANUFACTURER TYPE	1990 Revenues $M	1990 Revenues %	Forecast 1991 $M	1991 %	1992 $M	1992 %	1993 $M	1993 %	1994 $M	1994 %
U.S. Manufacturers										
IBM Captive	--	--	64.2	4.7%	178.9	8.9%	336.9	12.2%	485.9	13.3%
	--		--		+178.7%		+88.3%		+44.2%	
Other U.S. Captive	--	--	.4	--	53.2	2.6%	68.4	2.4%	93.2	2.5%
	--		--		--		+28.6%		+36.3%	
PCM/Reseller	26.7	2.9%	31.9	2.3%	55.8	2.7%	89.7	3.2%	125.3	3.4%
	+276.1%		+19.5%		+74.9%		+60.8%		+39.7%	
OEM/Integrator	21.5	2.3%	40.2	2.9%	74.4	3.7%	110.2	3.9%	153.3	4.1%
	+21.5%		+87.0%		+85.1%		+48.1%		+39.1%	
Total U.S. Manufacturers	48.2	5.2%	136.7	9.9%	362.3	17.9%	605.2	21.7%	857.7	23.3%
	+89.8%		+183.6%		+165.0%		+67.0%		+41.7%	
Non-U.S. Manufacturers										
Captive	332.6	36.2%	487.4	36.1%	659.8	32.9%	790.9	28.6%	1,031.3	28.2%
	+20.3%		+46.5%		+35.4%		+19.9%		+30.4%	
PCM/Reseller	182.3	19.8%	251.9	18.7%	303.0	15.1%	423.3	15.3%	560.3	15.3%
	+68.0%		+38.2%		+20.3%		+39.7%		+32.4%	
OEM/Integrator	354.7	38.8%	470.8	35.3%	679.9	34.1%	940.5	34.4%	1,202.3	33.2%
	+32.9%		+32.7%		+44.4%		+38.3%		+27.8%	
Total Non-U.S. Manufacturers	869.6	94.8%	1,210.1	90.1%	1,642.7	82.1%	2,154.7	78.3%	2,793.9	76.7%
	+33.4%		+39.2%		+35.7%		+31.2%		+29.7%	
Worldwide Recap										
Captive	332.6	36.2%	552.0	41.0%	891.9	44.5%	1,196.2	43.3%	1,610.4	44.1%
	+20.1%		+66.0%		+61.6%		+34.1%		+34.6%	
PCM/Reseller	209.0	22.8%	283.8	21.1%	358.8	17.9%	513.0	18.6%	685.6	18.8%
	+80.8%		+35.8%		+26.4%		+43.0%		+33.6%	
OEM/Integrator	376.2	41.0%	511.0	37.9%	754.3	37.6%	1,050.7	38.1%	1,355.6	37.1%
	+32.2%		+35.8%		+47.6%		+39.3%		+29.0%	
Total All Manufacturers	917.8	100.0%	1,346.8	100.0%	2,005.0	100.0%	2,759.9	100.0%	3,651.6	100.0%
	+35.5%		+46.7%		+48.9%		+37.7%		+32.3%	

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

TABLE 4

CONSOLIDATED WORLDWIDE REVENUES
OPTICAL LIBRARIES
MARKET CLASS REVIEW

REVENUE SUMMARY

WORLDWIDE REVENUES BY MANUFACTURER TYPE	1990 Revenues $M	1990 Revenues %	1991 $M	1991 %	1992 $M	1992 %	1993 $M	1993 %	1994 $M	1994 %
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	24.5	23.9%	29.0	18.0%	46.8	20.1%	62.3	22.2%	74.1	23.6%
	+14.0%		+18.4%		+61.4%		+33.1%		+18.9%	
PCM/Reseller	3.4	3.3%	6.7	4.1%	22.4	9.6%	27.5	9.8%	31.9	10.1%
	--		+97.1%		+234.3%		+22.8%		+16.0%	
OEM/Integrator	27.9	27.2%	53.5	33.2%	71.8	30.8%	82.3	29.3%	88.2	28.1%
	+4.1%		+91.8%		+34.2%		+14.6%		+7.2%	
Total U.S. Manufacturers	55.8	54.4%	89.2	55.3%	141.0	60.5%	172.1	61.3%	194.2	61.8%
	+15.1%		+59.9%		+58.1%		+22.1%		+12.8%	
Non-U.S. Manufacturers										
Captive	15.4	15.0%	16.3	10.1%	16.1	6.9%	16.6	5.9%	16.5	5.2%
	+120.0%		+5.8%		-1.2%		+3.1%		-.6%	
PCM/Reseller	8.7	8.5%	15.2	9.4%	20.2	8.6%	22.8	8.1%	24.5	7.8%
	--		+74.7%		+32.9%		+12.9%		+7.5%	
OEM/Integrator	22.4	22.1%	40.4	25.2%	55.5	24.0%	69.0	24.7%	78.6	25.2%
	+62.3%		+80.4%		+37.4%		+24.3%		+13.9%	
Total Non-U.S. Manufacturers	46.5	45.6%	71.9	44.7%	91.8	39.5%	108.4	38.7%	119.6	38.2%
	+123.6%		+54.6%		+27.7%		+18.1%		+10.3%	
Worldwide Recap										
Captive	39.9	39.0%	45.3	28.1%	62.9	27.0%	78.9	28.1%	90.6	28.9%
	+40.0%		+13.5%		+38.9%		+25.4%		+14.8%	
PCM/Reseller	12.1	11.8%	21.9	13.6%	42.6	18.3%	50.3	17.9%	56.4	18.0%
	--		+81.0%		+94.5%		+18.1%		+12.1%	
OEM/Integrator	50.3	49.2%	93.9	58.3%	127.3	54.7%	151.3	54.0%	166.8	53.1%
	+23.9%		+86.7%		+35.6%		+18.9%		+10.2%	
Total All Manufacturers	102.3	100.0%	161.1	100.0%	232.8	100.0%	280.5	100.0%	313.8	100.0%
	+47.6%		+57.5%		+44.5%		+20.5%		+11.9%	

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

Product mix

In 1990, read-only drives captured a 78.4% share of total worldwide optical drive unit shipments, down from 1989's 85.6% share, as a result of slowing in the games segment of the market. Read/write drives under 1 gigabyte increased share from 13.0% in 1989 to 20.4% in 1990, while read/write drives over 1 gigabyte declined from 1.4% to 1.2% of shipments.

1989 was the peak year for revenue leadership of the optical disk drive market by the read-only product group, as increasing sales of re-writable small diameter drives in 1990 reduced the read-only share of revenues to 31%. Read/write drives less than a gigabyte captured 52% and read/write drives over 1 gigabyte had 17%.

Over 91% of shipments of read/write drives less than 1 gigabyte will be erasable or multifunction drives in 1994. Read-only drive shipments will have passed the 3.0 million unit mark, achieving 67.9% of the total worldwide market. High capacity read/write drives over 1 gigabyte will hold a .6% share, with 27,700 units shipped, but will generate 10.3% of total revenue, due to high prices relative to other drives.

All application categories for read-only drives are expanding, with the consumer, game and automotive segments projected to be the fastest growing markets. Sales for read-only drives will benefit from the availability of multimedia drives, controllers and titles in volume after 1991.

For optical libraries, the largest segment in 1990 was the read-only library segment, with a 68.8% share of an 11,488 unit market. The next largest segment was the 1 to 39 cartridge library, which had a 17.9% share. The 40 to 69 cartridge libraries, which had the largest share in 1989, captured only a 10.9% share in 1990. Libraries with 70 or more cartridges held a 2.4% share. The main reason for the switch in rankings is the

relatively large number of low end libraries shipped in 1990.

In 1994, the 1 to 39 cartridge libraries and read-only libraries are expected to hold nearly equal shares of unit shipments, each product group with about 42%. 40 to 69 cartridge libraries will improve their share slightly to 11.9%. Libraries with 70 or more cartridges will obtain a 3.7% share. The rapidly expanding market for low-end libraries for use with personal computers and small workstations will swamp the classical library market in terms of unit shipments. However, while 1994 unit shipment statistics will favor the bottom of the line, 48.5% of revenues will be generated from the two top of the line categories and nearly as much, 45.6% of the 1994 revenue, will be generated by the 1 to 39 cartridge category. 5.9% will be generated by read-only libraries.

Industry participation

Ten U.S. companies, 25 Asian firms and 3 European organizations compete in the optical disk drive market. The number of U.S. firms has increased by one (Hewlett-Packard), but Optimem will make its last drive in the summer of 1991. The number of Asian drive producers remained even, and the European roster increased by one.

15 companies offer read-only drives, all of which are non-U.S. firms and 13 of which are Japanese organizations. 28 manufacturers are making read/write drives under 1 gigabyte: 16 of these have rewritable or multi-function drives.

8 U.S. firms, 11 Asian manufacturers and 4 European suppliers offer optical libraries. Of the 23 companies, 4 make read-only libraries, but do not participate in other product groups. 9 firms make only 5.25" libraries, while 5 make only larger diameter libraries.

TABLE 5

CONSOLIDATED WORLDWIDE REVENUES
OPTICAL DISK DRIVES
PRODUCT CATEGORY REVIEW

REVENUE SUMMARY

WORLDWIDE REVENUES	1990		Forecast							
ALL MANUFACTURERS	Revenues		1991		1992		1993		1994	
	$M	%	$M	%	$M	%	$M	%	$M	%
READ-ONLY	284.3	31.0%	304.1	22.6%	372.3	18.6%	502.0	18.2%	661.2	18.1%
ALL CAPACITIES	+7.9%		+7.0%		+22.4%		+34.8%		+31.7%	
READ/WRITE	477.6	52.0%	845.6	62.8%	1,371.5	68.5%	1,925.3	69.9%	2,609.4	71.6%
LESS THAN 1 GIGABYTE	+62.5%		+77.1%		+62.2%		+40.4%		+35.5%	
READ/WRITE	155.9	17.0%	197.1	14.6%	261.2	12.9%	332.6	11.9%	381.0	10.3%
MORE THAN 1 GIGABYTE	+30.4%		+26.4%		+32.5%		+27.3%		+14.6%	
Total Worldwide Revenue	917.8	100.0%	1,346.8	100.0%	2,005.0	100.0%	2,759.9	100.0%	3,651.6	100.0%
	+35.5%		+46.7%		+48.9%		+37.7%		+32.3%	
% U.S. Manufacturers	5.2%		10.1%		18.0%		21.9%		23.4%	

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

TABLE 6

CONSOLIDATED WORLDWIDE REVENUES
OPTICAL LIBRARIES
PRODUCT CATEGORY REVIEW

REVENUE SUMMARY

WORLDWIDE REVENUES	1990		Forecast							
ALL MANUFACTURERS	Revenues		1991		1992		1993		1994	
	$M	%	$M	%	$M	%	$M	%	$M	%
OPTICAL LIBRARIES	8.4	8.2%	11.1	6.9%	13.3	5.7%	15.7	5.6%	18.6	5.9%
READ-ONLY	+189.7%		+32.1%		+19.8%		+18.0%		+18.5%	
OPTICAL LIBRARIES	28.4	27.8%	63.7	39.5%	107.0	46.0%	129.4	46.1%	143.2	45.6%
1-39 DISKS	+136.7%		+124.3%		+68.0%		+20.9%		+10.7%	
OPTICAL LIBRARIES	40.4	39.5%	43.8	27.2%	51.7	22.2%	59.8	21.3%	67.1	21.4%
40-69 DISKS	+31.6%		+8.4%		+18.0%		+15.7%		+12.2%	
OPTICAL LIBRARIES	25.1	24.5%	42.5	26.4%	60.8	26.1%	75.6	27.0%	84.9	27.1%
70 OR MORE DISKS	+5.9%		+69.3%		+43.1%		+24.3%		+12.3%	
Total Worldwide Revenue	102.3	100.0%	161.1	100.0%	232.8	100.0%	280.5	100.0%	313.8	100.0%
	+47.6%		+57.5%		+44.5%		+20.5%		+11.9%	
% U.S. Manufacturers	54.5%		55.3%		60.5%		61.3%		61.8%	

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

TABLE 7

CONSOLIDATED WORLDWIDE SHIPMENTS
OPTICAL DISK DRIVES
PRODUCT CATEGORY REVIEW

UNIT SHIPMENT SUMMARY

UNIT SHIPMENTS	1990		Forecast							
IN THOUSANDS	Shipments		1991		1992		1993		1994	
	Units	%	Units	%	Units	%	Units	%	Units	%
READ-ONLY	712.8	78.4%	972.4	72.5%	1,413.0	69.0%	2,124.5	68.1%	3,088.9	67.9%
ALL CAPACITIES	+18.3%		+36.4%		+45.3%		+50.4%		+45.4%	
READ/WRITE	185.4	20.4%	356.1	26.5%	616.3	30.1%	972.2	31.1%	1,431.9	31.5%
LESS THAN 1 GIGABYTE	+102.6%		+92.1%		+73.1%		+57.7%		+47.3%	
READ/WRITE	11.7	1.2%	14.4	1.0%	19.4	.9%	24.7	.8%	27.7	.6%
MORE THAN 1 GIGABYTE	+12.5%		+23.1%		+34.7%		+27.3%		+12.1%	
Total Worldwide Shipments	909.9	100.0%	1,342.9	100.0%	2,048.7	100.0%	3,121.4	100.0%	4,548.5	100.0%
	+29.2%		+47.6%		+52.6%		+52.4%		+45.7%	
% U.S. Manufacturers	1.4%		4.5%		7.8%		9.5%		10.0%	

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

TABLE 8

CONSOLIDATED WORLDWIDE SHIPMENTS
OPTICAL LIBRARIES
PRODUCT CATEGORY REVIEW

UNIT SHIPMENT SUMMARY

SHIPMENTS IN SINGLE UNITS	1990 Shipments Units	1990 Shipments %	1991 Forecast Units	1991 Forecast %	1992 Forecast Units	1992 Forecast %	1993 Forecast Units	1993 Forecast %	1994 Forecast Units	1994 Forecast %
OPTICAL LIBRARIES	7,902.0	68.8%	9,672.0	56.1%	11,595.0	49.0%	13,140.0	45.2%	14,550.0	42.3%
READ-ONLY	+214.3%		+22.4%		+19.9%		+13.3%		+10.7%	
OPTICAL LIBRARIES	2,062.0	17.9%	5,112.0	29.6%	8,563.0	36.2%	11,529.0	39.6%	14,464.0	42.1%
1-39 DISKS	+251.3%		+147.9%		+67.5%		+34.6%		+25.5%	
OPTICAL LIBRARIES	1,253.0	10.9%	1,958.0	11.4%	2,683.0	11.3%	3,369.0	11.6%	4,098.0	11.9%
40-69 DISKS	+112.4%		+56.3%		+37.0%		+25.6%		+21.6%	
OPTICAL LIBRARIES	271.0	2.4%	500.0	2.9%	825.0	3.5%	1,063.0	3.6%	1,272.0	3.7%
70 OR MORE DISKS	+7.1%		+84.5%		+65.0%		+28.8%		+19.7%	
Total Worldwide Shipments	11,488.0	100.0%	17,242.0	100.0%	23,666.0	100.0%	29,101.0	100.0%	34,384.0	100.0%
	+191.3%		+50.1%		+37.3%		+23.0%		+18.2%	
% U.S. Manufacturers	18.5%		28.4%		35.1%		38.5%		41.3%	

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

Figure 3

WORLDWIDE SHIPMENT SUMMARY

Total Optical Disk Drives

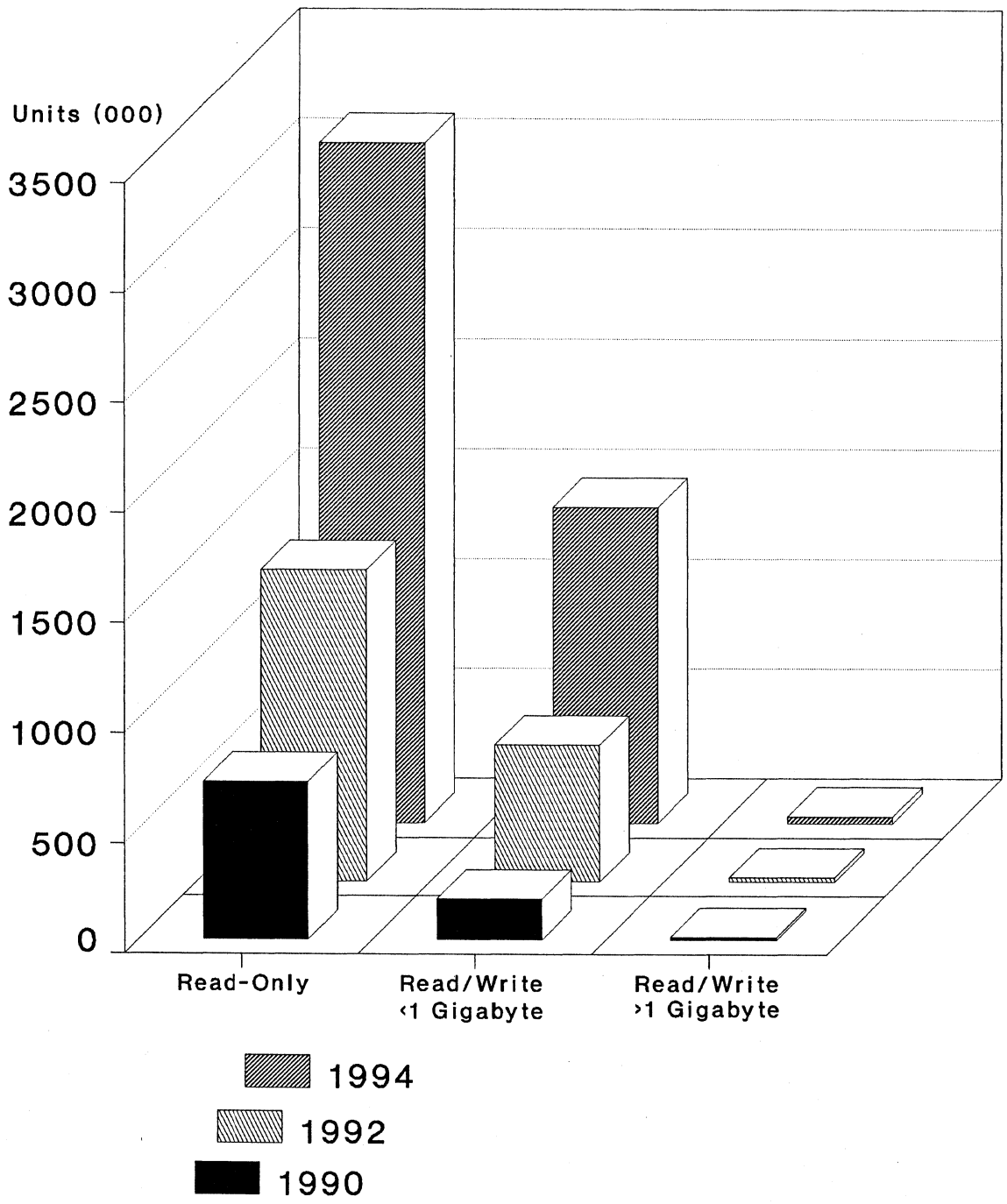
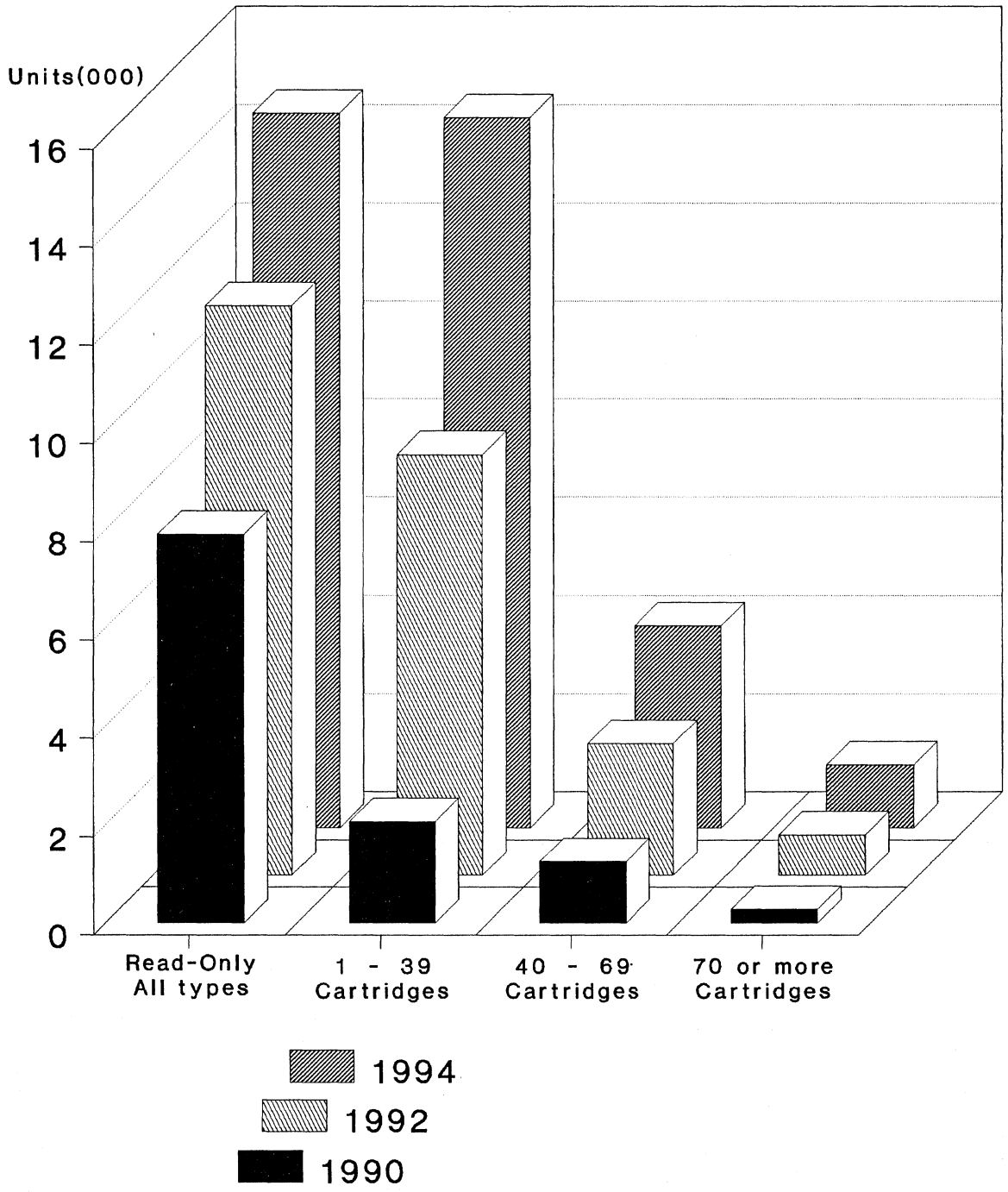


Figure 4

WORLDWIDE SHIPMENT SUMMARY

Total Optical Libraries



Non-captive market

In the non-captive distribution channels (OEM/Integrator and PCM/Reseller), read-only drives again led unit shipments, capturing 75.9% of the worldwide market. Read/write drives less than 1 gigabyte were next with 23.1% and read/write drives over 1 gigabyte held 1.0%. Increasing sales of rewritable drives are expected to expand the low capacity read/write drive share to 28.4% in 1994, while read-only drives will decline slightly to 71.1% and high capacity read/write drives will shrink to .5% of 1994 shipments.

1990 non-captive drive revenues were led by the low capacity read/write product group with 53.2%, followed by read-only drives with 32.7% and high capacity read/write drives with 14.1%. A similar ranking is expected in 1994, although the low capacity read/write drives will increase their revenue share to 63.1%, read-only will decline to 23.7%, and high capacity read/write drives will retain 13.2%.

The major OEM/Integrator revenue producers in 1990 were Sony, Toshiba, Hitachi and LMSI, in that order. These four companies accounted for 73.5% of total OEM/Integrator market value, and Sony alone held 47.2% of the OEM/Integrator total. Hitachi, Ricoh, Sony and Maxoptix were the leading PCM/Reseller channel suppliers, together holding 69.4% share. U.S. producers captured only 5.7% of OEM/Integrator revenues in 1990, but did somewhat better in the PCM/Reseller channel with 12.8% share.

The non-captive share of optical disk drive revenues is expected to shrink somewhat in the 1990-1994 period as a result of captive sales by IBM, Hewlett-Packard and others that have not occurred in previous years as well as the generally higher price levels for products sold on a captive basis.

73.1% of the optical libraries sold in the OEM/Integrator market were generated by the read-only product group, followed by 15.6% in the 1 to 39 disk product group. Emphasis on the low-end segments will continue through 1994, with the read-only library product group holding 46.0% share and the 1 to 39 cartridge libraries following with 38.6% share.

Library OEM/Integrator revenues are weighted more heavily to high-end libraries. In 1990, the 40 to 69 disk and more than 70 disk segments together captured 64.4% of 1990 non-captive revenue. By 1994, the 1 to 39 disk category is projected to have the lead with 35.7%, followed by the 40 to 69 disk segment with 27.9%, and the 70 or more disk product group with 20.3%. As with the shipment shares, revenue is shifting to lower-end segments with time, although the read-only segment 1994 share reaches only 8.3% because of the much lower pricing levels for most of the products in this segment.

U.S. library manufacturers captured 55.5% of the OEM/Integrator revenues and 45.6% of the PCM/Reseller revenues in 1990. Cygnet, Filenet and NKK were the leading OEM/Integrator channel suppliers with 45.3% of the revenues between them. In the PCM/Reseller channel, Hewlett-Packard, NKK and Pioneer were the leaders. Non-captive library revenues will rise from a 61.0% share of the worldwide total in 1990 to a 71.1% share in 1994, with the strongest growth coming in the PCM/Reseller area from sales of low-end libraries.

TABLE 9

NON-CAPTIVE WORLDWIDE REVENUES
OPTICAL DISK DRIVES
PRODUCT CATEGORY REVIEW

REVENUE SUMMARY

WORLDWIDE REVENUES ALL MANUFACTURERS	1990 Revenues		Forecast 1991		1992		1993		1994	
	$M	%	$M	%	$M	%	$M	%	$M	%
READ-ONLY	191.6	32.7%	212.5	26.7%	269.4	24.2%	383.4	24.5%	484.4	23.7%
ALL CAPACITIES	+11.1%		+10.9%		+26.8%		+42.3%		+26.3%	
READ/WRITE	310.4	53.2%	479.0	60.4%	685.1	61.7%	953.9	61.1%	1,285.5	63.1%
LESS THAN 1 GIGABYTE	+106.7%		+54.3%		+43.0%		+39.2%		+34.8%	
READ/WRITE	83.2	14.1%	103.3	12.9%	158.6	14.1%	226.4	14.4%	271.3	13.2%
MORE THAN 1 GIGABYTE	+7.5%		+24.2%		+53.5%		+42.7%		+19.8%	
Total Worldwide Revenues	585.2	100.0%	794.8	100.0%	1,113.1	100.0%	1,563.7	100.0%	2,041.2	100.0%
	+46.3%		+35.8%		+40.0%		+40.5%		+30.5%	
% U.S. Manufacturers	8.2%		9.0%		11.7%		12.7%		13.6%	

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

TABLE 10

NON-CAPTIVE WORLDWIDE REVENUES
OPTICAL LIBRARIES
PRODUCT CATEGORY REVIEW

REVENUE SUMMARY

WORLDWIDE REVENUES	1990		Forecast							
ALL MANUFACTURERS	Revenues		1991		1992		1993		1994	
	$M	%	$M	%	$M	%	$M	%	$M	%
OPTICAL LIBRARIES	8.4	13.5%	11.1	9.6%	13.3	7.8%	15.7	7.8%	18.6	8.3%
READ-ONLY	+189.7%		+32.1%		+19.8%		+18.0%		+18.5%	
OPTICAL LIBRARIES	13.8	22.1%	42.7	37.0%	74.7	44.1%	89.8	44.6%	96.7	43.5%
1-39 DISKS	+46.8%		+209.4%		+74.9%		+20.2%		+7.7%	
OPTICAL LIBRARIES	24.2	38.9%	35.3	30.4%	45.8	27.0%	54.0	26.8%	62.3	27.9%
40-69 DISKS	+79.3%		+45.9%		+29.7%		+17.9%		+15.4%	
OPTICAL LIBRARIES	16.0	25.5%	26.7	23.0%	36.1	21.1%	42.1	20.8%	45.6	20.3%
70 OR MORE DISKS	+6.7%		+66.9%		+35.2%		+16.6%		+8.3%	
Total Worldwide Revenues	62.4	100.0%	115.8	100.0%	169.9	100.0%	201.6	100.0%	223.2	100.0%
	+52.9%		+85.6%		+46.7%		+18.7%		+10.7%	
% U.S. Manufacturers	50.1%		51.9%		55.4%		54.4%		53.8%	

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

TABLE 11

NON-CAPTIVE WORLDWIDE SHIPMENTS
OPTICAL DISK DRIVES
PRODUCT CATEGORY REVIEW

UNIT SHIPMENT SUMMARY

UNIT SHIPMENTS	1990		Forecast							
IN THOUSANDS	Shipments		1991		1992		1993		1994	
	Units	%	Units	%	Units	%	Units	%	Units	%
READ-ONLY	496.6	75.9%	717.8	72.6%	1,095.0	71.6%	1,736.5	71.6%	2,517.9	71.1%
ALL CAPACITIES	+9.8%		+44.5%		+52.5%		+58.6%		+45.0%	
READ/WRITE	151.6	23.1%	263.7	26.6%	423.6	27.6%	673.7	27.7%	1,005.2	28.4%
LESS THAN 1 GIGABYTE	+124.3%		+73.9%		+60.6%		+59.0%		+49.2%	
READ/WRITE	7.2	1.0%	8.9	.8%	13.4	.8%	18.6	.7%	21.5	.5%
MORE THAN 1 GIGABYTE	-4.0%		+23.6%		+50.6%		+38.8%		+15.6%	
Total Worldwide Shipments	655.4	100.0%	990.4	100.0%	1,532.0	100.0%	2,428.8	100.0%	3,544.6	100.0%
	+24.3%		+51.1%		+54.7%		+58.5%		+45.9%	
% U.S. Manufacturers	1.9%		2.8%		4.4%		5.3%		5.8%	

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

TABLE 12

NON-CAPTIVE WORLDWIDE SHIPMENTS
OPTICAL LIBRARIES
PRODUCT CATEGORY REVIEW

UNIT SHIPMENT SUMMARY

SHIPMENTS IN SINGLE UNITS	1990 Shipments Units	1990 Shipments %	1991 Forecast Units	1991 Forecast %	1992 Forecast Units	1992 Forecast %	1993 Forecast Units	1993 Forecast %	1994 Forecast Units	1994 Forecast %
OPTICAL LIBRARIES READ-ONLY	7,902.0	73.1%	9,672.0	59.2%	11,595.0	52.5%	13,140.0	48.7%	14,550.0	46.0%
	+214.3%		+22.4%		+19.9%		+13.3%		+10.7%	
OPTICAL LIBRARIES 1-39 DISKS	1,690.0	15.6%	4,481.0	27.4%	7,325.0	33.1%	9,826.0	36.4%	12,214.0	38.6%
	+230.1%		+165.1%		+63.5%		+34.1%		+24.3%	
OPTICAL LIBRARIES 40-69 DISKS	1,014.0	9.4%	1,803.0	11.0%	2,535.0	11.5%	3,216.0	11.9%	3,939.0	12.4%
	+172.6%		+77.8%		+40.6%		+26.9%		+22.5%	
OPTICAL LIBRARIES 70 OR MORE DISKS	215.0	1.9%	402.0	2.4%	668.0	2.9%	837.0	3.0%	976.0	3.0%
	+8.0%		+87.0%		+66.2%		+25.3%		+16.6%	
Total Worldwide Shipments	10,821.0	100.0%	16,358.0	100.0%	22,123.0	100.0%	27,019.0	100.0%	31,679.0	100.0%
	+200.8%		+51.2%		+35.2%		+22.1%		+17.2%	
% U.S. Manufacturers	17.1%		27.0%		32.4%		35.4%		37.7%	

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

Figure 5

WORLDWIDE SHIPMENT SUMMARY

Non-Captive Optical Disk Drives

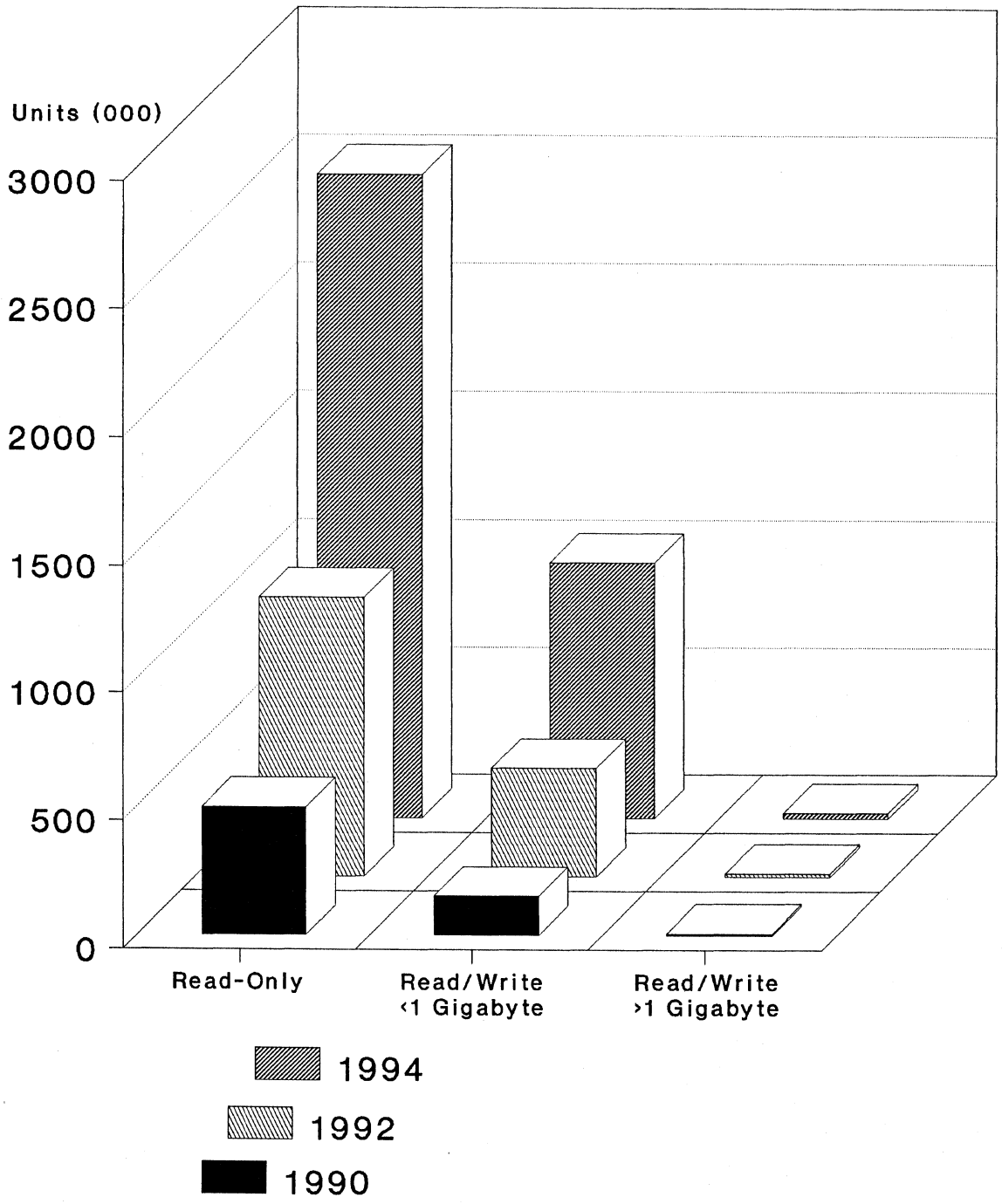


Figure 6

WORLDWIDE SHIPMENT SUMMARY

Total Optical Libraries

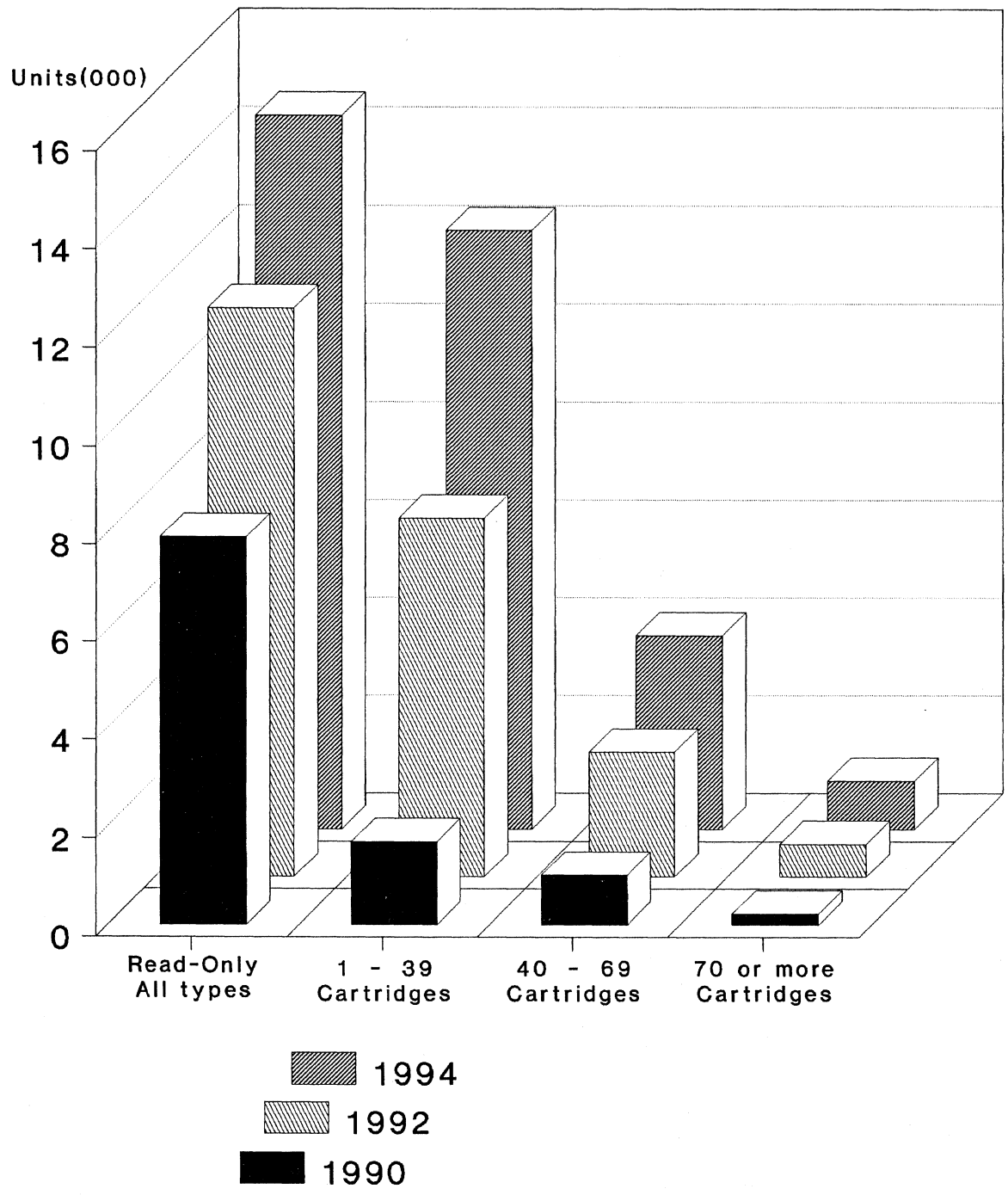


TABLE 13

1990 ESTIMATED MARKET SHARES

WORLDWIDE REVENUES OF ALL OPTICAL DISK DRIVES
(Value of non-U.S. currencies estimated at average 1990 rates)

	CAPTIVE		PCM/RESELLER		OEM/INTEGRATOR		TOTAL INDUSTRY	
	$M	%	$M	%	$M	%	$M	%
U.S. MANUFACTURERS								
Maxoptix	--	--	20.5	9.8	2.0	.5	22.5	2.5
Other U.S.	--	--	6.2	3.0	19.5	5.2	25.7	2.8
U.S. Total	--	--	26.7	12.8	21.5	5.7	48.2	5.3
NON-U.S. MANUFACTURERS								
A.T.G. Gigadisc	--	--	6.8	3.3	10.5	2.8	17.3	1.9
Canon	27.0	8.1	3.3	1.6	4.0	1.1	34.3	3.7
Hitachi	16.9	5.1	74.6	35.7	28.6	7.6	120.1	13.1
LMSI	--	--	8.4	4.0	27.2	7.2	35.6	3.9
Matsushita Electric	12.3	3.7	18.0	8.6	17.6	4.7	47.9	5.2
NEC	111.7	33.6	4.3	2.1	--	--	116.0	12.6
Pioneer	--	--	--	--	16.4	4.4	16.4	1.8
Ricoh	30.8	9.3	28.5	13.6	10.1	2.7	69.4	7.6
Sony	45.5	13.7	21.5	10.3	177.5	47.2	244.5	26.6
Toshiba	74.9	22.5	6.4	3.1	43.3	11.5	124.6	13.6
Other Non-U.S.	13.5	4.1	10.5	5.0	19.5	5.2	43.5	4.7
Non-U.S. Total	332.6	100.0	182.3	87.2	354.7	94.3	869.6	94.7
WORLDWIDE TOTAL	332.6	100.0	209.0	100.0	376.2	100.0	917.8	100.0

TABLE 14

1990 ESTIMATED MARKET SHARES

WORLDWIDE REVENUES OF ALL OPTICAL LIBRARIES
(Value of non-U.S. currencies estimated at average 1990 rates)

	CAPTIVE		PCM/RESELLER		OEM/INTEGRATOR		TOTAL INDUSTRY	
	$M	%	$M	%	$M	%	$M	%
U.S. MANUFACTURERS								
Cygnet Systems	--	--	--	--	10.0	19.9	10.0	9.4
Eastman Kodak	--	--	--	--	5.7	11.3	5.7	5.4
Filenet	18.4	46.1	--	--	6.7	13.3	25.1	23.6
Hewlett-Packard	5.6	14.0	4.3	26.9	2.7	5.4	12.6	11.9
Other U.S.	.5	1.3	3.0	18.8	2.8	5.6	6.3	5.9
U.S. Total	24.5	61.4	7.3	45.6	27.9	55.5	59.7	56.2
NON-U.S. MANUFACTURERS								
Hitachi	8.7	21.8	1.0	6.3	2.3	4.6	12.0	11.3
NKK	--	--	3.8	23.8	6.1	12.1	9.9	9.3
Pioneer	--	--	2.5	15.6	5.4	10.7	7.9	7.4
Sony	--	--	--	--	5.5	10.9	5.5	5.2
Other Non-U.S.	6.7	16.8	1.4	8.7	3.1	6.2	11.2	10.5
Non-U.S. Total	15.4	38.6	8.7	54.4	22.4	44.5	46.5	43.8
WORLDWIDE TOTAL	39.9	100.0	16.0	100.0	50.3	100.0	106.2	100.0

TABLE 15

CURRENT PRODUCT LINES
MANUFACTURERS OF OPTICAL DISK DRIVES

Codes: C = Captive
O = OEM/Integrator
P = PCM/Reseller
E = Erasable

DISK/TREND PRODUCT GROUP:		10	11	12
U.S. Manufacturers (10)	Type	Read-Only Optical Drives	Read/Write Optical Drives <1 GB	Read/Write Optical Drives >1 GB
Cherokee Data Systems	O		5.25	
Eastman Kodak	C,O			14
Hewlett-Packard	C,O,P		5.25 E	
Honeywell	O		5.25	
IBM	C		3.5 E	
Literal	O,P		5.25, 5.25 E	
Maximum Storage	O		5.25	
Maxoptix	O,P	5.25 E		
Mountain Optech	O		5.25, 5.25 E	
Optimem	O			12
Asian Manufacturers (25)				
Canon	C,O		5.25 E	
Chinon	O	4.72		
Fujitsu	C,O		5.25	8 E,12
Goldstar Telecommunication	O	4.72	5.25, 5.25 E	
Hitachi	C,O,P	4.72	5.25, 5.25 E	12
JVC	O		4.72	
Kawasaki Steel	O		5.25, 5.25 E	
Matsushita Electric Ind.	C,O	4.72	5.25, 5.25 E	
Matsushita Electronic Comp.	O	4.72		
Matsushita Graphic Commun.	C,O		8	
Mitsubishi Electric	O		5.25, 5.25 E	
Mitsumi Electric	O	4.72	4.72	
MOST	O,P		3.5 E	
NEC	C,O	4.72	5.25, 5.25 E	12
Nikon	O			12 E
Nippon Columbia	O	4.72		
Pentax Teknologies	O		5.25	
Pioneer Electronic	O	4.72	5.25, 5.25 E	
Ricoh	C,O		5.25, 5.25 E	
Sanyo	O,P	4.72		
Sharp	O		5.25 E	
Sony	C,O	3.15, 4.72	4.72, 5.25 E, 3.5 E	12
Texel (Shinano Kenshi)	O	4.72		
Toshiba	C,O	4.72	5.25	12
Yamaha	C		4.72	
European Manufacturers (3)				
ATG Gigadisc	O			12
Laser Magnetic Storage	C,O,P	4.72	5.25	12
Philips Consumer Elect.	C,P	4.72		

Numbers in table are diameters in inches.

TABLE 16

CURRENT PRODUCT LINES
MANUFACTURERS OF OPTICAL LIBRARIES

Codes: C = Captive
O = OEM/Integrator
P = PCM/Reseller

DISK/TREND PRODUCT GROUP:		50	51	52	53
U.S. Manufacturers (8)	Type	Read-Only Optical Libraries	Read/Write Optical Libraries 1-39 Disks	Read/Write Optical Libraries 40-69 Disks	Read/Write Optical Libraries 70+ Disks
Access	O		12		
Cygnet Systems	O		5.25	12	12
Document Imaging Systems	O			5.25	5.25
Eastman Kodak	C,O			5.25	14
Filenet	C,O			12	12
Hewlett-Packard	C,O,P		5.25		5.25
International Data Engin.	O,P		5.25		
Kubik Enterprises	O	4.72			
Asian Manufacturers (11)					
Aisin Seiki	O		5.25		
Hitachi	C,O		5.25, 12	5.25, 12	
Matsushita Electric Indus.	C,O			5.25	
Matsushita Graphic Commun.	C,O			8	
Mitsubishi Electric	C,O			5.25	5.25
NEC	C		12	5.25	
NKK	O,P			5.25	
Pioneer	O	4.72			
Ricoh	C		5.25	5.25	
Sony	C,O			12	
Toshiba	C		5.25, 12		
European Manufacturers (4)					
DSM	O,C		12	12	5.25, 12
Laser Magnetic Storage	O,P		12		
Next Technology	O	4.72			
NSM	O	4.72			

Numbers in table are diameters in inches.

TECHNICAL REVIEW

Optical data storage offers new capabilities applicable to a variety of storage requirements. Technologies currently used in various applications include:

* Read-only optical disk drives.
* Write-once (non-rewritable) optical disk drives.
* Erasable (rewritable) optical disk drives.
* Optical libraries

Despite thirty years of development there remain many areas in which improvements need to be made. Some of the more significant are:

* Higher power, higher frequency lasers needed for higher areal densities.
* High media fabrication costs and marginal yields.
* Incompatible physical and recording standards, preventing media interchange between systems.
* Low mass head design for improved performance and cost.
* Incompatibilities between optical drives and optical libraries.
* Repackaging of drives into smaller industry standard form factors.

These and other problem areas are actively being addressed, resulting in year to year improvements in optical disk drive and library capabilities. It is necessary to realize that optical storage is only one of several technologies to be considered as a potential solution in a given application. A significant cause of slow growth in the optical storage industry is the prior availability of proven solutions offering less risk and, often, lower cost. At present, not even optimistic observers expect optical drive performance and cost to equal that of the ever-improving magnetic rigid disk drive until the end of the current decade.

Major 1990 and 1991 product milestones include announcements of magneto-optical media with both write-once and rewritable functionality, drives rotating at 3,600 RPM, a production start for the first optical drive capable of reading both sides of the disk simultaneously, rewritable phase change media and drives, 3.5" magneto-optic drives, and lower cost 5.25" tabletop optical libraries.

Optical disk technology and applications

The three existing types of optical disk drives are discussed in the following sections.

* Read-only optical disks: The read-only optical disk group is dominated by 4.72" CD-ROM drives, which have typical capacities of 550 to 600 megabytes. A 3.15" format CD-ROM made its appearance in 1990 in the Sony "Data Discman", a portable data retrieval system initially sold only in Japan and now being considered for sale in the U.S.

  Because CD-ROM technology borrows heavily from the designs of 4.72" CD audio players now in volume production, performance has been sacrificed for low production cost. However, CD-ROM drives are inexpensive enough to permit the use of multiple drives in a system to improve overall performance.

  A few other optical read-only (OROM) solutions have been offered, including high performance 12" read-only drives offered for a few years by Reference Technology. Other formats for optical read-only memory (OROM) include OROM capability on 3.5" and 5.25" media. These are expected to be used as vehicles for software distribution and multimedia presentations as drive and media prices decline in the future.

  Most read-only optical drives will be used with small systems to provide personal access to large amounts of information, though some are appearing on file servers as well. CD-ROM is now an accepted medium for distributing system documentation and software as well as application packages. CD-ROM acceptance benefits from industry agreement on the CD and CD-ROM standards developed jointly by Sony and Philips and also upon the recording format standard for computer data proposed by the High Sierra group and later formalized as ISO standard 9660. The ISO standard will probably receive extensions to cover the use of CD-ROM drives operating with the UNIX operating system.

Apple Computer's announcement of a CD-ROM drive for its Macintosh line stimulated new publishing activity aimed at Apple users, but the applications to date are narrow in scope. IBM's 1990 announcement of systems incorporating CD-ROM broke no new technical ground, but widely anticipated "multimedia" offerings incorporating data, audio and video on CD-ROM drives have raised expectations for improvement in CD-ROM costs, as sales of multimedia products grow. Training, education and consumer applications are expected to be the early major uses for multimedia products. The technical demands of providing full screen, full motion video from CD-ROMs will probably result in the 1991 announcement of CD-ROM drives operating at twice the normal data transfer rate, achieved by doubling the drive RPM range.

Mass production of read-only optical disks must be done by a mastering and mass replication process, rather than by recording directly on the disk. While the cost per disk can be low, mastering costs and replication turnaround time can make production of single disks or very short runs economically unattractive. CD-WO drives appear poised to address this need.

* Non-reversible optical disks: The first optical disk recording systems to enter the market were "non-reversible" or "write-once" systems. A few systems with optical drives were sold in Japan in 1984, but it wasn't until 1986, after many years of costly development programs undertaken by manufacturers, that such devices began to move into production status.

  With track densities typically in the range of 16,000 tracks per inch, write-once drives are capable of higher areal densities than magnetic recording drives now in use. 12" and 14" drives can provide several gigabytes on a single removable disk.

  Writing techniques involve changing the reflectivity of an area of the disk, either by making a small hole or causing a surface reflectance change. Recording systems are available which alter the writing layer from an amorphous to a crystalline state, and others deform the surface of the media to cause a reflectance change at the point where a bit is written. In 1990, a group of drive and media producers proposed a type of write-once capability achieved using rewritable media pre-stamped with information indicating that it is to be used only in a write-once mode.

  Writing power required at the surface of the disk is in the range of 10 milliwatts for writing at useful rotation rates of the media. Losses in the optical subsystem of the head require a laser with emitted power in the 20 to 30 milliwatt range. Read power is typically in the 1.5 to 2 milliwatt range, but must be carefully controlled to avoid an inadvertent write, due to the cumulative effects of successive read operations. To achieve media interchange, drives must be able to sense the media formulation in use and adjust power levels as required.

Write-once drives require more complex logic to operate with computer operating systems which expect a disk drive to be rewritable, adding to system complexity and cost. Write-once storage also requires more user management than rewritable storage as the disks become completely written. Long latency, slow head positioning, read verification cycles and slow data transfer rates also make write-once storage an ineffective performance competitor to magnetic disk drives.

Although not yet demonstrated in field use, extensive accelerated testing indicates that write-once disks should provide archival lives which equal or exceed those of magnetic media, with 10 years being a commonly encountered specification for archival life of the media. Some firms specify a 30 year lifetime. The lifetime is limited by the gradual appearance of defects on the recording layer, typically an alloy of tellurium, 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. Some media based on dye or dye/polymer designs have no metallic films and are expected to be more corrosion resistant than the original generation of metallic films. Other optical media using platinum or tin alloys as recording layers offer corrosion resistance, but may trade off write sensitivity for the improved longevity obtained.

The largest application for write-once recording technology is the archival storage of documents. The document is typically stored as a document image, rather than as character data. The write-once systems now available or entering the market use comparable, but differing technologies, with capacities per disk in the range of 300 megabytes to over 6 gigabytes. The smaller capacity products are being marketed initially as OEM drives for use in small systems; larger capacity drives are being used in captive systems and by a few system manufacturers. Later write-once systems have offered a higher degree of sophistication, such as LMSI's dual head 12" drive which offers 5.6 gigabytes of disk capacity and has two heads, allowing on-line access to both sides of the disk.

Obviously, the market for write-once optical disk systems will be limited to niche markets which can tolerate non-reversibility. These niches do exist and the low cost per byte of optical stor-age has opened selected markets to write-once optical disk systems. In some applications, the ability of write-once storage systems to maintain an audit trail or indicate whether or not stored data has been modified is a significant benefit.

The 5.25" multifunction drives now entering the market are expected to gradually displace dedicated write-once 5.25" drives since the user will be able to determine drive functionality simply by choice of media.

* Rewritable optical disks: The best possibility for eventual inroads into the market for magnetic disk drives exists with rewritable optical disk systems. Some, such as the Maxoptix 5.25" Tahiti drive are beginning to approach the performance of previous generations of magnetic drives and are being used in place of the venerable SMD-type removable disk pack drives.

  Magneto-optical recording has seen development activity for more than thirty years, and rewritable "phase change" optical recording, which received considerable attention during the past few years, has emerged as a competitor with the introduction of a drive and media by Matsushita in 1990. Rewritable optical recording based upon dye/polymer technology developed by Optical Data, Inc., and related drives from Tandy initially received much attention but did not prove workable. ODI has since ceased operations, but has licensed the technology to Teijin, where further development is occurring. Tandy has stated that their development effort is delayed.

  Very high capacity rewritable drives await the availability of larger diameter rewritable media, which is difficult to fabricate with adequate yields within the current state of the art.

  Small diameter rewritable optical drives might eventually become more reliable than magnetic disk drives due to the decreased chance of head crashes or contact start-stop problems as a result of the optical drive's greater head/disk separation. However, laser lifetime still limits the MTBF of optical drives.

  Magnetic tape cartridge drives may be threatened as the costs of 3.5" rewritable drives decline. OEM quantity prices, now in the $800 range, are expected to gradually decline to the $300-400 range as production and competition increase.

  Current magneto-optic drive designs use a low power laser to change the magnetic state of the active layer on a disk. The laser raises the temperature of the active layer into the range of the Curie point while a magnetic field is present, causing individual magnetic domains on the disk to align with the direction of the external magnetic field. Changes in magnetic orientation are detected during reading, as the affected spot on the disk causes a small rotation in the polarized light reflected from the surface or transmitted through the disk.

  Magneto-optic media require less laser power for writing than write-once media because there is no need to physically deform the writing layer or cause it to melt, permitting the disk to rotate faster for a given available laser power. The faster rotation (Hewlett-Packard and Ricoh are up to 3,600 RPM) improves latency and data transfer rate. However, production magneto-optical disks have not yet shown the ability to overwrite in place: A complete sector must be erased before the

sector can be rewritten. While several approaches offer technical solutions to this problem, all seem to add undesirable complexity and cost to the drive or media and none seem likely to be available in the market before 1992. However, Matsushita's rewritable phase change drive introduced in 1990 does not require a separate erase pass and thus can be faster than magneto-optic drives in write mode. Sony made a preliminary announcement in 1991 of a 2.5" audio magneto-optic disk drive using inexpensive media and not requiring a separate erase pass. This new technology may appear in other rewritable products.

Phase change optical recording involves a different type of amorphous coating, in which individual spots on the disk are changed by laser irradiation from a crystalline state, during which light is reflected, to a non-crystalline state, during which light is absorbed. Alternatively, different crystalline states are used to vary reflectivity. Media stability with time, phase reversal time, and the limited number of possible write/erase cycles still represent problem areas for rewritable phase change technology. However, if the price is competitive with tape technology, phase change media having a write/erase cycle limit of at least 1,000 cycles could compete for backup and other applications where infinite rewritability is not required. Matsushita Electric has announced media with over 100,000 cycles capability, so this segment of the market seems within the grasp of the technology.

A third recording technology, potentially the least expensive to manufacture, is rewritable dye or dye/polymer. As of yet, only limited success has been obtained with this technique because developers have not been able to demonstrate a large number of write/erase cycles. As a result of the Tandy announcement, much industry attention was given to possible uses of low cost drives with limited erasability media. This type of drive/media combination could be used as a replacement for cartridge tape drives and some write-once optical drives, but it is still far from being a manufacturable product as a computer peripheral.

Individual firms are also working on other proposed reversible optical recording technologies, but none of these is known to have overcome all of the problems, which have included: Slow reversal cycle, limitations on the number of reversals before degradation, poor shelf life, and low recording density.

An increasing number of firms with rewritable drives have committed to the heavy investment required to establish volume production capability. Technology and product announcements of drives and media in 3.5" and 5.25" formats have been made by Canon, Maxoptix, IBM, 3M, Sony, Sharp, Ricoh, MOST and several other firms. Sony and Canon began to manufacture magneto-optic drives and media in volume in 1988, followed by Ricoh and Maxoptix in 1989. While media and drive producers have concentrated mostly upon magneto-optic recording, phase change technology may

acquire equal status now that acceptable stability, write/erase cycling and producibility have become feasible. In addition to its 5.25" phase change drive, Matsushita has demonstrated a 3.5" phase change drive as well.

Multifunction drives are capable of operating with at least two types of media, with write-once and rewritable being the typical combination. Several firms, including Ricoh, Pioneer and Matsushita have announced 5.25" multifunction drives, but none of these are compatible with each other or with the ISO CCS format. Several firms currently producing or using CCS format magneto-optic media are jointly working out a method of designating portions of a magneto-optic disk as write-once portions. The same principle has been applied to making a portion of the disk read-only, as has been done in the ANSI/ISO standards being prepared for 3.5" magneto-optic media.

* Optical libraries: Random-access libraries, commonly called "jukeboxes", are devices that automatically pick, load, unload and refile media units for an optical disk drive. While not part of the drive, they are frequently associated with the drive in high-end archival systems where very large amounts of data must be accessed and maintained on-line. Current library units can store from 10 to over 200 disk units. Typical retrieval and load times are in the order of a few seconds. Some of these devices have multiple picking assemblies so that disk cartridge access/load operations can be overlapped, reducing the cartridge exchange time.

  Early libraries used 12" drives and were too expensive to be attractive for use with lower capacity optical drives. However, small optical drives are beginning to receive library support and to be offered for use in departmental systems. Numerous 5.25" libraries have been introduced by firms such as NKK, Cygnet, and Hewlett-Packard. Random access disk libraries available for CD players have begun to migrate to the computer world as an accessory for the CD-ROM. Pioneer is actively selling a six disk library that incorporates a CD-ROM drive, Next Technology has introduced a library capable of storing up to 270 CD-ROM disks, and Kubik is in pilot line production of a carousel type library storing over 200 disks.

  Drives designed for use in libraries must be able to withstand many thousands of cartridge insertions by robot pickers and must accommodate electrical control of cartridge loading and unloading. They should also minimize spin-up time, load time and unload time. However, in a library environment, average access time tends to be hidden by the much longer load/unload cycle time. Drives may also be subject to an unusual amount of shock and vibration associated with the operation of the library mechanism, which can potentially cause reliability problems with mechanical and electronic components.

Integration of a library device into a computer system requires a substantial software design effort for even small systems. Integration into a mainframe environment is a major task that can involve several man-years of effort. Mainframe data access method support remains relatively limited.

Technical issues: Most of the technical issues apply to all three of the optical drive storage technologies described above. A few, such as the overwrite issue, apply to a specific technology. Key enhancements to optical storage performance are likely in the following areas.

* Recording heads: The optical recording head is a relatively complex device incorporating a diode laser, detector, optics, and, frequently, a fine positioning mechanism. The result is a head assembly with relatively high mass, which slows access time and increases the power required to position the head. For the first generation of write-once optical drives, which were used with document storage systems, the long average access time, typically in excess of 125 milliseconds, was not a critical factor. However, the desire of many firms to use optical drives in data processing systems is creating pressure for faster average access time. Considerable work is under way at many firms aimed at reducing the mass of optical head assemblies, and is beginning to bear fruit in such products as the Maxoptix 5.25" rewritable drive, which has an average seek time in the 35 millisecond range. This performance has been achieved by using a split optic system in which only the objective lens, focus and fine tracking mechanisms are mounted on the moving carriage, substantially reducing the total mass of the head assembly.

  Some optical drives are being fabricated using a single stage positioner, which assists in reducing head complexity and associated mass. An early example was a drive designed by Bernoulli Optical Systems (BOSCO), which used a single stage rotary actuator. This drive was also the first publicly demonstrated optical drive to incorporate two heads, one on each side of the disk, permitting both sides to be used independently and concurrently. BOSCO has no current production plans and is offering to license the drive design to other firms.

  LMSI brought the first two-headed drive to market. The LMSI introduction has had a major impact on the plans of drive producers, and many are now considering how to design multiple heads into their optical drives.

  The use of holographic optical elements to replace many of the heavier glass lenses and supporting structures is being explored by several firms. While providing simplicity, the transmission efficiency of holographic systems currently available is less

than that of conventional optics, restricting the use of holographic optics to applications which require less write power at the surface of the media.

Molded glass aspheric lenses will be used in smaller drives. These lenses, some of which are molded using plastic rather than glass, substantially reduce cost, weight and complexity of the optical path in the head. Some advanced techniques currently being explored at Osaka University and other institutions have the potential to result in a monolithic assembly in which laser and lens are fabricated as a single unit.

It is possible to design heads using composite laser assemblies that are capable of emitting separate read, write and erase beams through a common optical channel. These assemblies are intended to permit direct read-after-write operations in which the read beam can interrogate the disk immediately after a bit is written to insure that a write error was not made. Composite assemblies of this type are very difficult to fabricate and align. As error correction techniques improve, they may not be necessary to achieve adequate performance.

* Lasers: The amount of power available from the laser in the optical drive is a limit on how fast a spot on the disk can be written, and thus, a limit on the rotation speed and data transfer rate that can be obtained. Semiconductor lasers now in development appear able to double or triple the available power of lasers in use in current products. As these new laser diodes are found to be economically and technically suitable, a significant increase in data transfer rates and a significant decrease in latency will be obtained. Optical disk drives are expected to be able to approach the 10 megabit/second data transfer rates of small rigid disk drives in 1991. More powerful lasers permit the use of beam splitting techniques useful in improving tracking and direct read during write operations and will make it easier to use holographic lens systems at higher data transfer rates or with less sensitive media.

  A second limitation related to the laser is spot size, which is a function of laser wavelength, among other factors. Work on shorter wavelength lasers may result in smaller spot sizes and an increase in bit and track density. Doubling the frequency halves the spot size, which results in a theoretical quadrupling of the storage density. However, large improvements are not anticipated in the near future due to the difficulty of producing a semiconductor laser that will operate at near blue wavelengths with adequate power and stability and at reasonable cost. A promising indirect approach is the use of a frequency doubler as reported by Matsushita Electric and by IBM. IBM has demonstrated a laser producing 41 milliwatts at 428 nanometer wavelength, but the device is several years away from production status. Low power blue lasers suitable for use with read-only drives may become available before 1995.

The best improvement expected in the near future is an AlGaInP laser with a wavelength of about 650 nanometers, compared to the commonly used AlGaAs 780 nanometer devices of today. Production volumes of the improved lasers are expected in late 1991, and this should result in an areal density improvement by a factor of about 1.4.

* Recording disks: Media has been an area of major challenge. Media suppliers were not prepared for the rapid ramp up in rewritable drive production that began in late 1988. There were magneto-optic media shortages in 1989 due to yield problems, but these have abated as a result of additional production capacity and improved yields.

  Most read/write optical disks made to date use complex multi-layer designs and sputtering techniques to deposit the various layers. But manufacturing techniques have evolved to the point that disk media is able to withstand the range of temperatures and humidities most likely to be experienced without undue media degradation and yields are adequate.

  At present, there is over-capacity among media suppliers, in the aggregate. However, because write-once optical disks from different manufacturers are not widely interchangeable among drives, media availability is still a concern where specific pre-formatting is required and is available only from a single drive or media manufacturer. Manufacturers of rewritable drives claim that there will be a significant degree of media inter-change capability between drives of differing manufacturers. While this has been demonstrated for some 5.25" and 3.5" CCS format rewritable drives, incompatibility problems remain.

  There is considerable improvement in the raw error rate. Hitachi, for instance, has reported that with suitable process precautions, a raw error rate of one bit in ten million is obtainable. This is a thousand times better than the raw error rates obtained with early optical media.

  Some innovative products, such as the dye-based disks offered for use with the Pioneer and Ricoh write-once optical drive, offer potentially lower costs and improved environmental stabil-ity because the active layer has no metal components subject to corrosion. Rewritable dye-based media is being investigated as well, but the number of write/erase cycles demonstrated has so far not exceeded 10,000 cycles in the laboratory. The mid-1988 announcement by Tandy of rewritable drives and media using dye based technology, while very premature, pointed out the utility of even limited erasability media for consumer and some computer based applications.

  Most of the substrates used so far have been plastic. However, the ability of glass to provide smoothness, freedom from distor-tion at high rotation rates, minimal optical dispersion and

superior environmental protection is causing this material to be seriously evaluated as a substrate material. While glass substrates are expected to be much more expensive than plastic, a factor discouraging use, their potential for use in new generations of rigid magnetic disk drives suggests that economies of scale could develop sufficiently to make them attractive for wider use in optical media. There is evidence that glass substrates, being smoother, result in substantially improved error defect rates, which in turn can reduce drive latency due to error correction time.

The limitations of plastic when used for larger diameter disks and high stability requirements may encourage the use of glass. Media produced for the LMS 12" drives, for instance, uses glass substrates. In mid-1987, Sharp announced 5.25" rewritable optical disk drives using glass as a substrate. The 5.25" magneto-optic rewritable drive sold by Matsushita uses a glass substrate, and it is likely that many other rewritable drives will also eventually use media with glass substrates.

Magneto-optic media will have to make a transition through one more generation to arrive at designs permitting direct overwriting in place of previously recorded data, rather than requiring a separate erase pass before writing. It is likely that more than one overwrite solution will be offered, all probably incompatible, further aggravating the media interchange problem. Several firms have discussed methods of fabricating advanced magneto-optic media that will operate without a separate erase pass. Sony's proposed IRISTER media also permits doubling the track density and tripling linear density. However, the proposed media designs are more complex and may be difficult to manufacture. The method discussed in conjunction with the Sony 2.5" audio drive (turning on the laser and then varying the field with a magnetic head) may turn out to be more manufacturable. It remains to be seen if high performance computer peripherals can use this design technique effectively.

Media life is still a concern. Accelerated life tests indicate that rewritable media can be expected to have a useful life of 10 years or more (some suppliers claim 30), but there is no field experience of actual lifetimes of this duration.

* Head positioning methods: The track density achieved on an optical drive is much higher than that obtainable on a magnetic disk drive because most optical drive designs use a pregrooved substrate as a device to provide tracking information to the head positioning servo. This method is known as the continuous composite servo (CCS) method. Some designs, such as those fav ored by ATG Gigadisc and Laser Magnetic Storage, use an embedded servo technique known as sampled servo for fine tracking. There is considerable controversy as to which approach should be considered the standard approach. The two formats are not interchangeable in present drive designs. A variant of the sampled

servo, called sampled servo with RZ encoding, is in use by Literal and its licensees. Still another method, called the discrete block format, has been proposed for 3.5" rewritable drives and is being considered by standards committees.

Most optical drives use a two stage head positioning mechanism in which a conventional voice coil mechanism positions the head to a region of the disk and a vernier tracking mechanism in the head then steers the laser beam to the desired track. Some drive suppliers are evolving toward elimination of the vernier tracking mechanism.

Major increases in track density in the next two years are not expected, and most drives will remain in the range of 15,000 to 20,000 TPI. However, as manufacturers go to higher rotation rates to improve latency and transfer rates, it will be necessary to redesign tracking and focusing servo systems to operate at higher bandwidths.

* Packaging: Most early small optical drives were packaged to fit into a standard 5.25" form factor for easy mounting in personal computers widely produced in the second half of the 1980's. The next generation, offering 5.25" half-high profiles, is starting to appear. The first such products were CD-ROM drives, such as the ones introduced by Matsushita Electric and Toshiba, but half-high write-once and rewritable 5.25" optical drives are now being shipped. The 3.5" rewritable drives now entering the market will fit into a standard 41.3 millimeter high space, but pressures to go to even smaller form factors are already significant. 2.5" rewritable drives are in development at several firms and Sony has shown an audio version that may eventually be sold as a computer peripheral.

  Several firms are working on write-once and rewritable drives using the 4.72" CD-ROM format. The potential existence of such a product is looked upon with disfavor by many potential CD-ROM publishers, who are concerned that piracy will become a problem if copying is made too easy. The experience of the software industry suggests that these fears are valid, and writable CD-format drives may not be sold freely until a mechanism to prohibit copying of published CD-ROM titles can be devised. Yamaha introduced a CD format write-once system in 1989 using media supplied by Fuji Photo Film and Sony and Fujitsu demonstrated CD format write-once systems at the 1990 Microsoft CD-ROM conference. JVC and Mitsumi made preliminary announcements of write-once drives in late 1990. Tandy, Philips and others are working on rewritable CD-format drive designs.

  Because small diameter optical disk drives are forced to conform to magnetic disk drive form factor standards, which continue to evolve, within a few years 3.5" optical drives will be required to achieve heights of 19 or 25.4 millimeters. Reduced drive height is necessary to be attractive to system integrators

producing portable systems configured to accept magnetic drives in the small form factors.

There is less packaging pressure on larger diameter drives, but it is important for these drives to be designed in a way that enhances their use in automated library subsystems, or at least does not detract from it, as many of the larger diameter drives are used in optical library systems. Some larger diameter drives are table-top or rack mounted. 12" products are typically rack mounted.

* Interface: The most common interface encountered on optical drives is SCSI, covering the range from low-end CD-ROM players to larger drives intended for use with multiuser or document storage systems. Interfaces compatible with IBM personal computers are also common on CD-ROM hardware and 5.25" drives. Drives used in certain document filing systems -- largely of Japanese manufacture -- have frequently used proprietary interfaces, but the SCSI family of interfaces will remain the most common. Higher performance drives are migrating to the newer SCSI-2 interface.

  Early optical libraries used RS-232 channels to control the library mechanism, but later generations have tended to use SCSI, in some cases sharing a single SCSI port between library and drives to reduce cost.

* Software: Rewritable optical disk drives are logically similar to magnetic disk drives, so the preparation of system software that supports a rewritable optical disk is a routine task. However, software support for a write-once drive is a task of formidable magnitude. Lack of appropriate software is one of the factors that has slowed the acceptance of write-once optical drives. While drive manufacturers now supply such basic software items as routines that link the drive to major operating systems, manufacturers of complete systems or storage subsystems find that they must do the bulk of the software themselves or contract the work to a third party. Microsoft offers a CD-ROM device driver that is supplied with most CD-ROM drives shipped.

  Some firms have incorporated sophisticated firmware in their drives to avoid degradation of throughput caused by error correction, write verification, bad sector rewrites and other delay factors. While this does not affect the raw data transfer rate to or from the drive, the observed throughput can increase by as much as a factor of 10 over a drive without such features.

  Software for CD-ROM preparation and retrieval is becoming less difficult to locate. In many cases, software is supplied on the CD-ROM, with the published material. As most CD-ROM published works are of a textual or data base nature, publishers must obtain efficient text search or database search software. Over 50 software specialty houses make such programs available.

Software for optical libraries requires creation of drivers for control of the library mechanism and systems software for integrating the library seamlessly into the overall system. System integration becomes increasingly complex as system complexity grows. Several man-years of software development are required to add optical libraries to mainframes.

* Standards: Physical standards for CD and CD-ROM were initially jointly set by Sony and Philips. The initial joint design was for an audio consumer product and this effort by two major firms was sufficient to establish a de facto standard. The subsequent definition of the CD-ROM specification drew heavily upon the earlier design, and also became a de facto standard.

  Initial recording format standards for CD-ROM were prepared by the High Sierra Group, an ad hoc organization consisting of several firms concerned with CD-ROM. This proposed standard was submitted in mid-1986 to ANSI to begin the formal process of standards development. The work of the High Sierra group moved through the formal standards making process relatively quickly, and after only minor changes, became ISO standard 9660 in 1988. Standards interest in CD-ROM has now shifted to the interactive formats, user interface standards for retrieval software, and standards for a universal cataloging method for CD-ROM.

  Despite the availability of the ISO 9660 standard, some publishers of CD-ROM data have been reluctant to abandon previously used proprietary formats or the earlier High Sierra proposal, much to the inconvenience of end users who are trying to use multiple CD-ROM titles on their systems. The UNIX community is also displeased with aspects of the standard concerning file names and directory structures and is considering endorsing a modified version of the ISO 9660 standard named POSIX, which would allow the co-existence of UNIX-compatible and "standard" directory structures on a CD-ROM disk. UNIX specialists feel this is necessary for publication of extensive file sets, such as system documentation, and for operation under UNIX and UNIX-like operating systems.

  Multimedia formats are an area of standards conflict. Three approaches now contend in the marketplace: CD-I, DVI, and CDTV.

  In early 1986, Sony and Philips released an additional specification called CD-I (CD-Interactive) which defines a freestanding appliance rather than a computer peripheral. Another supplementary standard, CD-ROM XA was announced in 1988. XA is a supplement to the CD-ROM specification that applies to digital audio data interleaving with other types of data. Such interleaving permits rapid access to audio data associated with other recorded information without requiring head repositioning. Some minor drive redesign will be needed to accommodate the XA format. CD-I has been aimed at consumer, education, and a fewcommercial applications, such as point of sale displays.

DVI was developed by RCA and was acquired by General Electric when it acquired RCA. General Electric subsequently sold the DVI technology to Intel. DVI is supported by Lotus, IBM and other firms having interest in business applications of multimedia rather than consumer applications.

The third multimedia format, CDTV, is being used by Commodore. It is incompatible with the other two formats.

Physical standards for write-once optical drives are not as advanced, and lack of standardization has delayed acceptance of optical drives by OEMs. The ANSI X3B11 technical subcommittee has prepared unrecorded media standards for 5.25" write-once disks for ISO approval. X3B11 originally intended to propose only the continuous tracking servo approach, but the price for getting this through the committee was an agreement to also submit the sampled servo approach for inclusion in a "dual standard". X3B11 finally embraced both approaches as well as a third approach, sampled servo with RZ modulation (X3.191), sponsored by Literal. As a result, there is no universally accepted write-once standard for 5.25" drives.

Many manufacturers, recognizing that the market is small, have gone their own way and ignored the formatting aspects of standards efforts in favor of proprietary approaches to improved capacity or performance. Attempts to formulate a 12" standard have not succeeded because each supplier supports only its own technology. The current approach is to prepare a standard that will cover the next generation of 12" drives: The danger in this approach is that it may not permit backward compatibility.

The standards efforts of the various national standards groups have resulted in ISO draft standards, number 9171-1 and 9171-2, covering the 5.25" write-once cartridge and both of the proposed servo formats. Unfortunately, the dual format remains a confusion factor to OEMs considering inclusion of optical drives in their systems, and is one of the factors that has delayed final approval of the draft specification.

A draft standard for 14" write-once media has been prepared by X3B11 and forwarded to ISO for further action. As only Eastman Kodak and PDO manufacture 14" media, they have been the primary influences on the standard. Even this standard is ambiguous, as it covers two thicknesses for the media, one version made by PDO and the other by Eastman Kodak.

A subcommittee of X3B11, X3B11.1 was established in 1989 to formulate a proposed standard for a logical file format. While the main work of the X3B11 group so far has been concerned with media interchange among drives, X3B11.1 is concerned with interchange between systems. Working drafts for both write-once and rewritable media formats are in preparation.

Standardization efforts for rewritable drives and media have proceeded more quickly, as they were able to build on much of the work done for the 5.25" write-once effort. Draft standards for 5.25" and 3.5" families of drives and media are available now. The 5.25" rewritable CCS standard (ISO draft standard 10089) is close to final approval. The 3.5" standard (ISO draft standard 10090) has progressed toward a standard based on CCS, but alternate formats, such as the discrete block format (DBF) proposed by some Japanese firms, remain to be addressed. The outlook is for eventual coexistence of multiple formats, with the marketplace deciding the winner.

While IBM products frequently set de facto standards, IBM's activity in the optical storage area has been too weak to override the formal standards activities. IBM has been very active within X3B11 in the formulation of the 3.5" standards, but much less so concerning other standards. IBM pressed strongly for inclusion of read-only capability on 3.5" media, suggesting strong interest in software or document distribution.

At present, there is no standardization in larger sizes. There are already so many 12" drive designs in the field that standardization of this size is unlikely in the near future, although a standards project for 12" media exists. The diversity of existing designs makes it difficult for most manufacturers to agree to changes because of the major costs of product redesign. New generations of 12" drives may be standardized to a greater degree, as working groups have been set up within the American X3B11 subcommittee and the Japanese SC23 standards subcommittees to consider standards for newer products. Progress has been slow, and many manufacturers don't express much enthusiasm for a 12" optical disk standard.

* Optical library disk exchange time: The most critical aspect of the optical library is its ability to exchange disks quickly. Exchange times typically range from a few seconds to fifteen seconds, and exchange time can severely limit the number of requests a library system can service in a period of time. The use of dual picker mechanisms on the elevator assemblies of second generation libraries has helped reduce the effective exchange time seen by the system.

* Spin-up and spin-down times: While not important in freestanding optical disk drives, spin-up time (including drive initialization time) and spin-down time become important when the drives are used in automated libraries, because these times add to the total system latency experienced when a disk cartridge must be exchanged. These times typically range from two to five seconds each and are significant delays. Plastic media substrates have less mass than glass substrates, enabling disks made with plastic substrates to accelerate and decelerate somewhat more quickly than disks fabricated with glass.

* Error correction: Error detection and correction (EDAC) will continue to be required to deal with the relatively high defect density of optical media. The techniques and designs developed to cope with this problem in optical storage may also migrate to the magnetic storage arena as storage densities increase and the impact of small physical defects on magnetic media become proportionately greater.

  Most errors that occur are single-bit errors and can be readily corrected in minimal time. ECC techniques can also handle multiple bit errors up to the design limit of the system, but the correction process can add noticeably to the latency of the data retrieval process.

  A number of algorithms are being used for the ECC function. At the present time, standards efforts in the U.S. favor the use of long distance Reed-Solomon codes for the purpose of error detection and correction in read/write drives. Some Japanese firms have preferred product codes, a method of performing error correction on a multidimensional data array.

  Error correction can be implemented in chip form. This is the case for CD-ROM already, and ECC chips for other optical drives have been prepared by several firms. At least two firms in the U.S., Cyclotomics (an Eastman Kodak subsidiary) and Data Systems Technology (now a Cirrus Logic subsidiary), have developed algorithms and chips that will perform the bulk of the error detection and correction process, so the implementation of these functions should not be onerously expensive. Both of these firms are using Reed-Solomon codes.

  Error correction is a complex process and requires an amount of time that introduces significant delays in data transmission from the drive to the host computer. Overall performance can be greatly improved by efficient on-the-fly error correction implementations. Laserdrive (folded into Literal Corporation in 1990) developed such a product, and other firms are expected to develop sophisticated custom VLSI chips to offer this feature. The use of media with an inherently low raw bit error rate, where the errors are mostly single bit errors, also helps to minimize pipeline time for error correction.

Competing technologies

In making technology comparisons, it is important to remember that all technologies evolve and must be considered as "moving targets." Almost all forms of data storage have shown consistently improving bit storage density, track density, lower power requirements, faster access

times, more intelligence and smaller size. Much of the experience gained in developing magnetic disk drives is applicable to the design of optical disk drives, and it appears that some techniques used by optical drive designers may be applicable to the design of magnetic disk drives. This type of cross-fertilization hastens the development of both technologies.

Because development is a slow process and acceptance of a new product does not occur overnight, displacement of existing products by the new optical products will be far from instantaneous, even where the optical product is highly suitable for a given task. The following sections review technology contenders and expected progress in the years ahead.

Magnetic disk drives

* Rigid disk drives: Rigid magnetic disk drives are the mainstay of today's auxiliary storage devices. Except on the lower end of the performance range, they appear largely immune from serious displacement by optical drives over the next few years. The relatively high mass of the optical drive head makes it quite difficult for optical drives to match the access time performance of today's voice coil magnetic drives. Furthermore, a typical optical drive has only one data surface under the head at any one time, while a typical magnetic drive has several surfaces available, reducing effective seek time.

  Magnetic disk drive technology has continued to improve. While optical drives have improved performance to the point where they can offer 30-40 millisecond average seek time on a 325 megabyte drive, magnetic drives typically offer sub-20 millisecond times on drives of the same capacity or larger. Sub-12 millisecond times are offered by the most advanced rigid magnetic drives. Optical disk drives are just beginning to achieve 3,600 RPM rotation rates, while magnetic drives are moving to 4,300 or 5,400 RPM at the high end of the performance range. It is unlikely, therefore, that the magnetic drive will be seriously threatened by optical disk drives for the next few years in its role as a high performance system disk.

  Where removability is important, the ability of an optical disk drive to perform the combined functions of a tape drive and a rigid system disk drive, or to build large on-line data libraries, may outweigh performance considerations. Such applications can include graphics design projects, data distribution, save/restore of data, or use as a system disk in a security oriented environment. Here, the rewritable optical disk will

make inroads on the uses of rigid magnetic disks. But the cost of even a low-end optical drive will substantially exceed that of a low-end magnetic drive for some years to come, so mass displacement of magnetic disk drives by optical disk drives is considered to be improbable.

* High capacity flexible disk drives: It is within the capabilities of today's technology to fabricate a floppy disk drive offering over 40 megabytes of storage capacity, and 20 megabyte devices are expected to be in high volume production from Brier Technology, Insite Peripherals and Iomega in 1991. Several Japanese firms are also expected to produce 20 megabyte and up floppy drives in the future.

  As they gradually evolve to the 40 megabyte and 80 megabyte capacity ranges, these high capacity floppy drives could compete with the very low-end of potential optical disk drive product.

  A major disadvantage is that of incompatibility. So far, none of the proposed drives being considered are interchangeable with each other. It would be very unusual for a business area based upon removable media to be successful without widespread interchangeability.

Alternative optical devices: Cards and tape

* Optical cards: Two companies have announced optical cards: Drexler Technology Corporation and Optical Recording Corporation. The optical card announced in 1981 by Drexler Technology offers up to 4.11 megabytes of read-only or write-once storage contained on a credit card sized plastic substrate. Drexler has sold licenses to produce optical cards to the Optical Memory Card Business Corporation, a Japanese organization formed by Dai Nippon Printing Corporation and three licensees, and to Canon. Twenty six companies have purchased licenses permitting them to make optical card drives using Drexler patents.

  In 1986 Optical Recording Corporation, a Canadian firm, announced optical card technology capable of storing up to 200 megabytes in a credit card size format, although current development is aimed at 50 megabyte capacity per card. The active recording layer is a metal/dye combination. So far, only read-only and write-once card media have been produced.

  In addition, Toppan Printing Company, Sony, Canon and Dai Nippon Printing have announced alternate formats, but these do not have the momentum of the Drexler-led effort.

  Production of drives and controllers suitable for use with the Drexler type card media on a commercial scale is expected to begin in 1991. Omron announced a planned production start in late 1991, and other licensees have indicated their intentions to begin manufacturing in the 1991/1992 period.

The Drexler cards are being proposed for use by insurance or medical organizations for client/patient record keeping. The card format allows ready transportation and read back of large volumes of information. The card is capable of withstanding considerable handling and is suitable for usage by individual patients. Other potential applications include software distribution, inventory control, security/access control, and programming of numerical control machines, process controllers and other industrial automatic equipment.

Nippon Conlux, Omron Tateisi, Olympus Optical and Kyocera are prospective sources for Drexler-compatible optical card readers. Kyocera will be the supplier for CSK, a Japanese software company that holds a Drexler license.

In March, 1989, a European standard for 2.6 megabyte optical cards and drives was published by the Drexler European Licensees Association, (now called the Optical Memory Card forum) which includes both European and Japanese companies. The standard presents an interchange format to allow cards to be read or written by equipment from participating manufacturers. The ANSI X3B10.4 technical subcommittee is preparing a similar standard for use in the United States. An ISO activity is also under way.

The write-once format and limited capacity of the Drexler card limit it to specialized applications. The cost of the drive is unlikely to decrease below the cost of a floppy disk drive, so the optical card is unlikely to displace the large number of floppy disk drives widely used for software distribution.

Because of its relatively limited capacity and/or performance, the optical card is not a competitor to the optical disk drive. The optical card will make its mark in the development of new applications rather than displace existing storage devices, and will compete in such markets as the POS and security access markets against other portable storage devices such as semiconductor memory cards.

* Optical tape: Optical tape drives, just leaving the developmental stage, represent another potential solution for those needing a way to store large amounts of archival data. So far, only write-once technology has been shown to be feasible for these devices. While optical tape devices are inherently less capable of fast access to data than are disks, they do provide substantially greater capacity than magnetic tape in a single media unit, eliminating the need to handle as many media units per volume of data accessed. So far, only a few firms have been active in the optical tape field. The earliest were Docdata N.V., which has been developing a 6.2 gigabyte tape drive for use with IBM compatible tape controllers, and Laserstore, which has been working on a 2.5 gigabyte product. The Laserstore product will have a SCSI interface and be packaged in an 8" form

factor. LaserTape Systems, a startup company, is developing an optical tape drive that will use a 50 gigabyte tape cartridge similar in dimensions to the IBM 3480 tape cartridge.

CREO Products, a Canadian firm, has been working with ICI on a write-once optical tape drive. CREO made its first shipment to the Canadian Government in 1990.

Magnetic tape drives

* High performance tape drives: Magnetic tape drives have shifted away from reel-to-reel format in favor of cartridge formats. The IBM 3480 set a standard for high-end tape drives and imitators have appeared. 3480 class products are competitive with the lower end of the optical disk product lines in terms of capacity and are superior in terms of data transfer rate, but are inferior in terms of average access time. Rewritable optical disk drives have the potential to displace a significant portion of the magnetic tape drives used for save/restore applications as optical drive and media prices decline.

  Storage Technology Corporation has introduced an automated tape cartridge library that uses standard IBM 3480 tape cartridges and can hold up to 6,000 tapes in each modular unit. It will eventually be challenged by optical drive based systems as IBM introduces anticipated rewritable disk based library storage systems, possibly beginning in 1992.

  Helical scan tape drives can also compete for archival and save/restore applications. A variety of recording formats, all incompatible, are being offered, including modified VHS videotape recorders, 8 millimeter cartridge, and DAT (digital audio tape). Several companies currently offer helical scan recorders. These products offer large capacities (from 1.2 to 5 gigabytes) and a low cost per bit stored, but suffer from relatively long access times, as do all tape storage systems. For most of them, data transfer rates are unimpressive, lying in the 180 to 500 kilobyte per second range. However, data compression techniques can multiply the effective capacity and transfer rate by a factor of 2 to 5.

  Because all of these technologies are based upon consumer electronics designs, media is widely available. The availability of existing consumer products reduces the cost of developing and manufacturing derivative products as computer peripherals. However, much redesign is required to transform consumer grade helical scan tape products into reliable computer peripherals.

  The most notable success in the helical scan computer peripheral market is Exabyte, which has achieved great success for its 8 millimeter format drives. Much as CD-ROM has benefited from the sales and technology of CD audio players, the data version of 4 millimeter DAT should also benefit as consumer product sales

grow. However, it remains to be seen if DAT can be price competitive against other technologies competing for the save/restore niche.

* Low performance tape drives: Cartridge tape drives using parallel track formats have been increasing in capacity and performance since their introduction in the 1970s. Three tape widths are in use: .15", .25", and .5". Tape capacities range from 40 megabytes to 5 gigabytes in the .25" and smaller tape formats. The .5" parallel track tape cartridge drives offer 200 to 400 megabytes in a 5.25" form factor. Drives operating in a serpentine mode can store up to 2.6 gigabytes. Some manufacturers adopted the physical format of the IBM 3480 cartridge in their drives but not the recording format; such products are less expensive than the 3480 but don't offer media interchangeability with IBM systems.

  These products are threatened to some degree by write-once technology, and will definitely be impacted by small rewritable optical disks offering similar or greater capacity at equivalent prices. The optical drives also have the advantage of being able to share a controller with the magnetic disk drive being backed up, resulting in overall cost savings for system OEMs. Given the current state of optical technology, displacement ef fects won't be felt for several years.

  The primary use of low-end cartridge tape drives is to back up rigid disk drives. They are also occasionally used for software distribution, especially for multiuser systems. Because the price of optical media is expected to be several times that of cartridge tape media, the use of optical media for software distribution will not become widespread until media costs are approximately equivalent.

  Most programs load from the distribution media sequentially, and random access is not as important a consideration as it would be in general purpose storage/retrieval operations. However, data transfer rate is an issue for many users and some optical disk drives can outperform tape drives, at least in read mode.

  Low performance reel-to-reel tape drives are currently used for data logging, for program and data interchange, and for hard disk backup on minicomputers and some multiuser microcomputers. These products are relatively expensive and bulky, and are vulnerable to gradual displacement as optical storage devices and high capacity tape cartridge devices come into wide use.

Other technologies

Other interesting, but low probability optical technologies have commercial possibilities, but are far from manufacturing status.

* Electron Trapping: The second approach, which is being developed by Optex Corporation, involves "electron trapping," by shifting the energy level of electrons in a material which holds them in a stable state for long periods in either the high or low energy state. A visible wavelength laser pulse moves an illuminated area to a high energy state. An infrared laser pulse causes the electrons to revert to the low energy state, emitting light as they do so. The presence or absence of light in response to a read (infrared) pulse yields a bit of information. The process is infinitely reversible, but is subject to interference from unwanted ambient light.

* Holographic storage: Holographic storage has been a theoretical possibility for several decades, but limitations of materials and economics have kept it from being a practical reality. Holographic storage requires a three-dimensional storage medium exhibiting photorefraction, plus appropriate electronic scanning devices for data writing and reading. Storage cell materials used have typically included lithium niobate, gallium arsenide and other photorefractive crystalline substances.

  Several firms are cosponsoring a research program at MCC to develop a prototype rewritable fast high capacity holographic memory. If successful, the sponsoring companies will then have the rights to further develop and manufacture products using the MCC designs. An operating prototype is expected by MCC in 1992. If successful, holographic memories might be marketed by 1995.

  The MCC holographic memory is targeted for capacities in the 200 megabyte to 10 gigabyte range, with 1 to 10 microsecond access times. Data rate can range from 1 to 50 gigabytes/second, and all of this will be packaged in a 5.25" full size form factor. The active memory element is an array of strontium barium niobate or lithium niobate crystal fibers. There are no moving parts, as the crystal array is scanned using solid state acoustically modulated scanners. A CCD array is used for readout.

  In 1991 IBM and the University of California (Irvine) both announced some details of various experimental holographic memories currently under development, but neither is close to being a real product. The IBM approach uses an amorphous epoxy (NNDN-NAN) to which an organic photoconductor material (DEH) has been added as the memory element. These materials are relatively inexpensive compared to crystalline materials, but so far have not produced the diffraction efficiency obtainable from crystalline materials. The UC approach involves photochromic materials mixed with a polymer material. It must be operated at very cold temperatures for good performance.

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 and optical library manufacturers use them.

MARKET CLASSIFICATION

Market class is used here, arbitrarily, to differentiate captive, PCM/Reseller and OEM/Integrator disk drive and optical library marketing activities.

Captive: Disk drives or libraries manufactured internally or by a subsidiary of a computer manufacturer, and sold or leased primarily for use with systems offered by the manufacturer. Note that the term is used to describe the products, not the manufacturer; drives and libraries sold to PCM/Reseller or OEM/Integrator market classes are classified accordingly. Most DISK/TREND statistics separate data between IBM captive and "other captive", but the term still pertains to the disk drives and libraries involved, not the manufacturer.

Examples:

* Drives sold by Canon with its office systems are considered captive, if internally manufactured. Libraries sold by Filenet with its systems are captive, if internally manufactured.

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

Example:

* Shipments by Toshiba are non-captive, except for drives sold with systems made by the parent company or other subsidiaries.

PCM/Reseller: Disk drives and libraries sold or leased by "plug compatible manufacturers" or their distributing organizations directly to end users for use with systems sold by another manufacturer. Also includes drives and libraries sold in the "aftermarket" -- shipments by drive manufacturers to subsystem producers, distributors, retail chains, mail order firms and individual dealers. It includes drives and libraries to be connected to systems of all types, including personal computers, mini-

computers and mainframes, or drives and libraries sold as add-on devices by distributors and dealers.

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

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. 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: 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.

Examples:

* Maxoptix is considered a U.S. manufacturer, even though the firm manufactures some of its disk drives in non-U.S locations.

* LMSI is considered a non-U.S. manufacturer, since the majority ownership is non-U.S.

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. Optical drives currently produced all have one spindle, but future drive configurations may include more than one spindle.

Positioners: The basic unit used in counting optical libraries. One positioner consists of the robotic mechanism needed to service a related number of optical drives and disk cartridge storage slots. A few optical libraries have more than one positioner unit in a physical system.

Revenue: Based on sales of disk drives or libraries alone, as normally sold by individual manufacturers. Controllers and library units 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. Library revenue is reported without the value of installed drives unless the sale is always made on a 'drives included' basis. Sale prices are estimated public sale transaction prices, whether at captive end user, PCM/Reseller or OEM/Integrator levels. All prices are in 1990 constant dollars.

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

Examples:

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

* Innovations such as non-standard 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:

Mainframe/superminicomputer: Disk drives or libraries attached to the processor or to a terminal associated with a mainframe or superminicomputer.

Minicomputers/multiple user microcomputers: Drives and libraries attached to smaller general purpose processors typically serving multiple users, including network file servers. Examples: IBM System AS/400, DEC 433MP, Hewlett-Packard 3000

Personal computers: Attached to a general purpose microcomputer normally used by a single user. Examples: IBM PS/2, Apple Macintosh, Compaq SLT/286.

Office systems/workstations: Specialized equipment for dedicated use in specific office applications such as word processing, electronic mail or document storage. Specialized hardware is normally used. Examples: Toshiba TOSFILE, Hitachi HITFILE.

Non-office systems/workstations: Attached to dedicated processors and workstations used in a non-office application, such as order processing/shipping, point-of-sale, medical, factory production control, law enforcement, CAD/CAM/CAE, military, etc.

Consumer and hobby computers: Systems sold primarily to consumers for non-business applications. Examples: Commodore 64, MSX systems, most Atari models (Apple II is considered to be a professional/business microcomputer). Multimedia systems for home use, such as the Commodore CDTV are also included in this category.

Other applications: Any application not included above.

READ-ONLY OPTICAL DISK DRIVES

1991 DISK/TREND REPORT

READ-ONLY OPTICAL DISK DRIVES

Coverage

Examples of disk drives in this group include:

4.72" disk diameter (CD-ROM)

Chinon	CDS-430, CDS 431
Goldstar Telecommunication	GCDR-200
Hitachi	CDR 1700S, CDR-3600
Laser Magnetic Storage	CM131, CM210, CM231, CM50
Matsushita Electric	CR-501B, CR-521B, LK-MC501S
Matsushita Electronic Comp.	EMO-103, EMO-104, EMO-201
Mitsumi Electric	CMRC-LUO, CRS-UF, CRS-XP
NEC	PC-CD10, PC-CD103, N5267-38
NEC Home Electronics	CDR-36, CDR-83, CDR-90
Nippon Columbia (Denon)	DRD-251, DRD-550, DRD-551
Philips (Magnavox)	CDD461, CDD401, CDI-601
Pioneer	DRM-600/610
Sanyo	ROM-3001, ROM-4005, ROM-7006
Shinano Kenshi (Texel)	DM-3120, DM-5011, DM-5120
Sony	CDU-541, CDU-6100, CDU-7101
Toshiba	XM-3201B, XM-3301B, XM-5100A

3.15" disk diameter (CD-ROM)

Sony	Data Discman

A read-only optical drive is equipped only to read an optical disk. It does not have a laser capable of developing write power, a method to switch the laser into a writing mode, nor electronics required for writing data. The optical read-only drive is sometimes referred to generically as OROM (Optical Read-Only Memory), but almost all drives in this category are of the CD-ROM type and are capable of reading 4.72" or smaller media.

The CD-ROM is the dominant product type in this group because manufacturers leveraged the design, manufacturing and standards infrastructure developed for CD audio players, but CD-ROM performance suffers because of its design similarity to audio CD players. In this report, CD audio players equipped with electronics to read CD-ROM formatted disks are counted as CD-ROM drives.

Market status

1990 saw a slowing of growth for this product group due to economic and political factors as well as weaker than anticipated demand in the games and automotive markets. However, most CD-ROM manufacturers experienced improved growth in late 1990 and early 1991.

Unit shipments rose 18.3% to 712,800 units in 1990, up from 602,500 units in 1989. Revenue grew only 7.9%, from $263.6 million to $284.3 million, as a result of declining prices and product mix. The number of participants remained constant: JVC stopped manufacturing CD-ROMs, but Philips has begun marketing CD-ROMs and CD-I players under its Magnavox brand as well as through its subsidiary, LMSI. Philips, Matsushita and NEC now have more than one unit within their organizations manufacturing CD-ROM drives. All read-only drives are made by non-U.S. companies.

In 1990, Sony introduced the Data Discman, still the only product to incorporate a 3.15" (8 centimeter) drive. As of mid-1991 Sony was the only producer of 3.15" drives. Other firms are considering introducing a 3.15" drive but have delayed because of a lack of supporting titles.

IBM offers 4.72" CD-ROM as a peripheral device on the system RS/6000 and PS/2 personal computers. Hewlett-Packard, DEC, Sun Microsystems and other firms use the CD-ROM as a means of distributing system documentation or software.

Sony and Hitachi were the leading non-captive producers in 1990, followed by Toshiba, Matsushita Electric and LMSI. NEC remained the leading captive producer on the strength of sales for its game products.

Promotion of CD-ROM drives by bundling popular disks with a drive is being increasingly encountered. For example, Sony and NEC began offering such packages in 1991. Additional similar promotions are expected.

Marketing trends

3,088,900 CD-ROM drives are forecasted for shipment in 1994, with revenues expected to rise to $661.2 million. Shipments of 3.15" drives, about 12.2% of 1990 shipments, are expected to make up 21.3% of unit shipments in 1994. Overall OEM prices are expected to decrease from an average $306 in 1990 to $144 in 1994, under the stimulus of increased competition, larger quantities and an increasingly consumer oriented share of the applications mix. Non-U.S. firms will continue to be the only producers, but Asian countries other than Japan are expected to gradually improve their market share. Non-captive shipments of the 3.15" form factor CD-ROM are expected to be moderate until publishers offer an adequate selection of titles in that format.

About 50% of 1994 shipments are projected to be through OEM channels, up from 38.4% in 1990. Reseller shipments, 31.2% of the 1990 total, will remain flat at 31.5% in 1994. The share of captive shipments is expected to decline 30.3% in 1990 to 18.5% in 1994. Both captive and reseller unit shipments are increasing, but will decline as a percentage of the total because OEM sales will grow faster.

Low performance, low cost drives will make up an increasingly large fraction of total shipments. Some drives, such as the Mitsumi unit remarketed by Tandy as the CDR-1000, have retail prices under $400, and are expected to broaden the market. 31.2% of 4.72" drive shipments in 1990 were low-end, increasing to 38.2% of such shipments in 1994. If low-end 3.15" drives are included, then the low-end drives were 43.5% of 1990 shipments and will account for 49.9% in 1994. The growth rate increase in low-end share of 4.72" drives at the end of the forecast period is the result of increasing sales of consumer oriented systems using CD-ROMs.

While sales of the low-end 3.15" drive will grow, their limited capacity compared to the 4.72" drive is expected to keep their overall share nearly constant through the forecast period. The early growth of 3.15" drive shipments will be slower than for 4.72" until Sony is joined by other manufacturers and more applications for the drive become available.

Market share of low-end CD-ROM drives

Worldwide total unit shipments (000)	1990	1992	1994
3.15"	88.0 12.3%	170.0 12.0%	360.0 11.7%
4.72"	222.0 31.1%	474.0 33.5%	1,180.0 38.2%
Low-end subtotal	310.0 43.5%	644.0 45.6%	1,540.0 49.9%
All CD-ROM drives	712.8	1,413.0	3,088.9

The introduction of multimedia (interleaved data, audio, and video) on CD-ROM is expected to increase the size of the market for CD-ROM, especially in the consumer, education, industrial training, and point-of-sale markets. Shipments should begin in 1991 and reach substantial volume in 1993.

There are two major multimedia formats: CD-I, sponsored by Sony and Philips, and DVI, which has been embraced by Intel, IBM, Lotus and other major companies. DVI chips and boards are currently available for developers, and this format appears most likely to succeed in the business oriented marketplace. CD-I has attracted most of its followers in the education, point-of-sale and consumer camps. CDTV, Commodore's consumer oriented CD-ROM multimedia player using still a third format, was intro-

duced formally in the spring of 1991. CDTV is not compatible with the other major multimedia formats.

Finally, the demand for read-only storage is driven by the information that external and in-house publishers provide for it. In addition to the estimated 2,000 titles now sold by external CD-ROM publishers, there are an approximately equal number of "titles" published by companies for internal use. Typical internal titles include catalogs, parts lists, policy/procedure manuals, and equipment maintenance documentation. The desire to publish such internally distributed data has spawned a do-it-yourself CD-ROM publishing industry that continues to grow as the price of authoring tools comes down and they become easier to use.

Applications

Currently, read-only drives appear primarily on micro-based systems, including individual personal computers, which accounted for 56.3% of drive unit shipments in 1990. Consumer computer and other applications, notably games such as the NEC PC Engine, accounted for 19.9%. In 1994, consumer applications, led by entertainment, education and automotive uses, are expected to be the largest application area, with 33.9% of the units sold. Single user business computers will follow closely, with 30.3% of the shipments in 1994.

CD-ROM drives will be attached in larger numbers to department level network file servers, and to large processors through microcomputer based file servers, to provide access to CD-ROM data bases for mainframe and minicomputer users. In 1994, larger systems, including file servers, are expected to absorb 6.6% of the units sold. This is a decline from

7.6% in 1990 and reflects the impact of an expected surge in single user and consumer usage, due to increasing numbers of multimedia type applications in the 1993-1994 time frame.

The 3.15" format is expected to be heavily oriented toward consumer applications, but business applications are expected to use 3.15" drives where portability is required, such as field maintenance. Many of the data bases currently published are small enough to fit within the capabilities of the 3.15" drive, but users of desktop and file server type installations will want the flexibility of using either 3.15" or 4.72" media and will prefer the 4.72" drive.

The published content of a CD-ROM can be of broad general interest, such as a dictionary or an atlas, or specific to a company, such as a manual or parts list. Typical data bases currently distributed include U.S., state and local statistics and regulations, information on poisons and drug side effects, legal research materials, computer system and software documentation, construction materials catalogs, and selected professional publications. Text oriented data bases are especially suitable for implementation on read-only memory. These include legal cases, encyclopedias and other educational materials, news files, technical papers and all types of reference works. Video and audio data bases containing images (clip art) and sound sequences are also available.

CD-ROM has the inherent capability to store and recover digitized images and audio, a characteristic which suggests many applications in the field of technical training, language instruction, and other educational uses. The generic ability to handle text, audio and video data is often referred to as "multimedia". Multimedia is not restricted to any particular type of storage medium, but the large amounts of storage required by

digitized audio and video make CD-ROM an appropriate vehicle for multimedia titles. The 3.15" CD-ROM is not expected to be as important a multimedia vehicle as the 4.72" drive because of its limited capacity.

The growth of demand for multimedia capable systems will be limited initially by the higher costs of multimedia-capable equipment, the relative scarcity of multimedia titles, confusion caused by the presence of competing formats and the considerable costs of authoring a professional multimedia product. While equipment shipments from Commodore and Philips will begin in 1991, volume is expected to build only gradually in 1992, with 1993 being the first year of significant shipments.

CD-ROM is finding a market in on-board mapping systems for vehicle navigation and dispatching. Several firms are developing such applications to provide location and routing data for sales staffs, public service personnel, taxi drivers, urban planners, and public utilities. Interest also exists in the U.S. defense community. In Japan, top-of-the-line autos are being equipped with CD-ROM drives as part of personal navigation systems. Similar systems are being considered for the U.S. market, but are delayed by the lack of digitized detailed maps for the entire U.S. road system and disagreement as to the best method of locating a vehicle's position.

Technical trends

The technology in this product group is relatively stable, as it derives from the consumer CD player. The areas receiving the most attention are:

Multimedia: Integration of audio and video content into CD published materials. Both hardware and software development are

required. The XA format, which permits interleaving of audio and data, requires new functions to be added to existing drive electronics. Older CD-ROM drives are not able to operate with the XA format and will require modification or special adapters.

Standards: A yet unresolved issue concerns the cartridge (caddy) used to contain the disk. The cartridge holds the disk in place within the drive, preventing loss of focus due to vibration, shock, or mounting in other than a horizontal position, and permits the drive to be used in vehicles or to be mounted in a vertical position within a system enclosure. By mid-1989 most of the Japanese suppliers had adopted a common approach, but LMSI still prefers its own design.

The early establishment of the Sony/Philips de facto standard for CD-ROM established a basis for CD-ROM physical disk interchangeability and provided a mechanism for identification of a disk and files upon the disk. The High Sierra Group, an ad hoc task force consisting of a group of companies interested in CD-ROM, subsequently prepared a proposed recording standard and submitted it in 1986 to ANSI and ECMA. This has now become ISO standard 9660. The XA format proposed by Philips, Sony and Microsoft in 1988 appears likely to extend an orderly standards process into the interactive format area. ISO 9660 may require modification to fit the needs of the UNIX operating system, and a new ad hoc task force called the Rock Ridge group is preparing proposals to that end.

Standards for motion video compression being worked out by MPEG (Motion Picture Experts Group) are likely to be adopted in 1991 for CD-I. A similar group, JPEG, is concentrating on compression standards for still video images. The Commodore CDTV player is ISO 9660 compatible but not MPEG compatible.

Other standards issues do not involve the drive directly. A standard user interface is highly desirable so that end users do not have to learn a host of different data retrieval formats. More standardized interfaces between data retrieval software, data, and user interfaces are also needed.

Performance: Average access times, which decreased below the .5 second range in 1986 have dipped well under 400 milliseconds since 1989. Further gains without raising cost significantly are difficult. Users would like faster data transfer rates, especially when multimedia is used, but as the data format is fixed, this requires faster rotation rates. Several firms are expected to offer drives with at least double the current data transfer rate, with the improvement in performance achieved by doubling the rotation rate.

Software: Development of software to support use with major operating systems and application programs, such as text search and the whole spectrum of multimedia applications, is under way.

Cost reduction: Cost reduction programs are continuing. Plastic molded lenses, for instance, have replaced polished glass lenses.

Packaging: The packaging of CD-ROM drives has changed rapidly. In 1986, most of the drives shipped were not compatible with the full height and half high form factors that have been adopted for 5.25" magnetic disk drive products. Today, most CD-ROM drive models in production are half high models. However, since the computer industry has moved to the 3.5" packaging profile, CD-ROM drives are usually mounted externally to the desktop computers and internally in tower configurations.

Sony, as noted previously, has already used the 3.15" format in its Data Discman. Other firms are currently discussing possible 3.15" drives with potential customers, but no shipments from other firms are expected before 1992.

Authoring systems: Publishers of CD-ROMs require tools to help them prepare various types of content including text, data bases, audio and video for mastering and replication. Multimedia projects, in particular, are complex and require sophisticated tools to help non-experts prepare multimedia titles.

Networks and libraries: System integrators are considering adding CD-ROM capabilities on file servers. As a result, there is interest in jukeboxes for CD format drives, but the slow access time of the CD-ROM has led most server designers to design multiple drive configurations. Four firms (Kubik, NSM, Pioneer, and Next Technology) have announced autochangers for CD-ROM. The relatively slow bandwidths and throughput obtained from heavily loaded networks may make it impractical for servers containing multimedia formatted disks to adequately respond to user expectations for image motion and audio continuity. Fiber optic based networks may be needed to use multimedia in a network environment efficiently.

Reliability: Some CD-ROM drives have experienced failures due to the accumulation of dust on the lens. The industry has responded with a variety of solutions, including lens cleaning kits and self cleaning drives. The best solution seems to be avoidance of designs that allow dust-laden air to be pulled through the drive. Dust resistant designs have appeared in 1990 and 1991 from Toshiba, Mitsumi and others.

Writable CD: Except for mastering systems, writable CD-format media and systems are still not readily available, and the early enthusiasm of Philips and other potential producers cooled as a result of concerns about piracy and uncertainty as to whether development should be aimed at write-once or erasable media. Tandy's development of dye-based rewritable media has been delayed due to technical problems. Other companies have investigated magneto-optic recording. The prospects for writable CD-format drives are reviewed in the discussion of read/write drives with under 1 gigabyte capacity.

Potential competition: There is potential competition for CD-ROM from the 2.5" minidisk magneto-optic drive announced by Sony in the spring of 1991. The drive has both rewritable and read-only capabilities. While this drive is aimed primarily at the audio market and at digital tape competition, it could be developed as a computer peripheral. If so, its projected low cost would make it a potential competitor for CD-ROM.

In addition, the 3.5" magneto-optic drives announced by IBM and Sony also have read-only capability and could be used in many of the same applications as CD-ROM drives. However, their capacity is lower and their price substantially higher, which makes strong competition unlikely.

Forecasting assumptions

1. CD-ROM players will remain in production status in at least fifteen companies in 1991. The form factor will fit within the 5.25" half high standard, but acceptance of the 3.15" form factor drive by firms other than Sony will not occur until 1992.

2. The ISO formatted disk interchange standard for CD-ROM will be accepted almost universally by drive manufacturers and publishers, and the Japanese cartridge format will become the dominant form, even in the absence of a formal standard.

3. Non-U.S. suppliers will continue to dominate the CD-ROM hardware market. There will be no significant production by U.S. firms.

4. The automotive segment and games segment will resume strong growth in 1992. 1991 growth will be moderate.

5. There will be an increasing demand for CD-ROMs by system and subsystem integrators for use in specialized workstations, file servers, and memory subsystems.

6. CD form factor write-once or rewritable drives will appear mainly in CD-ROM mastering applications and will have little negative impact on CD-ROM sales. No other form of read-only optical memory will seriously challenge CD-ROM through 1994.

7. The CD-I format will impact primarily the home and education markets. Final hardware will not appear until the latter part of 1991 and there will be additional shipment delays while programs and published materials are prepared. CD-I will have relatively minor impact on the CD-ROM in the business market. DVI will have no significant impact until 1992, and the first year of significant volume shipments related to multimedia will be 1993.

8. Media mastering and replicating capacity will be adequate and will not restrict growth for read-only optical memory markets.

9. Automated libraries for CD-ROMs attached to file servers will be available to make CD-ROMs practical peripheral devices for mainframe and minicomputer systems. Small libraries attachable to individual personal computers or freestanding workstations will also be available.

10. There will be no significant impact on CD-ROM shipments from the Sony 2.5" minidisk or other unannounced low-end optical drives until 1995.

TABLE 17

READ-ONLY OPTICAL DISK DRIVES, ALL CAPACITIES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1990 Revenues		Forecast 1991		1992		1993		1994	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	--	--	--	--	--	--	--	--	--	--
TOTAL U.S. CAPTIVE	--	--	--	--	--	--	--	--	--	--
PCM/Reseller	--	--	--	--	--	--	--	--	--	--
OEM/Integrator	--	--	--	--	--	--	--	--	--	--
TOTAL U.S. NON-CAPTIVE	--	--	--	--	--	--	--	--	--	--
TOTAL U.S. REVENUES	--	--	--	--	--	--	--	--	--	--
Non-U.S. Manufacturers										
Captive	11.4	92.7	14.5	91.6	42.4	102.9	50.1	118.6	78.4	176.8
PCM/Reseller	69.8	107.9	65.9	98.7	81.9	122.5	121.2	188.2	164.8	262.0
OEM/Integrator	58.6	83.7	82.3	113.8	105.1	146.9	138.6	195.2	146.6	222.4
TOTAL NON-U.S. REVENUES	139.8	284.3	162.7	304.1	229.4	372.3	309.9	502.0	389.8	661.2
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	139.8	284.3	162.7	304.1	229.4	372.3	309.9	502.0	389.8	661.2
OEM Average Price ($000)		.306		.237		.203		.177		.144

TABLE 18

READ-ONLY OPTICAL DISK DRIVES, ALL CAPACITIES

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1990 Shipments		Forecast							
			1991		1992		1993		1994	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	--	--	--	--	--	--	--	--	--	--
TOTAL U.S. CAPTIVE	--	--	--	--	--	--	--	--	--	--
PCM/Reseller	--	--	--	--	--	--	--	--	--	--
OEM/Integrator	--	--	--	--	--	--	--	--	--	--
TOTAL U.S. NON-CAPTIVE	--	--	--	--	--	--	--	--	--	--
TOTAL U.S. SHIPMENTS	--	--	--	--	--	--	--	--	--	--
Non-U.S. Manufacturers										
Captive	20.7	216.2	41.7	254.6	129.0	318.0	163.0	388.0	255.0	571.0
PCM/Reseller	144.9	222.7	164.2	238.2	248.5	372.0	407.2	633.0	611.3	972.5
OEM/Integrator	177.8	273.9	336.3	479.6	517.5	723.0	789.2	1,103.5	1,045.0	1,545.4
TOTAL NON-U.S. SHIPMENTS	343.4	712.8	542.2	972.4	895.0	1,413.0	1,359.4	2,124.5	1,911.3	3,088.9
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	343.4	712.8	542.2	972.4	895.0	1,413.0	1,359.4	2,124.5	1,911.3	3,088.9
Cumulative Shipments (Units in thousands)										
IBM	--	--	--	--	--	--	--	--	--	--
Non-IBM	774.4	1,649.2	1,316.6	2,621.6	2,211.6	4,034.6	3,571.0	6,159.1	5,482.3	9,248.0
WORLDWIDE TOTAL	774.4	1,649.2	1,316.6	2,621.6	2,211.6	4,034.6	3,571.0	6,159.1	5,482.3	9,248.0

TABLE 19

READ-ONLY OPTICAL DISK DRIVES, ALL CAPACITIES

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1990 Revenues		Forecast 1991		1992		1993		1994	
	4.72"	3.15"	4.72"	3.15"	4.72"	3.15"	4.72"	3.15"	4.72"	3.15"
U.S. MANUFACTURERS										
TOTAL U.S. REVENUES	--	--	--	--	--	--	--	--	--	--
NON-U.S. MANUFACTURERS										
Captive	73.8	18.9	68.0	23.6	70.9	32.0	82.0	36.6	129.7	47.1
PCM/Reseller	107.9	--	98.7	--	118.8	3.7	158.3	29.9	207.1	54.9
OEM/Integrator	83.7	--	113.8	--	146.1	.8	176.2	19.0	176.4	46.0
TOTAL NON-U.S. REVENUES	265.4	18.9	280.5	23.6	335.8	36.5	416.5	85.5	513.2	148.0
WORLDWIDE RECAP										
Captive	73.8 -19.0%	18.9 --	68.0 -7.9%	23.6 +24.9%	70.9 +4.3%	32.0 +35.6%	82.0 +15.7%	36.6 +14.4%	129.7 +58.2%	47.1 +28.7%
PCM/Reseller	107.9 +38.2%	-- --	98.7 -8.5%	-- --	118.8 +20.4%	3.7 --	158.3 +33.2%	29.9 +708.1%	207.1 +30.8%	54.9 +83.6%
OEM/Integrator	83.7 -11.3%	-- --	113.8 +36.0%	-- --	146.1 +28.4%	.8 --	176.2 +20.6%	19.0 --	176.4 --	46.0 +142.1%
Total Revenues	265.4 +.7%	18.9 --	280.5 +5.7%	23.6 +24.9%	335.8 +19.7%	36.5 +54.7%	416.5 +24.0%	85.5 +134.2%	513.2 +23.2%	148.0 +73.1%
ANNUAL SHARE, BY DIAMETER	93.5%	6.5%	92.3%	7.7%	90.3%	9.7%	83.1%	16.9%	77.7%	22.3%

TABLE 20

READ-ONLY OPTICAL DISK DRIVES, ALL CAPACITIES

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DISK DIAMETER

	1990 Shipments		Forecast							
			1991		1992		1993		1994	
	4.72"	3.15"	4.72"	3.15"	4.72"	3.15"	4.72"	3.15"	4.72"	3.15"
U.S. MANUFACTURERS										
TOTAL U.S. SHIPMENTS	--	--	--	--	--	--	--	--	--	--
NON-U.S. MANUFACTURERS										
Captive	128.2	88.0	139.7	114.9	159.0	159.0	203.0	185.0	331.0	240.0
PCM/Reseller	222.7	--	238.2	--	360.0	12.0	526.0	107.0	761.5	211.0
OEM/Integrator	273.9	--	479.6	--	720.0	3.0	1,030.5	73.0	1,336.4	209.0
TOTAL NON-U.S. SHIPMENTS	624.8	88.0	857.5	114.9	1,239.0	174.0	1,759.5	365.0	2,428.9	660.0
WORLDWIDE RECAP										
Captive	128.2	88.0	139.7	114.9	159.0	159.0	203.0	185.0	331.0	240.0
	-14.6%	--	+9.0%	+30.6%	+13.8%	+38.4%	+27.7%	+16.4%	+63.1%	+29.7%
PCM/Reseller	222.7	--	238.2	--	360.0	12.0	526.0	107.0	761.5	211.0
	+51.0%	--	+7.0%	--	+51.1%	--	+46.1%	+791.7%	+44.8%	+97.2%
OEM/Integrator	273.9	--	479.6	--	720.0	3.0	1,030.5	73.0	1,336.4	209.0
	-10.1%	--	+75.1%	--	+50.1%	--	+43.1%	--	+29.7%	+186.3%
Total Shipments	624.8	88.0	857.5	114.9	1,239.0	174.0	1,759.5	365.0	2,428.9	660.0
	+3.7%	--	+37.2%	+30.6%	+44.5%	+51.4%	+42.0%	+109.8%	+38.0%	+80.8%
ANNUAL SHARE, BY DIAMETER	87.8%	12.2%	88.3%	11.7%	87.8%	12.2%	82.9%	17.1%	78.7%	21.3%

TABLE 21

READ-ONLY OPTICAL DISK DRIVES, ALL CAPACITIES

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1990 Estimate Units (000)	1990 Estimate %	1994 Projection Units (000)	1994 Projection %
MAINFRAME/SUPERMINI				
General purpose	--	--	6.3	.2
MINICOMPUTERS AND MULTI-USER MICROS				
Business and professional, including networks	54.0	7.6	197.7	6.4
PERSONAL COMPUTERS				
Business and professional, single user	401.1	56.3	935.9	30.3
OFFICE SYSTEMS AND WORKSTATIONS				
Dedicated application	50.6	7.1	142.1	4.6
NON-OFFICE SYSTEMS AND WORKSTATIONS				
Technical, distribution, medical, other specialized	65.6	9.2	599.2	19.4
CONSUMER AND HOBBY COMPUTERS	117.6	16.5	1,047.1	33.9
OTHER APPLICATIONS	23.9	3.4	160.6	5.2
Total	712.8	100.1	3,088.9	100.0

TABLE 22

READ-ONLY OPTICAL DISK DRIVES, ALL CAPACITIES

MARKET SHARE SUMMARY
Worldwide Shipments of Non-Captive Disk Drives

	1990 Net Shipments					
	To United States Destinations			Worldwide		
	Units (000)		%	Units (000)		%
Drive Manufacturers	4.72"	Total		4.72"	Total	
Sony	114.3	114.3	35.4	148.5	148.5	29.9
Hitachi	96.3	96.3	29.8	148.2	148.2	29.8
Toshiba	64.1	64.1	19.9	70.1	70.1	14.1
Matsushita Electric	9.8	9.8	3.0	46.6	46.6	9.4
LMSI	15.0	15.0	4.6	30.0	30.0	6.0
Other U.S.	--	--	--	--	--	--
Other Non-U.S.	33.0	33.0	7.3	99.8	99.8	20.2
TOTAL	322.7	322.7	100.0	496.6	496.6	100.0

READ/WRITE OPTICAL DRIVES LESS THAN 1 GIGABYTE

1991 DISK/TREND REPORT

READ/WRITE OPTICAL DISK DRIVES LESS THAN 1 GIGABYTE

Coverage

Examples of disk drives in this group include:

3.5" disk diameter

IBM	MD 3125A (E)
MOST	RMD 5128-S (E)
Sony	SMO-D301 (E)

4.72" disk diameter

JVC	XR-W1001
Mitsumi Electric	CWS-3
Sony	CDW-W1
Yamaha	YPR-1

5.25" disk diameter

Canon	MO-5001S (E), OM-500D (E)
Cherokee Data Systems	Tracker, M600, M8820
Fujitsu	M2505B, M2502
Goldstar Telecommunication	GSO-5560 (E), GSO-5650WS
Hewlett-Packard	C1716C (E)
Hitachi	OD 101-1, OD-112-1 (E)
Honeywell	AN/MU-928
Kawasaki Steel	KL1200S, KHE640 (E)
Laser Magnetic Storage	510
Literal	525 GB, 525 GBX2
Matsushita Electric Industrial	LF-5010, LF-7010 (E), LF-9000(E)
Maximum Storage	APX-3200, APX-5100
Maxoptix	Tahiti I (E), Tahiti II (E)
Mitsubishi Electric	MW-5D1, ME-5E1 (E)
Mountain Optech	CS-400, SEL-2C, SE-400M
NEC	PC-CD102, N7915 (E)
Pentax Teknologies	LW-S501
Pioneer	DDU-5101, DE-U7001 (E)
Ricoh	RO-5043, RO-5042 (E), RO-5031E (E)
Sharp	JY-700 (E)
Sony	SMO-D501 (E), SMO-E501 (E)
Toshiba	WM-D070, WM-S070

8" disk diameter

Matsushita Graphic Commun.	PF-10, PF-3000

(E) indicates erasable or multifunction drive.

Two types of drives are included in this group: Write Once Read Many, (WORM) and Erasable (Rewritable). Provided that a drive is capable of writing and reading, it is classified in this group even if it can also be used with read-only media. CD-Write-Once (CD-WO) also fits into this category. Multifunction drives capable of using either rewritable or write-once media are considered rewritable drives for purposes of this report. Multifunction drives first appeared on the market in 1990.

The read/write drives discussed in this section are typically used with small computer systems of the mini and micro class and with intelligent workstations. Small automated libraries (jukeboxes, in industry parlance) used in departmental level mass storage subsystems are usually equipped with 5.25" read/write drives and 5.25" drives are increasingly being used in larger libraries as well. As of mid-1991, there were no 3.5" drives used in automated libraries.

Market status

1990 saw a continuance of the accelerated pace of product introductions that began in 1989 and has continued into 1991. JVC and Mitsumi announced 4.72" CD format write-once drives at the 1990 fall Comdex conference, upgraded versions of rewritable and write-once drives were shipped by several firms, and IBM and Sony announced 3.5" rewritable drives in 1991. Hewlett-Packard also joined the ranks of 5.25" rewritable drive producers with a high performance drive announcement in 1991.

In 1990, unit shipments reached 185,400 units, up 102.6% from 1989 as a result of continued very strong shipments of rewritable drives. Sony, Ricoh, and Matsushita Electric, were the leading producers. Worldwide revenues increased 62.5% to $477.6 million. Matsushita became the

leading manufacturer of write-once drives, while Sony remained the leader in rewritable drives. Rewritable drive shipments significantly outnumbered write-once drive shipments for the first time, with rewritable drives claiming 71.1% of unit shipments. Most of the rewritable drives shipped in this product group were 5.25" drives, although significant quantities of 3.5" drives will be shipped in 1991 and later years of the forecast period. Media shortages no longer limit drive sales.

8" drives, mostly used in Japan for stand-alone document storage systems, have been largely phased out, replaced by 5.25" drives. 8" drives offered more capacity, but were physically larger and priced higher. No further major production is expected.

Sony, Ricoh, and Canon have shipped substantial numbers of 5.25" magneto-optic drives and were joined in mid-1990 by Matsushita Electric, which announced the first phase-change rewritable drive in June. MOST began shipping a 3.5" magneto-optic drive in 1990, and 3.5" rewritable drive development efforts finally resulted in announcements in 1991 for IBM and Sony. Additional 3.5" drive technology announcements were made by Mitsubishi and Toshiba in mid-1991 at the Tokyo Business Show.

Marketing trends

Continued strong growth of 5.25" rewritable drive shipments is anticipated, but growth in shipments of 5.25" write-once drives is expected to weaken after 1992 as multifunction drives become more standardized and accepted. Demand for 128 megabyte 3.5" rewritable drives will be moderate, as many system producers will find their benefits marginal until prices come down or packaging, performance and capacity improve.

For the total product group, 356,100 units are expected to ship in 1991, growing to 1,431,900 units in 1994. Rewritable drives are expected to account for 91% of shipments in 1994, of which 47.6% will be 3.5" and 52.4% will be 5.25" units. Only 9% of the forecasted 1994 total will be write-once units, mostly 5.25", but including a moderate number of 4.72" drives operating in CD-ROM compatible format.

In May of 1991, Sony made a preliminary announcement of a 2.5" magneto-optic drive aimed at the audio market. While no immediate plans were announced for a 2.5" computer peripheral, it is possible that Sony or some other company may produce a 2.5" drive during the forecast period. The Sony product is significant in that there is no need for an erase pass before writing, a feature that can be expected in computer peripherals in the future. The Sony technique is to use the laser to increase the temperature of the recording layer to the point where writing is possible, combined with a magnetic head that actually writes the data.

Small quantities of 4.72" (CD-WO) write-once drives began shipping in 1989, but the outlook for erasable 4.72" drive shipments is unclear and shipments are unlikely before late 1993. Shipments of professional mastering systems using CD-WO will decline after 1991, partly because initial demand will be fulfilled and partially because of lower cost drives, such as the JVC unit, that can be used with personal computers to perform the disk mastering function.

The forecasted growth in 3.5" erasable drive shipments results from competition due to an increasing number of sources, the positive influence anticipated from IBM's endorsement of the technology, growth of multimedia applications, and some displacement of cartridge tape drives used with small systems for backup or save/restore applications. Growth could be

even larger if OEM prices, initially expected to exceed the $800 level, are lowered to compete more effectively with small tape drives.

Projected growth: Write-once vs. erasable drives, 5.25" and smaller

Worldwide total unit shipments (In thousands)	1992			1993			1994		
	5.25"	4.72"	3.5"	5.25"	4.72"	3.5"	5.25"	4.72"	3.5"
Write-once	79.5	13.5	--	84.0	28.4	--	70.2	58.1	--
Erasable	335.4	--	187.9	481.4	--	378.4	682.2	--	621.4
Total	414.9	13.5	187.9	565.4	28.4	378.4	752.4	58.1	621.4

The write-once drives are expected to grow moderately through 1992 as a result of continued interest by information resource managers and a strong market for document storage systems. However, multifunction drives are starting to make inroads and should begin to strongly displace write-once drives in this application in 1993 and after.

The 4.72" write-once drive is a read/write drive capable of producing disks readable by a CD-ROM. The first such products, based on CD-ROM mechanisms, had modest performance, and were available only as part of mastering systems produced by Yamaha and Sony, which do not intend to produce the drive for OEM sale. JVC has indicated intent to produce a relatively inexpensive CD-WO drive in 1992 that is expected to achieve a modest popularity with companies wishing to publish their own CD-ROM format disks for internal use. Tandy, Sony and Philips have discussed the possibility of rewritable CD format drives and media, but have given no firm indication of availability, detailed specifications, or price.

While writable CD format data drives offered at a price under $500 could generate large sales, publishers of CD-ROM disks, fearing a recur-

rence of the piracy that has plagued personal computer software publishers, discourage the development and marketing of an inexpensive read/write drive in CD-ROM format. Companies manufacturing the 3.5" rewritable/read-only multifunction drives should not be faced with the same degree of concern, as the drive and media do not have the capacity of CD-ROM and are not format compatible with CD-ROM or CD-WO in any case.

Applications

In 1990, personal computers were the largest application of optical drives in this product group, accounting for 43.3% of the units shipped. Office workstations and non-office workstations accounted for 25.7% and 21.4% respectively, while 7.8% were used with multiuser systems. This is a substantial change from 1989's pattern, which emphasized the workstation categories rather than personal computers. The shift is believed to be associated with increased shipments of rewritable drives, which are more likely to be used for project oriented storage in many applications, rather than being focussed upon document imaging applications as is typical of write once drives.

The 3.5" drives now entering the market will largely be associated with personal computers and will be responsible for a slight increase in the share of drives used with personal computers in 1994. The share of usage by networks will increase somewhat, while the share held by dedicated office workstations will decrease somewhat as personal computers take over some of the functions currently performed by dedicated systems. This shift also occurred with word processing equipment as the market matured, but will not be as complete because of the specialized needs of document storage systems.

About 3% to 5% of the production of drives in this product group is expected to be used in jukebox subsystems, such as those sold by Hewlett-Packard, Cygnet, Hitachi, NKK and others.

Write-once and rewritable optical drives under 1 gigabyte are finding applications as save/restore devices in microcomputer and minicomputer systems where interchange isn't required, but are used primarily as a method for storing images in office, medical, and other specialized systems. As interchange capability for rewritable drives is proven, they will also begin to acquire the role of a data distribution device.

The faster erasable drives such as the Maxoptix "Tahiti" are finding additional uses as system disks in high security applications requiring vault storage of recorded media when the equipment is unattended. They are also an attractive replacement for magnetic disk pack drives, offering equivalent performance and much lower cost and space requirements. When optical drive performance and packaging begins to compete with the performance of small form factor Winchester disk drives, optical drives are expected to displace some rigid disk drives in other situations where removability is an advantage.

For most backup purposes, media with a 10,000 write/erase cycle capability would be more than adequate. With annual small rigid disk drive shipments surpassing the thirty million unit mark and cartridge tape drive shipments near two million units, a backup device having performance superior to tape and competitive cost may have good sales prospects.

Media with both a read-only section and a writable section, when available, can serve as a vehicle for software and data base distribution, providing that cost of the media is low. The writability feature permits

timely update of a previously installed data base. Furthermore, the ability to write gives the data base publisher certain security and anti-piracy options not readily available on read-only media, in that individual disks or sections of disks can be serialized or encrypted for use on a specific system or group of systems at nominal cost.

Many departmental level systems for document or image storage use the read/write drives in this product group. Engineering documentation and medical and record management applications tend to favor write-once technology, whereas rewritable or multifunction drives are the choice in applications such as desktop publishing, design, and project management where stored information changes frequently. Departmental applications may use small library units with five to thirty-two media units to contain all the required records in a conveniently accessible form. Larger organizations will use libraries containing hundreds of disks. Entry level systems will be found in office automation, medical, law enforcement, CAD/CAM, and smaller financial applications, and their larger cousins will be found in corporate or divisional information centers of large financial institutions, government agencies, transportation firms, defense contractors and aerospace firms.

The information management functions of larger organizations are more likely to prefer write-once storage because of its archival nature and perceived greater security. Smaller organizations or individual work groups in large organizations are more likely to prefer rewritable drives and media for the flexibility and ease of storage management they provide.

Erasable optical storage has an opportunity to significantly displace tape storage devices for backup when drive prices decline below $500. However, the current high user price of the media ($100 to $200, compared

to $15 to $20 for a tape reel or cartridge) would still limit acceptance. 5.25" rewritable media prices are expected to decline significantly in 1991 due to competitive pressure and the influence of 3.5" media, which is being priced in the $50 to $70 range, a level significantly under the price of 5.25" media. Further declines are expected as volume increases. It is probable that by the time the drive prices reach the sub-$500 level that media prices will be at an acceptable level.

3.5" drives may have an additional role as upgrade replacements for rigid drives in small systems originally equipped with low capacity, slower rigid drives. In situations where it is also desirable to have removable media, the extra cost of the optical drive over a modern rigid drive of equivalent capacity may be justifiable.

Specific applications for drives in this product group include:

Save/restore operations

* Save/restore disk data backup.
* Archival storage of files.

Reference level storage

* Storage of programs, freeing up fixed magnetic disk drives for data.
* Storage of data bases frequently used but infrequently changed.

Document storage and processing

* Storage of images for use in departmental or small organizational CAD/CAM, medical, law enforcement, and financial record systems.
* Office automation systems, especially those involving storing images of documents.
* Convenient storage of all files and programs related to a particular document.

Data distribution

* Production and distribution of updatable data bases in quantities

too small to warrant mass replication costs or where replication delays are too long for timeliness.

System disk

* Function as system disk where moderate performance is adequate and high capacity with removability is needed.

* Replacement of older, lower capacity rigid disk drives where removability is desired as well as higher capacity.

Graphic presentation and multimedia

* Contains large files required for presentations involving complex graphics, audio and video.

Technical trends

Drive technology continues to improve and the rate of product development is rapid. The key areas of change are reviewed below. These comments apply to high capacity drives as well, unless otherwise noted.

Capacity: Capacity of 5.25" drives is expected to increase to the 700 to 800 megabyte per side range over the next two years, with some firms looking at 1 gigabyte per side as a possibility. The increase will be due to a combination of factors, including improved optics and shorter laser wavelength permitting smaller spots, the adoption of edge encoding, and zone bit recording. For drives that will be dedicated to image storage, embedded data compression implemented in a single chip or small chip set should be feasible.

The capacity of announced 3.5" drives starts at 128 megabytes, but there is substantial pressure from users for higher capacity, so drive producers have incentive to produce drives with 220 to 256 megabytes of capacity as soon as possible. Some prototypes of drives with capacity over 200 megabytes have been shown, most notably Sony's 224 megabyte drive displayed early in 1990. A 256 megabyte drive is considered the most probable next step because of the need to establish backward compatibility in both read and write modes easily.

Write-once recording: A variety of optical recording technologies and media fabrication processes are in use, creating interchange problems and OEM confusion. At present, pit forming or bubble forming writing methods are in the majority, but writing using the phase change between amorphous and crystalline states to vary reflectivity at a spot is becoming more common. Sony, Fujitsu and Matsushita are currently using phase change recording. Write-once dye based media is being used by Pioneer and Ricoh. In general,

media using these separate recording methods are not interchangeable, although more sophisticated drives capable of detecting media type could accommodate some degree of interchange.

Hewlett-Packard, Sony and several other drive and media companies are offering a form of magneto-optic media which the drive can recognize as write-once media by virtue of a prestamped pattern on the disk. This approach has the benefit of allowing erasable drives capable of recognizing the pattern to operate as multifunction drives.

Rewritability: There are several technologies contending for acceptance in rewritable optical media, but magneto-optical media is the most commonly used method capable of meeting user demands for sensitivity, erasability, and stability. However, magneto-optical techniques may not be the long range solution. Progress has been made in erasable phase change and other types of erasable recording, even though these technologies are behind magneto-optical in development. Phase change media offering at least 100,000 write cycles was introduced in 1990, and there are prospects for extending the number of write cycles over one million.

Phase change media permits the interchange of write-once and erasable media on a single drive. Multifunctionality can also be achieved on magneto-optic media by designating some portion of the media as write-once or read-only. A group of 14 drive and media producers, including Hewlett-Packard, Maxoptix, Ricoh, and Sony started work in 1990 to establish a de facto standard for adding write-once functionality to magneto-optic media.

Dye-based media may eventually become commercially significant for erasable optical disks. Still in R&D status, this type of media is less subject to degradation problems, uses inexpensive materials and appears less expensive to produce because it is likely to be solvent coatable. Obtaining an adequate number of write/erase cycles is technically difficult, and dye based erasable media is not likely to be available until 1993 or later. Furthermore, multiple lasers may be required in drives using dye-based media, raising drive cost.

Media lifetime: While accelerated life tests seem to indicate that media lifetimes of 10 years or more are achievable, this aspect of media performance will remain unproven until actually demonstrated. Some suppliers are claiming in excess of 20 year lifetimes, but archivists remain concerned about media lifetime and whether future generations of drives will be compatible with today's media and recording formats. Because organic recording layers such as dyes seem to have better corrosion resistance than the metal films typically used, they may eventually displace the original metal film types used for write-once recording.

Substrates: Plastic is the currently preferred material, in order to reduce media cost and improve manufacturability. At present,

Polycarbonate appears to be the future material of choice, displacing PMMA. PMMA is permeable to water vapor which, in turn, can cause corrosion of the active layer.

While casting polycarbonate with low birefringence (a form of optical distortion) is difficult, proper formulation and control of the molding process has been shown by some substrate manufacturers to permit fabrication of substrates adequate for 5.25" media. Making polycarbonate 12" substrates is even more difficult because of the problem of keeping tight tolerances over a larger area.

Glass is used as a substrate for some small diameter media. The material is free of birefringence effects that distort the optical path, is non-permeable to moisture, is flat, and distortion free. Most drive makers are now convinced that glass substrates are safe to use in small diameter drives, although more costly than plastic. Sharp, Maxoptix and Matsushita have announced 5.25" erasable drives that can use glass substrate media. Other manufacturers are likely to do the same. The flat glass surface, coupled with high purity materials, can produce media with inherent defect levels considerably better than average. This has the advantage of reducing overall latency in the drive due to the reduced need to perform error correction during data reads.

Average access times: One of the major limitations of optical drives is average access time (seek time plus latency), which exceeds 50 milliseconds on 5.25" drives yet announced except for erasable drives from Hewlett-Packard, Maxoptix, Ricoh, certain Mitsubishi drives, plus the MOST and Sony 3.5" drives. The first generation of magneto-optical drives have an additional latency for writing operations caused by the need to erase each sector before writing. This lack of overwrite capability requires that an additional complete rotation be performed before the drive is ready to write in the selected sector.

Several techniques have been proposed to eliminate the need for an erase pass, and it is likely that future generations of M-O drives will not require a separate erase pass. The overwrite solution will come at the expense of additional complexity in the drive, media or both, so there will be a trade-off of performance for cost. Phase change drives do not need an erase pass.

Optical drives may have additional latency associated with write operations due to write verification delays. In both read and write operations, latency is increased if media defects have forced a file to be written in non-contiguous segments, as is frequently the situation.

The long access times of today's optical disk drives are less significant when the optical drive is used in an automated library, because the disk exchange and drive spin-up times are long in comparison to the drive access time. Reduction of drive spin-up time is important when the drive is used in a library based system

in order to minimize the length of the waiting-for-access queue. Spin-up times of 2 seconds or less are desirable. Plastic substrates usually have less mass than do glass substrates, so are preferable to minimize spin-up time.

Some 5.25" drives are now achieving total average access times well under 50 milliseconds, and times in the 30 millisecond range seem achievable using improved head designs, such as split optics. Current 3.5" drives exhibit total average access times in the 35 to 70 millisecond range, and can be expected to decrease to the 25 to 30 millisecond range eventually as drive RPM increases and head design improves.

Because most optical drives have both fine and coarse head positioning mechanisms, the average access time to data within the range of the fine head positioner may be very competitive with the average access times of small magnetic disk drives for similar amounts of data. For instance, a Sony 5.25" drive can access a band of tracks from the fine positioner's nominal center position. About 20 megabytes lie within this range, and any point in the range can be reached within 30 milliseconds, including latency. This suggests that suitable software could improve the throughput of optical drives, much as the use of cache improves the performance of magnetic disk drives.

Most optical disk drives rotate at lower speeds than typical magnetic disk drives, so optical drive rotational latency worsens the performance of optical drives in comparison with magnetic drives. A few drives, such as the Hewlett-Packard 5.25" drive and Ricoh's most recent rewritable drive spin at 3,600 RPM. Toshiba's demonstration of a 3.5" drive also showed the drive operating at 3,600 RPM, the first 3.5" drive to do so. Erasable media requires slightly less write power than write-once media, an advantage which can be translated into higher rotation speeds for erasable drives.

Error rate: Error correcting codes are used to compensate for the high raw error rate of optical media. The codes used, typically long distance Reed-Solomon codes, are able to deal with the higher defect density that occurs at the end of media life. While there is a reduction of data capacity on the disk to accommodate the redundancy needed by ECC methods, the loss may be as little as 8%, depending upon the ECC technique used. Where media have a high defect density, the error correction process can add substantial latency to data retrieval times. Drives will begin to incorporate more sophisticated ECC circuitry capable of doing on-the-fly error correction so quickly that ECC latency will not be observed.

Packaging: Most optical disk drives using read/write 5.25" disks are still packaged to conform with the envelope of a full height 5.25" floppy disk drive, limiting use to external mounting with many personal computers. Half height designs are starting to become available. Ricoh announced a half high model in 1988 and Pioneer offers a half height mechanism.

3.5" models will usually fit the 41.3 mm profile, but difficulties in reducing the size of the optics will delay development of smaller profile drives. When integrated head assemblies become available, then repackaging of 3.5" drives in 25.4 mm height or smaller profiles should be straightforward.

Military interest has spurred the design of ruggedized optical drives. At least 3 firms are actively engaged in pursuing this product area, including Cherokee, Mountain Optech and Honeywell.

Many drive producers are improving packaging through integration of logic functions into custom designed VLSI chips or using chip sets available from semiconductor companies for interface functions.

Standards: ANSI X3B11, ECMA TC31, ISO TC91/SC23 are all involved in standardization programs for unrecorded 5.25" and 3.5" media. ISO standards 9171-1 and 9171-2 cover write-once media in CCS and sampled servo formats. ISO draft standards 10089 and 10090 cover rewritable 5.25" and 3.5" media respectively. Final versions should be completed by ISO and ANSI in 1992. The ANSI version will not cover the sampled servo format. The 5.25" rewritable cartridge borrows from the work done on the write-once standard, but the same conflicts on the track following servo that bedeviled the write-once standards caused enough conflict to delay the appearance of erasable 5.25" and 3.5" drive standards. Most 5.25" rewritable drives adhere to the CCS format, as do all of the 3.5" drives formally announced to date. An alternative 3.5" sampled servo format known as DBF (Discrete Block Format) has been proposed as an alternative to the CCS format, but offers less capacity (117 megabytes) and may not be well accepted as a result.

Since June, 1989, the X3B11.1 technical subcommittee has been working on a logical interchange format. Work is going well and final ANSI approval is expected in late 1991. As currently envisioned, the format proposed will be transparent to track following approach, operating system used, or whether the media is rewritable, write-once or read-only.

No standard device level interface for optical drives exists, but at the system level, SCSI appears to have the status of a de facto standard. The IBM PC/AT interface, usually achieved by use of a host adapter, also has de facto standard status for both CD-ROM and read/write small drives.

The multifunction approach using magneto-optic media for both rewritable and write-once capability appears to have enough industry support to become a de facto standard and, possibly, to generate a proposal for a formal standard eventually.

Software: Read/write optical disk drives require specific supporting software, including drivers, operating system utilities, and application programs.

Basic software must address problems presented by the nature of the optical disk drive:

* More storage capacity is available than unmodified small computer operating systems can handle.

* Write-once disks require nonstandard file management utilities and drivers. File updates may result in degraded performance if files and directories are dispersed across the disk.

* Magneto-optical disks require modified system software to handle the overwrite requirement, or must have this function performed by the disk electronics or controller.

* File management functions in the computer operating system must be modified so that the optical disk appears to the operating system to be identical to a magnetic disk drive.

An additional software problem expected to develop is related to the probable migration of multimedia formats to read/write optical drives. The exact formats used on CD-ROM may not be directly transferable to read/write disks that conform to standards other than ISO 9660.

Forecasting assumptions

1. IBM is developing a rewritable 5.25" drive for internal manufacture. The timing and product form are uncertain, but an announcement is expected in late 1991.

2. Rewritable and write-once media will be available in adequate production quantities throughout the forecast period.

3. Low cost rewritable drives using limited erasability media will enter the market after 1991.

4. 4.72" write-once drives will remain in limited production through 1994. Rewritable 4.72" drives and media are not anticipated until late 1993. JVC and others will be producing 4.72" write-once drives in 1992 and after.

5. No 2.5" drives will be offered in this product group until after 1994.

6. Strong growth from the document storage systems industry and the conservatism of information resource managers will extend the growth of write-once drives through 1994.

7. IBM will provide software support for the 3.5" drive to permit its effective use as a system backup device and as a multimedia file storage device.

TABLE 23

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 1 GIGABYTE

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1990 Revenues		Forecast 1991		1992		1993		1994	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	46.2	64.2	138.2	178.9	254.2	336.9	342.2	485.9
Other U.S. Captive	--	--	.4	.4	38.0	53.2	47.9	68.4	63.6	93.2
TOTAL U.S. CAPTIVE	--	--	46.6	64.6	176.2	232.1	302.1	405.3	405.8	579.1
PCM/Reseller	19.4	26.7	22.4	31.9	39.3	55.8	62.9	89.7	85.1	125.3
OEM/Integrator	12.8	13.5	30.4	34.4	56.1	72.0	78.5	105.4	112.8	146.1
TOTAL U.S. NON-CAPTIVE	32.2	40.2	52.8	66.3	95.4	127.8	141.4	195.1	197.9	271.4
TOTAL U.S. REVENUES	32.2	40.2	99.4	130.9	271.6	359.9	443.5	600.4	603.7	850.5
Non-U.S. Manufacturers										
Captive	15.1	167.2	54.6	302.0	88.6	454.3	106.3	566.1	142.7	744.8
PCM/Reseller	35.2	65.6	99.8	142.2	117.9	166.9	153.6	217.0	189.4	275.3
OEM/Integrator	142.5	204.6	160.6	270.5	235.7	390.4	314.6	541.8	436.2	738.8
TOTAL NON-U.S. REVENUES	192.8	437.4	315.0	714.7	442.2	1,011.6	574.5	1,324.9	768.3	1,758.9
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	225.0	477.6	414.4	845.6	713.8	1,371.5	1,018.0	1,925.3	1,372.0	2,609.4
OEM Average Price ($000)		1.9		1.8		1.6		1.3		1.2

TABLE 24

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 1 GIGABYTE

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1990 Shipments		Forecast 1991		1992		1993		1994	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	23.3	32.4	60.1	79.0	112.6	150.1	159.9	224.4
Other U.S. Captive	--	--	.1	.1	10.0	14.0	12.6	18.0	17.2	25.2
TOTAL U.S. CAPTIVE	--	--	23.4	32.5	70.1	93.0	125.2	168.1	177.1	249.6
PCM/Reseller	5.9	8.1	8.5	12.2	19.0	27.9	40.7	58.4	64.8	95.8
OEM/Integrator	4.0	4.2	13.2	16.1	29.7	40.5	49.8	70.7	81.7	111.1
TOTAL U.S. NON-CAPTIVE	9.9	12.3	21.7	28.3	48.7	68.4	90.5	129.1	146.5	206.9
TOTAL U.S. SHIPMENTS	9.9	12.3	45.1	60.8	118.8	161.4	215.7	297.2	323.6	456.5
Non-U.S. Manufacturers										
Captive	4.1	33.8	10.7	59.9	18.4	99.7	23.7	130.4	32.8	177.1
PCM/Reseller	16.1	31.2	59.2	85.4	74.7	107.1	103.6	149.7	141.9	214.2
OEM/Integrator	76.6	108.1	89.5	150.0	145.8	248.1	224.4	394.9	332.3	584.1
TOTAL NON-U.S. SHIPMENTS	96.8	173.1	159.4	295.3	238.9	454.9	351.7	675.0	507.0	975.4
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	106.7	185.4	204.5	356.1	357.7	616.3	567.4	972.2	830.6	1,431.9
Cumulative Shipments (Units in thousands)										
IBM	2.0	2.7	25.3	35.1	85.4	114.1	198.0	264.2	357.9	488.6
Non-IBM	192.9	339.9	374.1	663.6	671.7	1,200.9	1,126.5	2,023.0	1,797.2	3,230.5
WORLDWIDE TOTAL	194.9	342.6	399.4	698.7	757.1	1,315.0	1,324.5	2,287.2	2,155.1	3,719.1

TABLE 25

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 1 GIGABYTE

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1990 Revenues				Forecast 1991				1992			1993			1994		
	8"	5.25"	4.72"	3.5"	8"	5.25"	4.72"	3.5"	5.25"	4.72"	3.5"	5.25"	4.72"	3.5"	5.25"	4.72"	3.5"
U.S. MANUFACTURERS																	
IBM Captive	--	--	--	--	--	1.2	--	63.0	74.4	--	104.5	180.1	--	156.8	263.5	--	222.4
Other U.S. Captive	--	--	--	--	--	.4	--	--	53.2	--	--	68.4	--	--	93.2	--	--
PCM/Reseller	--	26.7	--	--	--	28.8	--	3.1	44.4	--	11.4	53.4	--	36.3	64.1	--	61.2
OEM/Integrator	--	13.5	--	--	--	29.7	--	4.7	61.1	--	10.9	82.9	--	22.5	111.8	--	34.3
TOTAL U.S. REVENUES	--	40.2	--	--	--	60.1	--	70.8	233.1	--	126.8	384.8	--	215.6	532.6	--	317.9
NON-U.S. MANUFACTURERS																	
Captive	3.0	158.7	5.5	--	.8	272.8	27.8	.6	398.0	30.5	25.8	489.4	32.4	44.3	645.4	34.4	65.0
PCM/Reseller	--	65.4	--	.2	--	113.2	--	29.0	135.7	--	31.2	174.5	--	42.5	208.6	--	66.7
OEM/Integrator	--	200.5	4.1	--	--	252.2	6.6	11.7	300.0	36.0	54.4	364.2	62.5	115.1	430.9	119.3	188.6
TOTAL NON-U.S. REVENUES	3.0	424.6	9.6	.2	.8	638.2	34.4	41.3	833.7	66.5	111.4	1,028.1	94.9	201.9	1,284.9	153.7	320.3
WORLDWIDE RECAP																	
Captive	3.0	158.7	5.5	--	.8	274.4	27.8	63.6	525.6	30.5	130.3	737.9	32.4	201.1	1,002.1	34.4	287.4
	-43.4%	+16.8%	+120.0%	--	-73.3%	+72.9%	+405.5%	--	+91.5%	+9.7%	+104.9%	+40.4%	+6.2%	+54.3%	+35.8%	+6.2%	+42.9%
PCM/Reseller	--	92.1	--	.2	--	142.0	--	32.1	180.1	--	42.6	227.9	--	78.8	272.7	--	127.9
	--	+211.1%	--	--	--	+54.2%	--	--	+26.8%	--	+32.7%	+26.5%	--	+85.0%	+19.7%	--	+62.3%
OEM/Integrator	--	214.0	4.1	--	--	281.9	6.6	16.4	361.1	36.0	65.3	447.1	62.5	137.6	542.7	119.3	222.9
	-100.0%	+78.5%	--	--	--	+31.7%	+61.0%	--	+28.1%	+445.5%	+298.2%	+23.8%	+73.6%	+110.7%	+21.4%	+90.9%	+62.0%
Total Revenues	3.0	464.8	9.6	.2	.8	698.3	34.4	112.1	1,066.8	66.5	238.2	1,412.9	94.9	417.5	1,817.5	153.7	638.2
	-50.0%	+62.9%	+284.0%	--	-73.3%	+50.2%	+258.3%	--	+52.8%	+93.3%	+112.5%	+32.4%	+42.7%	+75.3%	+28.6%	+62.0%	+52.9%
ANNUAL SHARE, BY DIAMETER	.6%	97.4%	2.0%	--	.1%	82.7%	4.1%	13.1%	77.9%	4.8%	17.3%	73.5%	4.9%	21.6%	69.8%	5.9%	24.3%

TABLE 26

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 1 GIGABYTE

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DISK DIAMETER

	1990 Shipments				Forecast											
	1991				1992			1993			1994		
	8"	5.25"	4.72"	3.5"	8"	5.25"	4.72"	3.5"	5.25"	4.72"	3.5"	5.25"	4.72"	3.5"	5.25"	4.72"	3.5"
U.S. MANUFACTURERS																	
IBM Captive	--	--	--	--	--	.4	--	32.0	24.0	--	55.0	57.9	--	92.2	89.6	--	134.8
Other U.S. Captive	--	--	--	--	--	.1	--	--	14.0	--	--	18.0	--	--	25.2	--	--
PCM/Reseller	--	8.1	--	--	--	9.2	--	3.0	15.9	--	12.0	19.4	--	39.0	27.8	--	68.0
OEM/Integrator	--	4.2	--	--	--	11.1	--	5.0	27.5	--	13.0	42.2	--	28.5	65.4	--	45.7
TOTAL U.S. SHIPMENTS	--	12.3	--	--	--	20.8	--	40.0	81.4	--	80.0	137.5	--	159.7	208.0	--	248.5
NON-U.S. MANUFACTURERS																	
Captive	.2	33.4	.2	--	.1	58.6	1.0	.2	89.4	1.1	9.2	112.8	1.2	16.4	149.8	1.3	26.0
PCM/Reseller	--	31.1	--	.1	--	59.3	--	26.1	76.5	--	30.6	103.0	--	46.7	132.9	--	81.3
OEM/Integrator	--	107.9	.2	--	--	138.4	.5	11.1	167.6	12.4	68.1	212.1	27.2	155.6	261.7	56.8	265.6
TOTAL NON-U.S. SHIPMENTS	.2	172.4	.4	.1	.1	256.3	1.5	37.4	333.5	13.5	107.9	427.9	28.4	218.7	544.4	58.1	372.9
WORLDWIDE RECAP																	
Captive	.2	33.4	.2	--	.1	59.1	1.0	32.2	127.4	1.1	64.2	188.7	1.2	108.6	264.6	1.3	160.8
	-50.0%	+42.7%	+100.0%	--	-50.0%	+76.9%	+400.0%	--	+115.6%	+10.0%	+99.4%	+48.1%	+9.1%	+69.2%	+40.2%	+8.3%	+48.1%
PCM/Reseller	--	39.2	--	.1	--	68.5	--	29.1	92.4	--	42.6	122.4	--	85.7	160.7	--	149.3
	--	+288.1%	--	--	--	+74.7%	--	--	+34.9%	--	+46.4%	+32.5%	--	+101.2%	+31.3%	--	+74.2%
OEM/Integrator	--	112.1	.2	--	--	149.5	.5	16.1	195.1	12.4	81.1	254.3	27.2	184.1	327.1	56.8	311.3
	-100.0%	+95.3%	--	--	--	+33.4%	+150.0%	--	+30.5%	--	+403.7%	+30.3%	+119.4%	+127.0%	+28.6%	+108.8%	+69.1%
Total Shipments	.2	184.7	.4	.1	.1	277.1	1.5	77.4	414.9	13.5	187.9	565.4	28.4	378.4	752.4	58.1	621.4
	-60.0%	+103.2%	+300.0%	--	-50.0%	+50.0%	+275.0%	--	+49.7%	+800.0%	+142.8%	+36.3%	+110.4%	+101.4%	+33.1%	+104.6%	+64.2%
ANNUAL SHARE, BY DIAMETER	.1%	99.7%	.2%	--	--	77.9%	.4%	21.7%	67.4%	2.2%	30.4%	58.3%	2.9%	38.8%	52.6%	4.1%	43.3%

TABLE 27

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 1 GIGABYTE

WORLDWIDE SHIPMENTS (000)

ERASABLE/WRITE-ONCE DRIVE ANALYSIS

	1990		Forecast							
	--Shipments--		-----1991----		-----1992----		-----1993----		-----1994----	
	Units	%	Units	%	Units	%	Units	%	Units	%
U.S. MANUFACTURERS										
Captive Total	--		32.5		93.0		168.1		249.6	
Write-Once	--	--	--	--	--	--	--	--	--	--
Erasable	--	--	32.5	100.0	93.0	100.0	168.1	100.0	249.6	100.0
OEM/PCM Total	12.3		28.3		68.4		129.1		206.9	
Write-Once	5.5	44.7	6.5	23.0	7.8	11.4	8.1	6.3	8.0	3.9
Erasable	6.8	55.3	21.8	77.0	60.6	88.6	121.0	93.7	198.9	96.1
Total U.S.	12.3		60.8		161.4		297.2		456.5	
Write-Once	5.5	44.7	6.5	10.7	7.8	4.8	8.1	2.7	8.0	1.8
Erasable	6.8	55.3	54.3	89.3	153.6	95.2	289.1	97.3	448.5	98.2
NON-U.S. MANUFACTURERS										
Captive Total	33.8		59.9		99.7		130.4		177.1	
Write-Once	13.2	39.1	20.1	33.6	26.7	26.8	32.0	24.5	30.7	17.3
Erasable	20.6	60.9	39.8	66.4	73.0	73.2	98.4	75.5	146.4	82.7
OEM/PCM Total	139.3		235.4		355.2		544.6		798.3	
Write-Once	34.9	25.1	41.3	17.5	58.5	16.5	72.3	13.3	89.6	11.2
Erasable	104.4	74.9	194.1	82.5	296.7	83.5	472.3	86.7	708.7	88.8
Total Non-U.S.	173.1		295.3		454.9		675.0		975.4	
Write-Once	48.1	27.8	61.4	20.8	85.2	18.7	104.3	15.5	120.3	12.3
Erasable	125.0	72.2	233.9	79.2	369.7	81.3	570.7	84.5	855.1	87.7
WORLDWIDE RECAP										
Total Worldwide Shipments	185.4		356.1		616.3		972.2		1,431.9	
	+102.6%		+92.0%		+73.0%		+57.7%		+47.2%	
Write-Once	53.6	28.9	67.9	19.1	93.0	15.1	112.4	11.6	128.3	9.0
	+18.3%		+26.6%		+36.9%		+20.8%		+14.1%	
Erasable	131.8	71.1	288.2	80.9	523.3	84.9	859.8	88.4	1,303.6	91.0
	+185.2%		+118.6%		+81.5%		+64.3%		+51.6%	

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

TABLE 28

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 1 GIGABYTE

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1990 Estimate Units (000)	1990 Estimate %	1994 Projection Units (000)	1994 Projection %
MAINFRAME/SUPERMINI General purpose	1.6	.9	25.8	1.8
MINICOMPUTERS AND MULTI-USER MICROS Business and professional, including networks	14.5	7.8	147.5	10.3
PERSONAL COMPUTERS Business and professional, single user	80.2	43.3	641.4	44.8
OFFICE SYSTEMS AND WORKSTATIONS Dedicated application	47.7	25.7	317.9	22.2
NON-OFFICE SYSTEMS AND WORKSTATIONS Technical, distribution, medical, other specialized	39.7	21.4	263.5	18.4
CONSUMER AND HOBBY COMPUTERS	.4	.2	15.8	1.1
OTHER APPLICATIONS	1.3	.7	20.0	1.4
Total	185.4	100.0	1,431.9	100.0

TABLE 29

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 1 GIGABYTE

MARKET SHARE SUMMARY
Worldwide Shipments of Non-Captive Disk Drives

	1990 Net Shipments							
	To United States Destinations				Worldwide			
	Units (000)			%	Units (000)			%
Drive Manufacturers	5.25"	4.72"	Total		5.25"	4.72"	Total	
Sony	60.2	--	60.2	58.7	76.4	--	76.4	50.4
Ricoh	9.8	--	9.8	9.6	22.8	--	22.8	15.0
Matsushita Electric	10.7	--	10.7	10.4	15.9	--	15.9	10.5
Other U.S.	9.9	--	9.9	9.6	12.3	--	12.3	8.1
Other Non-U.S.	11.8	.2	12.0	11.7	24.0	.2	24.2	16.0
TOTAL	102.4	.2	102.6	100.0	151.4	.2	151.6	100.0

Note: 5.25" drive totals include 3.5" drives.

READ/WRITE OPTICAL DRIVES MORE THAN 1 GIGABYTE

1991 DISK/TREND REPORT

READ/WRITE OPTICAL DISK DRIVES, MORE THAN 1 GIGABYTE

Coverage

Examples of disk drives in this group include:

14" disk diameter

Eastman Kodak	6800

12" disk diameter

ATG Gigadisc	GD1002, GD6000, GD6001
Fujitsu	M2502A/B
Hitachi	OD 301A-1, OD 321-1
Laser Magnetic Storage	1200E, 1250E, LD 4100
NEC	N7913/N6513-23, N6513-20
Nikon	MO-DD120C (Erasable)
Optimem	1000, 2400, 4400
Sony	WDD 600, WDD 3000
Toshiba	WM-S500

8" diameter

Fujitsu	F6443 (Erasable)

High capacity optical disk drives are read/write drives, either write-once or erasable. At present, only write-once drives are widely available in this capacity range, although Nikon has made a technology announcement of a 12" erasable drive and Fujitsu has shipped small numbers of a non-removable 8" erasable drive.

The existing write-once drives are used primarily with large minicomputers and mainframes in specialized imaging, document storage, or archiving applications. They are frequently used with library devices to provide random access mass storage subsystems capable of handling hundreds of gigabytes of storage. Presently, all but two of the available drives in this group use 12" media, and all but one access a single side of a disk. LMSI offers a drive that accesses both sides of the disk simultaneously.

Market status

11,700 drives were shipped worldwide in 1990, an increase of 12.5% from 1989. Shipments from U.S. firms and non-captive shipments of non-U.S. firms were down slightly, but the decrease was swamped by gains in captive shipments from non-U.S. producers. 1990 revenues increased to $155.9 million, a 30.4% gain over 1989 that was achieved through selective price increases on older drives, the introduction of new products at higher prices, and a shift in distribution mix favoring sales of drives in the captive channel where prices are higher. 48% of revenues came from non-captive sales, down from 58.9% in 1989.

Almost 96% of units shipped were produced by non-U.S. firms, a slightly higher share than in 1989. 1990's leading producers were Laser Magnetic Storage, Toshiba, Sony, and Hitachi, with Toshiba continuing as the leading captive supplier and LMSI remaining the leading OEM supplier on a worldwide basis.

Japanese firms were the first to enter this drive group because of early emphasis for use on systems capable of storing documents produced in Asian character sets. Of the Japanese firms, Sony and Hitachi have most aggressively pressed forward with improved designs.

Government and financial organizations continue to be major markets for high capacity optical disk drives in this group, and some system integrators, including IBM, Unisys and DEC, routinely quote on orders of significant magnitude. IBM now routinely integrates optical drives and libraries with its systems for specific customers. Eastman Kodak's willingness to sell optical drives to replace microfilm equipment for records management has also helped to expand the available market.

Marketing trends

Because large diameter, high capacity optical disk drives are used mostly in specialized applications, shipment growth rates for drives with more than 1 gigabyte capacity remain smaller than for other optical disk drive groups. Worldwide unit shipments are expected to grow from 11,700 units in 1990 to 27,700 units in 1994. Revenues in this same period are expected to grow from $155.9 million (17% of the worldwide optical disk drive market) to $381 million (a decline to 10.3% of the worldwide optical disk drive market). The appearance of 5.25" drives with over a gigabyte of on-line capability is expected within the forecast period, but as the timing is very uncertain, no explicit forecast has been made for them.

Growth within the forecast period may be slowed by competition from newer, higher capacity 5.25" optical disks with capacities in the 600 to 800 megabyte per side area, long lead times on application and system software development for use with optical drives in large systems, and the generally higher price levels of storage subsystems based on the large capacity drives. Nevertheless, acceleration of growth will occur in 1991 and 1992 as the customers react to the dual head drives now entering the marketplace. Growth will decline subsequently under pressures from higher capacity 5.25" drives with capacities approaching a gigabyte per side as such drives become available during the forecast period.

While IBM has an optical disk drive development program under way, no early introduction of internally produced drives over 1 gigabyte from IBM is anticipated. IBM's current policy is to purchase 12" WORM drives from LMSI and library units from Filenet, offering them as standard peripheral subsystems with existing system product lines using appropriate software provided by IBM and other firms. DEC has taken similar action, offering

the LMSI 12" drive as the DEC model RV20, and Unisys has purchased 12" drives from Hitachi to run on its 1100 mainframes. IBM's 1991 introduction of a family of 5.25" optical libraries based upon Hewlett-Packard models further suggest IBM has no immediate interest in internal development of 12" optical drives.

Plug compatible hardware vendors, including Data/Ware Development and Comparex, also offer optical drive subsystems for attachment to IBM mainframes, and other firms are also expected to offer such attachments.

Applications

The largest application areas in 1990 for high capacity optical drives were again office systems and non-office workstations. Together, these categories accounted for 67.5% of unit shipments, up from 58.2% in 1989 and close to the 64% measured in 1988. The change is due to the recovery of captive drive shipments by non-U.S. producers, which had declined in 1989. In 1994, this pattern will be much the same except with more emphasis on dedicated application office systems, due to growth of demand for document filing systems and integrated information handling systems incorporating document image storage. Major applications for optical disk drives over 1 gigabyte capacity include records management, medical, geophysical, military or industrial imaging, and storage of transaction documents that must be kept for future reference. Almost all of these applications are archival in nature and favor the use of write-once optical disk technology.

Scientific, industrial and defense oriented users of high capacity drives use them for acquiring high volume digitized data from real time

inputs and storing it for subsequent analysis, as well as for administrative uses. Some financial institutions use them for accumulating various types of transaction data in other than image form, reproducing the actual form only upon printing or displaying the document.

Typical usage includes:

Engineering and manufacturing systems

* Centralized drawing/document storage and distribution.
* Document storage for computer integrated manufacturing.
* Document storage and dissemination for construction projects.

Records management

* Personnel records.
* Tax records and tax rolls.
* X-ray and scanner images.
* Law enforcement records.
* Social Security, patent and other government records.
* Large library index files.

Save/restore operations

* Disk backup.
* Archival storage.

Office automation

* Storage and dissemination of office documents.
* Storage of legal documents incorporating signatures and other personal identification.

Transaction audit trails

* Records of reservations, bank and credit card transactions, etc.
* Secure area access records.
* Insurance claim and policy records.

Data acquisition

* Capture of data from scanners, seismic detectors or other imaging devices.

* Capture of data having military or intelligence significance.

The early users of high capacity drives have concentrated on the storage of images, including document filing systems used within government bodies such as taxing agencies, law enforcement, and military/intelligence agencies. Drive library units (jukeboxes) are available for use with high capacity optical disk drives, allowing the creation of on-line mass storage subsystems that are being used by insurance companies, banks, and other large organizations that must have ready recall of large amounts of account related data.

Approximately 13.6% of the drives in this group were shipped in automated library subsystems in 1990, and this percentage is increasing at a rate of about .5% to 1% annually, so that in 1994, 18 to 19% of the units in this group are expected to be installed in jukeboxes upon shipment to the ultimate end user. An automated library system using large capacity drives usually has two or more drives to improve overall response time, but the single drive, five cartridge LMSI library is a notable exception. The number of drives per library is expected to increase with time, so that by 1994 the typical library will average between three and four drives installed.

While the records management market is a significant consumer of high capacity optical disk drives, this market tends to experience slow growth due to its conservative nature, reluctance to abandon large investments in existing systems, concern about hidden perils in new technology and, in some organizations, infighting between MIS managers and records managers.

In some countries, the legal system discourages the use of optical storage because only original documents are acceptable as legal evidence. However, there has been enough accumulated experience in the use of optical storage systems as of mid-1991 so that optical disk drives, especially high capacity drives, are entering a period of broad acceptance that will help sustain growth of the high capacity segment of the optical drive industry and the write-once segment in particular.

The commencement of shipments of the LMSI dual head drive and library in 1991 will hasten the rate of market development, because it provides a vehicle for experimentation at reasonable cost, plus enough capacity and performance to do useful work.

Large capacity optical disk drives will continue to be employed in dedicated departmental systems that store and manipulate engineering drawings, technical specifications and reference materials. These smaller systems will need smaller library units to meet departmental needs. This segment of the market will have to be defended against smaller diameter drives used with library units of 10-20 disk capacity. The LMSI drive and library announced in 1990 are an attempt to preempt competition from smaller diameter drives in the departmental system market segment.

Technical trends

Many of the technical issues discussed in the section on optical disk drives under 1 gigabyte capacity also apply to the larger capacity drives in this section. The issues are reviewed here as they pertain specifically to the higher capacity drives.

* Performance: Almost all of the released products in this group currently use complex optical head assemblies, resulting in excessive head positioning times. This is of less consequence when the drive is used in a library subsystem, because of the

long time required to locate, mount, and spin-up the disk to operating speed. Considerable work is being done by manufacturers to reduce drive complexity and to improve access time. Even so, it will probably be several years before typical head positioning times are below 100 milliseconds for these drives.

For a 12" drive operating at 1,800 RPM, a practical data transfer rate limit is about 10 megabits/second, limited by the spot size and power of the laser. As lasers improve, and as RPM increases, the interface and controller will have to cope with significantly higher data transfer rates. A future 12" drive equipped with a green semiconductor laser and spinning at 3,600 RPM could generate a data transfer rate exceeding 37 megabits/second.

* Standards: Standards for very high capacity media will take several years to materialize, because the initial product designs are already established, even though incompatible. The ANSI X3B11 technical subcommittee, which has the U.S. charter to develop such a standard, has begun deliberations, but does not expect to have a standard for 12" media for some years to come. IBM could change this situation by announcing a high capacity internally manufactured optical drive and creating a de facto standard, but as already noted, an early IBM announcement of a large capacity drive is unlikely, nor is it clear that any such product would be a large diameter design.

* System design: Many large capacity optical disk storage systems will incorporate an automated library. Several firms, including Cygnet, Filenet, Laser Magnetic Storage, Hitachi and others have designed libraries, discovering in the process that it is a major project, requiring substantial time and investment. To be a generally applicable product, the library may have to accommodate several brands of disk drives, an awkward consideration given the lack of product standardization in the industry. The library unit also has to be interfaced to the computer system with which it is to be used, requiring significant development time. The drives themselves must be designed to withstand thousands of cartridge insertions without failure and must accommodate library control and signaling functions.

* Software: The software required to integrate a write-once optical disk into the operating system environment of a mainframe computer represents a major project, requiring many man years of effort. The integration of erasable disks should be easier, but even these will present some problems. Those aspects of the drive unique to optical storage may be masked by the controller, so that the optical storage subsystem appears as a standard magnetic disk to the operating system.

* Capacity: Capacity per disk is increasing through the use of zoned recording and data compression techniques. Newer 12" drives offer over 3 gigabytes per side, improved from a typical capacity of 1 gigabyte per side in earlier models. Eastman

Kodak's 14" drive uses disks with over 5 gigabytes per side. Shorter wavelength lasers are expected to bring an additional 30% to 40% improvement by late 1992.

* Multiple heads: The larger form factor of the high capacity drive permits the eventual use of multiple, independent heads and actuators when economically feasible. Multiple head/actuator assemblies for both sides of the media were prototyped by BOSCO in its flexible 1.3 gigabyte 5.25" drive development effort and were introduced in a new 12" drive by LMSI in 1990. The use of multiple heads in a 5.25" drive with capacity of 500 megabytes per side or more will eventually create a 5.25" diameter category in this product group.

* Rewritability: Nikon has made technology announcements of a rewritable 12" drive and media, but no other firms have yet indicated definite intentions to offer a production drive. Fujitsu's 8" drive incorporates several non-removable disks, but performance is slow. Media yields for large diameter rewritable media are projected to be low by media suppliers, so when and if such drives do appear, media will be scarce and expensive. Consequently, shipments are likely to be modest until media is available and the technology has matured to the point that customers feel confident about the technology.

  Sony and Hewlett-Packard have discussed 5.25" rewritable magneto-optic media of over 1 gigabyte capacity as a future possibility, but have been non-committal on the availability of a dual head drive.

* Non-removable multiple disks: A multidisk Winchester-like configuration has been considered by various system manufacturers, but probably won't be aggressively marketed until the characteristics of optical drive components have advanced to the point where a drive could closely approach the costs and performance of high capacity magnetic disk drives. The disk diameters employed will probably be 5.25" or 8", and the media will, naturally, be rewritable. Fujitsu has made limited quantities of such a drive with 8" disks.

* Packaging: The larger capacity optical disk drives typically have a rack mount configuration. Because these drives are often used with library devices, there is a need to define a standardized mechanical interface that will permit any drive to be used with any library load/unload mechanism.

  For the next few years, the 12" form factor will remain the most frequently encountered size in this product group. As areal density improves and dual head drives are introduced, 5.25" drives are expected to fall into this class of optical drive.

  There is no expectation of any 3.5" drives in this group within the foreseeable future. Major improvements in lasers and other

components will be required before even a dual head 1 gigabyte drive is practical.

* Track following: Pregrooving of the media continues to be the primary method of providing tracking information to the tracking servo for this product group. There has been some interest in using sector servo techniques to improve tracking. ATG Gigadisc has done substantial development work with this technique and has incorporated it into the design of the ATG 12" drive. ATG and other supporters of the sector servo approach believe sector servoing improves the ability of the drive to accept write-once, erasable, and read-only media on the same drive and makes the drive less sensitive to variations in groove shape and depth. This approach has been proposed by ATG in the preparation of a standard for 12" optical media. Laser Magnetic Storage also favors a sector servo approach for its future products.

* Interface: SCSI is the most commonly encountered interface on the large capacity optical drives. SCSI is likely to remain the preferred choice because of design commitments or until drives with higher performance are technically possible. For many drives, proprietary interfaces are used at the device level, but the desire of manufacturers to sell drive/library combinations attachable to a variety of host systems favors the SCSI interface. For drives to be sold to manufacturers of optical disk libraries, the use of the SCSI interface is a necessity.

* Lasers: The larger form factors of the high capacity optical drive favor the use of head assemblies with multiple lasers. The use of multiple lasers can improve drive performance by permitting direct read during write, higher bit densities, use of unusual active layer material, and possibly other benefits. If head designs that separate the laser from the head optics are adopted to reduce mass, it may also be possible to use non-semiconductor lasers and still achieve reasonable performance.

  Because non-semiconductor lasers can operate at higher frequencies and powers, very high performance may be possible by using them in optical storage systems. RCA, for instance, has produced a few specialized systems for the U.S. government using non-semiconductor lasers. However, cost and reliability will have to be traded for performance in such designs. The short wavelength semiconductor lasers being developed by IBM and others probably have more applicability.

* Media: Larger diameter media requires substrates that will not deform at high rotation rates and will maintain consistent optical properties over the usable area of the disk. The latter point is especially significant for magneto-optical media in which distortion caused by locked-in or dynamic stresses in the substrate creates signal degradation. These mechanical problems may be a significant obstacle to improving the performance of high capacity optical drives.

The current limit on rotational velocity for larger diameter disks is created by available laser write power and the performance of focus and tracking servos, rather than by material failure. 1,800 RPM is considered today's advanced state of the art for high capacity 12" drives, and many commercial products operate at half this RPM or less. There are expectations of achieving 2,800 to 3,600 RPM in the future through the use of non-mechanical focusing techniques and improved substrate materials.

* Substrates: Both plastic and glass are in use for 12" media substrates, and Eastman Kodak is using an aluminum substrate for its 14" drive. Because of the difficulty in molding large diameter plastic substrates with adequately low birefringence, it seems likely that glass will play an increasingly prominent role in attempts to fabricate readily producible erasable media for large diameter drives. Producers of glass substrates have demonstrated that glass hardened by ion bombardment has adequate mechanical strength to withstand routine use under projected conditions for future drive designs. However, concern remains as to the effects of small imperfections such as nicks, scratches or chips caused during handling of the disk. More work must be done by drive, media, and substrate producers to determine if such imperfections are a longer term hazard.

Forecasting assumptions

1. No IBM-produced units in this product group will be shipped through 1994.

2. There will continue to be an adequate supply of write-once media for products in this group.

3. Generally recognized media interchange standards for this product group will not exist during the forecast period.

4. There will be no significant shipments of 5.25" or 8" drives in this product group within the forecast period.

5. Rewritable 12" drives and media will have only marginal impact through 1994.

6. LMSI's dual head drive will be a major factor in market growth in this category. Shipments will begin in 1991.

TABLE 30

READ/WRITE OPTICAL DISK DRIVES, MORE THAN 1 GIGABYTE

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1990 Revenues		Forecast 1991		1992		1993		1994	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	--	--	--	--	--	--	--	--	--	--
TOTAL U.S. CAPTIVE	--	--	--	--	--	--	--	--	--	--
PCM/Reseller	--	--	--	--	--	--	--	--	--	--
OEM/Integrator	8.0	8.0	4.1	5.8	2.4	2.4	4.8	4.8	4.8	7.2
TOTAL U.S. NON-CAPTIVE	8.0	8.0	4.1	5.8	2.4	2.4	4.8	4.8	4.8	7.2
TOTAL U.S. REVENUES	8.0	8.0	4.1	5.8	2.4	2.4	4.8	4.8	4.8	7.2
Non-U.S. Manufacturers										
Captive	3.4	72.7	1.9	93.8	3.4	102.6	3.5	106.2	5.3	109.7
PCM/Reseller	1.0	8.8	1.0	11.0	1.4	13.6	1.4	18.1	1.4	23.0
OEM/Integrator	27.9	66.4	46.8	86.5	91.6	142.6	128.5	203.5	146.4	241.1
TOTAL NON-U.S. REVENUES	32.3	147.9	49.7	191.3	96.4	258.8	133.4	327.8	153.1	373.8
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	40.3	155.9	53.8	197.1	98.8	261.2	138.2	332.6	157.9	381.0
OEM Average Price ($000)		11.2		11.4		11.6		12.0		12.4

TABLE 31

READ/WRITE OPTICAL DISK DRIVES, MORE THAN 1 GIGABYTE

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1990		Forecast							
	Shipments		1991		1992		1993		1994	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	--	--	--	--	--	--	--	--	--	--
TOTAL U.S. CAPTIVE	--	--	--	--	--	--	--	--	--	--
PCM/Reseller	--	--	--	--	--	--	--	--	--	--
OEM/Integrator	.5	.5	.2	.3	.1	.1	.2	.2	.2	.3
TOTAL U.S. NON-CAPTIVE	.5	.5	.2	.3	.1	.1	.2	.2	.2	.3
TOTAL U.S. SHIPMENTS	.5	.5	.2	.3	.1	.1	.2	.2	.2	.3
Non-U.S. Manufacturers										
Captive	.2	4.5	.1	5.5	.2	6.0	.2	6.1	.3	6.2
PCM/Reseller	.1	.6	.1	.8	.1	1.0	.1	1.3	.1	1.6
OEM/Integrator	2.8	6.1	4.3	7.8	7.9	12.3	10.8	17.1	11.9	19.6
TOTAL NON-U.S. SHIPMENTS	3.1	11.2	4.5	14.1	8.2	19.3	11.1	24.5	12.3	27.4
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	3.6	11.7	4.7	14.4	8.3	19.4	11.3	24.7	12.5	27.7
Cumulative Shipments (Units in thousands)										
IBM	--	--	--	--	--	--	--	--	--	--
Non-IBM	23.9	56.7	28.6	71.1	36.9	90.5	48.2	115.2	60.7	142.9
WORLDWIDE TOTAL	23.9	56.7	28.6	71.1	36.9	90.5	48.2	115.2	60.7	142.9

TABLE 32

READ/WRITE OPTICAL DISK DRIVES, MORE THAN 1 GIGABYTE

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1990 Estimate Units (000)	1990 Estimate %	1994 Projection Units (000)	1994 Projection %
MAINFRAME/SUPERMINI General purpose	1.4	11.7	1.7	6.2
MINICOMPUTERS AND MULTI-USER MICROS Business and professional, including networks	1.9	16.4	5.6	20.3
PERSONAL COMPUTERS Business and professional, single user	.5	4.4	.4	1.6
OFFICE SYSTEMS AND WORKSTATIONS Dedicated application	4.9	41.5	11.9	42.7
NON-OFFICE SYSTEMS AND WORKSTATIONS Technical, distribution, medical, other specialized	3.0	26.0	8.0	28.9
CONSUMER AND HOBBY COMPUTERS	--	--	--	--
OTHER APPLICATIONS	--	--	.1	.3
Total	11.7	100.0	27.7	100.0

READ-ONLY OPTICAL LIBRARIES

1991 DISK/TREND REPORT

READ-ONLY OPTICAL LIBRARIES

Coverage

Examples of optical disk libraries in this group include:

4.72" disk diameter (CD-ROM)

Kubik Enterprises	DDC-240, Multi-Server
Next Technology	Voyager
NSM	CDR-100
Pioneer	DRM-600, DRM610

Read-only optical disk libraries currently make use of CD-ROM drives only, and it is unlikely that other read-only disk drive formats will become significant, because multifunction drives will be able to handle read-only media in other formats. For the most part, CD-ROM optical disk libraries are derivatives of designs incorporating audio drives.

Market status

The market for read-only optical disk libraries is just getting started. Only three firms are in production and of these, only Pioneer has significant shipment volume. The products range in sophistication from the 270 disk library of Next Technology to the integrated drive and six unit capacity of Pioneer, which is derived from the design of a multi-disk CD audio player.

The Kubik library, an unusual rotary mechanism that operates much like a carousel-type slide projector, is still in pilot line production status. NSM, a German organization, has begun to offer a library based upon a previous audio player version.

Marketing trends

Read-only optical library revenues were $8.4 million in 1990, up substantially from $400,000 in 1989, largely as a result of efforts by Pioneer to promote its six disk library and is expected to reach $18.6 million in 1994. The number of competitors is expected to increase in order to serve network users interested in adding CD-ROM capability to their networks, but the thin market will probably attract only firms which have developed applicable technology for other markets.

Unit shipments in 1990 were 7,902 units. In 1994, shipments of 14,550 units are projected, but the majority of these shipments are expected to be low-end, low performance devices holding no more than ten disks. About 60% of the total unit shipments will be to U.S. companies, and of this amount, 55% will be sold to OEMs. 58% of all reseller shipments will also be to U.S. companies, as will 62% of OEM sales.

Applications

The primary applications for the read-only optical library is in file servers on networks and for high-end personal computers and workstations. High-end read-only libraries are likely to find applications in large institutional libraries and in organizations that must provide network access to large amounts of documentation for many users located at diverse sites. Low-end libraries, such as the Pioneer unit, will be used primarily with single-user computers and workstations or with servers in small networks with low transaction rates.

Certain users of CD-ROM data bases that span more than one disk will find the low-end read-only libraries particularly convenient. Legal case records, citations and regulatory material often fit this pattern, as do

CD-ROM records of archival material such as patent records. Other beneficiaries of low-end libraries could include users of large clip art files, those concerned with large numbers of maps, and analysts wishing to keep large collections of historical financial data readily available.

Technical trends

Read-only disk library technology is derived from other well established product designs. The Pioneer library is an adaptation of an audio player/changer, while the Next Technology design is very much like that of other jukeboxes, incorporating an elevator, dual pickers, and up to eight drives. Kubik's rotary carousel design is innovative and provides a relatively high storage density. Interfaces are standard RS-232 or SCSI variants.

A potentially troublesome problem is that CD-ROM drives are not engineered to withstand the physical stresses of thousands of disk insertions and ejections in a short period of time. Some current CD-ROM disk load/eject mechanism designs require modification so that the drive can be used in a library.

Forecasting assumptions

1. Read-only library sales will continue to be dominated by low cost, low performance devices.
2. Non-U.S. suppliers will dominate the read-only library market. There will be only minor production by U.S. firms.
3. There will be no significant changes in technology affecting read-only libraries over the period of the forecast.
4. Additional competitors will appear in the low-end library market, resulting in price competition that will spur unit shipments.

TABLE 33

OPTICAL LIBRARIES, READ-ONLY

REVENUE SUMMARY

	LIBRARY REVENUES, BY SHIPMENT DESTINATION ($M)									
	1990 Revenues		Forecast 1991		1992		1993		1994	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	--	--	--	--	--	--	--	--	--	--
TOTAL U.S. CAPTIVE	--	--	--	--	--	--	--	--	--	--
PCM/Reseller	.5	.5	.6	.6	.8	.8	.9	.9	.9	1.1
OEM/Integrator	--	--	.7	.7	1.1	1.1	2.0	2.0	3.1	3.5
TOTAL U.S. NON-CAPTIVE	.5	.5	1.3	1.3	1.9	1.9	2.9	2.9	4.0	4.6
TOTAL U.S. REVENUES	.5	.5	1.3	1.3	1.9	1.9	2.9	2.9	4.0	4.6
Non-U.S. Manufacturers										
Captive	--	--	--	--	--	--	--	--	--	--
PCM/Reseller	1.5	2.5	2.4	4.0	2.9	5.0	3.5	6.0	4.0	6.9
OEM/Integrator	3.5	5.4	3.6	5.8	3.9	6.4	4.1	6.8	4.3	7.1
TOTAL NON-U.S. REVENUES	5.0	7.9	6.0	9.8	6.8	11.4	7.6	12.8	8.3	14.0
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	5.5	8.4	7.3	11.1	8.7	13.3	10.5	15.7	12.3	18.6
OEM Average Price ($000)		1.0		1.1		1.2		1.2		1.4

TABLE 34

OPTICAL LIBRARIES, READ-ONLY

UNIT SHIPMENT SUMMARY (SINGLE UNITS)

	LIBRARY UNIT SHIPMENTS, BY SHIPMENT DESTINATION									
	1990 Shipments		Forecast 1991		1992		1993		1994	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	--	--	--	--	--	--	--	--	--	--
TOTAL U.S. CAPTIVE	--	--	--	--	--	--	--	--	--	--
PCM/Reseller	30.0	30.0	40.0	40.0	65.0	65.0	75.0	75.0	80.0	100.0
OEM/Integrator	--	--	80.0	80.0	120.0	120.0	250.0	250.0	440.0	500.0
TOTAL U.S. NON-CAPTIVE	30.0	30.0	120.0	120.0	185.0	185.0	325.0	325.0	520.0	600.0
TOTAL U.S. SHIPMENTS	30.0	30.0	120.0	120.0	185.0	185.0	325.0	325.0	520.0	600.0
Non-U.S. Manufacturers										
Captive	--	--	--	--	--	--	--	--	--	--
PCM/Reseller	1,481.0	2,472.0	2,286.0	3,752.0	2,920.0	5,010.0	3,505.0	6,015.0	3,950.0	6,850.0
OEM/Integrator	3,460.0	5,400.0	3,600.0	5,800.0	3,900.0	6,400.0	4,100.0	6,800.0	4,300.0	7,100.0
TOTAL NON-U.S. SHIPMENTS	4,941.0	7,872.0	5,886.0	9,552.0	6,820.0	11,410.0	7,605.0	12,815.0	8,250.0	13,950.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	4,971.0	7,902.0	6,006.0	9,672.0	7,005.0	11,595.0	7,930.0	13,140.0	8,770.0	14,550.0
Cumulative Shipments (Single units)										
IBM	--	--	--	--	--	--	--	--	--	--
Non-IBM	6,983.0	10,416.0	12,989.0	20,088.0	19,994.0	31,683.0	27,924.0	44,823.0	36,694.0	59,373.0
WORLDWIDE TOTAL	6,983.0	10,416.0	12,989.0	20,088.0	19,994.0	31,683.0	27,924.0	44,823.0	36,694.0	59,373.0

READ/WRITE OPTICAL LIBRARIES 1-39 CARTRIDGES

1991 DISK/TREND REPORT

READ/WRITE OPTICAL LIBRARIES, 1 - 39 CARTRIDGES

Coverage

Examples of optical disk libraries in this group include:

5.25" disk diameter

Aisin Seiki	JC2000
Cygnet Systems	5250/W
DSM	20, 27, 28, 30, 38
Fujitsu	F6442-B2
Hewlett-Packard	C1710A, C1710M-105
Hitachi	OL101, OL112
International Data Engineering	7000, 9000
Mitsubishi Electric	MW-5G2-Z
Ricoh	RJ5160
Toshiba	WM-A012

12" disk diameter

Access	ODSR
DSM	20, 27, 28, 30, 38
Hitachi	OL301
Laser Magnetic Storage	LF 4500
NEC	N7923
Toshiba	WM-A320

Until recent years, libraries in this group were all 12" units, but 5.25" models are now the predominant type. When 3.5" libraries are produced, they will probably appear first in this group. The libraries represented in the list above are quite diverse, ranging from the table-top, single drive, 10 disk unit of IDE to sophisticated multidrive units produced by Hitachi, Hewlett-Packard and DSM.

Also included is the LMSI library, which incorporates the first dual head optical drive, enabling twenty percent of its 28 gigabyte capacity to be on-line at all times. Drives included in libraries of this group are either write-once or rewritable for 5.25" types, but 12" types are still limited to write-once drives because no 12" rewritable drives are currently in production.

Market status

In 1990, 2,062 libraries were shipped for this group, up 251.3% from 1989. Revenues grew by 136.7% from $10 million to $28.4 million. About 53% of 1990 revenues were generated by U.S. manufacturers, notably Hewlett-Packard and IDE. Almost 58% of shipments were made to the U.S.

The vigorous growth in this product group and the strength of the U.S. market reflects the success of IDE, which shipped approximately two thirds of the units sold, realizing success in both the OEM/Integrator and PCM/Reseller distribution channels.

Library producers usually install drives before shipping to customers. Frequently, drives are ordered and supplied by the library producer's customer to the library producer for installation. In other cases, library producers (such as Cygnet, Hewlett-Packard and Hitachi) specify and buy drives and there is no other choice.

This pattern recognizes the wide range of variation in drive performance, reliability and manufacturing tolerances: Not all drives operate equally well in a given library. Business reasons may also dictate the choice of a single drive supplier to reduce development and support costs for captive producers.

Marketing trends

Unit shipments in 1994 are expected to climb to 14,464 units worldwide, with about 65% of the total being sold in the U.S. Both the number of units and the U.S./non-U.S. ratio will be affected by shipment growth of inexpensive tabletop libraries sold for use with workstations and high-end personal computers. The increasing proportion of single-drive libraries will also cause a rapid decline in the average price within this

group during the forecast period. However, viewed separately, high-end and low-end price declines will occur more gradually.

About 62% of the 1994 shipments are projected to be made to OEMs and system integrators. 22% will be through PCM/Resellers, and 16% will be captive shipments. 5.25" shipments, which were 90.1% of the 1990 total shipments, will decline slightly to 86.1% in 1994, as a result of the anticipated success of the 12" LMSI autochanger in this product group.

1994 revenues are expected to reach $143.2 million, 61% by U.S. firms. 63% of the worldwide revenues are expected to be generated by the U.S. market.

An increase in the number of competitors in this group is anticipated during the forecast period, with many innovative product designs expected. Both the LMSI and the IDE libraries will probably be imitated by other producers, and most of the increased competition will be felt in the single drive library category as new designs for small networks and work-station support become available. A new generation of tabletop libraries with 5 to 10 disk capacities is expected to appear in 1991.

As noted previously, the majority of shipments after 1990 will be on an OEM basis, with about 62% of 1994 unit shipments (mostly low-end) made to OEM/Integrators. High-end libraries in this group will also be shipped as part of complete systems supplied by Hewlett-Packard, Hitachi and other system manufacturers which may elect to produce their own libraries. In most cases, however, system manufacturers will elect to be purchasers of libraries rather than make them, and some existing internally manufactured libraries will be phased out and replaced by purchased models.

Applications

Optical libraries with single drives, regardless of diameter, are being used in stand-alone applications where their relatively low price and limited storage capacities are appropriate. Multidrive libraries are more likely to be used in multiuser systems where response time to an inquiry is a critical parameter and the cost is shared among a number of system users.

The LMSI library occupies a middle ground: While relatively low in price, and having only one drive, the dual head drive design provides on-line capacity so large that throughput may frequently be better than that of multidrive 5.25" units. In cases where rewritable media is not required, the LMSI library may displace some 5.25" libraries in both single user and multiuser systems. The LMSI library, and any similar 12" libraries yet to be introduced, are the only types of write-once libraries in this product class expected to sustain growth through 1994.

Technical trends

The success of the IDE tabletop library is expected to lead to the introduction of even smaller libraries, typically holding 5 cartridges, in 1991. Some of these had already been shipped to prospective customers for evaluation as of mid-1991.

For the time being, libraries in this product group will continue to use 5.25" or 12" drives and media. 3.5" libraries are being studied, but until drives with capacities in the 200-300 megabyte range appear, 3.5" libraries will offer so much less throughput than 5.25" libraries that they will be unattractive.

Performance, in terms of average media exchange time, is expected to

improve somewhat for high-end libraries, but is not a critical issue for stand-alone workstations, where convenience, ease of installation and price are likely to be more important parameters. Again, the unique nature of the LMSI library poses a challenge. It is fast (3 second specified average exchange time) and comparatively inexpensive, and its high data availability and throughput will provide difficult performance criteria for conventional 5.25" library designs to meet. Should direct overwrite rewritable 12" drives and media become readily available, small 12" libraries will become more important competitors in all but the most price sensitive situations.

The use of advanced components such as optical position sensors, optical position encoders and non-volatile semiconductor memory for controller functions is improving reliability. Some libraries will perform several hundred thousand cartridge exchanges between failures.

Forecasting assumptions

1. There will be no 3.5" library units in the market until the end of the forecast period, if then.

2. The 5.25" format will be the most commonly used, but it will receive competition from 12" libraries with dual head drives.

3. Erasable drives will be used in more libraries than will write-once drives, and will eventually be supplanted in many applications by multifunction drives when they are available with standard interchange formats.

4. There are no significant changes in technology anticipated affecting libraries over the period of the forecast, but drive capacity improvements will favor the growth of 5.25" libraries over 12" libraries.

5. Single drive 5.25" libraries will be used mostly with stand-alone workstations. Single drive 12" units will be used with workstations and in small multiuser systems. Multidrive libraries will be used in medium to large multiuser systems.

TABLE 35

OPTICAL LIBRARIES, 1-39 DISKS

REVENUE SUMMARY

	LIBRARY REVENUES, BY SHIPMENT DESTINATION ($M)									
	1990 Revenues		Forecast 1991		1992		1993		1994	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	4.0	6.0	7.4	11.2	14.9	21.6	19.9	28.6	24.1	35.8
TOTAL U.S. CAPTIVE	4.0	6.0	7.4	11.2	14.9	21.6	19.9	28.6	24.1	35.8
PCM/Reseller	2.2	2.9	3.6	5.1	14.1	20.0	17.4	24.3	20.0	27.9
OEM/Integrator	4.4	6.2	11.4	16.8	15.6	22.9	16.4	24.9	15.2	23.9
TOTAL U.S. NON-CAPTIVE	6.6	9.1	15.0	21.9	29.7	42.9	33.8	49.2	35.2	51.8
TOTAL U.S. REVENUES	10.6	15.1	22.4	33.1	44.6	64.5	53.7	77.8	59.3	87.6
Non-U.S. Manufacturers										
Captive	.2	8.6	.4	9.8	.6	10.7	.6	11.0	.5	10.7
PCM/Reseller	--	1.1	.7	2.3	.7	3.1	.7	3.0	.6	2.5
OEM/Integrator	.2	3.6	9.9	18.5	18.4	28.7	25.1	37.6	29.7	42.4
TOTAL NON-U.S. REVENUES	.4	13.3	11.0	30.6	19.7	42.5	26.4	51.6	30.8	55.6
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	11.0	28.4	33.4	63.7	64.3	107.0	80.1	129.4	90.1	143.2
OEM Average Price ($000)		12.5		11.9		9.7		8.6		7.3

TABLE 36

OPTICAL LIBRARIES, 1-39 DISKS

UNIT SHIPMENT SUMMARY (SINGLE UNITS)

	LIBRARY UNIT SHIPMENTS, BY SHIPMENT DESTINATION									
	1990		Forecast							
	---Shipments---		------1991-----		------1992-----		------1993-----		------1994-----	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	112.0	168.0	258.0	392.0	668.0	972.0	989.0	1,426.0	1,326.0	1,978.0
TOTAL U.S. CAPTIVE	112.0	168.0	258.0	392.0	668.0	972.0	989.0	1,426.0	1,326.0	1,978.0
PCM/Reseller	604.0	849.0	1,007.0	1,435.0	1,307.0	1,859.0	1,731.0	2,427.0	2,143.0	2,998.0
OEM/Integrator	456.0	665.0	1,352.0	1,983.0	2,484.0	3,707.0	3,227.0	4,953.0	3,824.0	6,036.0
TOTAL U.S. NON-CAPTIVE	1,060.0	1,514.0	2,359.0	3,418.0	3,791.0	5,566.0	4,958.0	7,380.0	5,967.0	9,034.0
TOTAL U.S. SHIPMENTS	1,172.0	1,682.0	2,617.0	3,810.0	4,459.0	6,538.0	5,947.0	8,806.0	7,293.0	11,012.0
Non-U.S. Manufacturers										
Captive	5.0	204.0	14.0	239.0	21.0	266.0	24.0	277.0	22.0	272.0
PCM/Reseller	--	60.0	20.0	90.0	30.0	125.0	41.0	161.0	54.0	190.0
OEM/Integrator	10.0	116.0	585.0	973.0	1,076.0	1,634.0	1,516.0	2,285.0	2,022.0	2,990.0
TOTAL NON-U.S. SHIPMENTS	15.0	380.0	619.0	1,302.0	1,127.0	2,025.0	1,581.0	2,723.0	2,098.0	3,452.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	1,187.0	2,062.0	3,236.0	5,112.0	5,586.0	8,563.0	7,528.0	11,529.0	9,391.0	14,464.0
Cumulative Shipments (Single units)										
IBM	--	--	--	--	--	--	--	--	--	--
Non-IBM	1,506.0	2,649.0	4,742.0	7,761.0	10,328.0	16,324.0	17,856.0	27,853.0	27,247.0	42,317.0
WORLDWIDE TOTAL	1,506.0	2,649.0	4,742.0	7,761.0	10,328.0	16,324.0	17,856.0	27,853.0	27,247.0	42,317.0

TABLE 37

OPTICAL LIBRARIES, 1-39 DISKS

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1990 Revenues		Forecast							
			1991		1992		1993		1994	
	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"
U.S. MANUFACTURERS										
U.S. Captive	5.6	.4	10.8	.4	21.2	.4	28.3	.3	35.5	.3
PCM/Reseller	2.9	--	5.1	--	20.0	--	24.3	--	27.9	--
OEM/Integrator	4.8	1.4	15.7	1.1	22.0	.9	24.2	.7	23.6	.3
TOTAL U.S. REVENUES	13.3	1.8	31.6	1.5	63.2	1.3	76.8	1.0	87.0	.6
NON-U.S. MANUFACTURERS										
Captive	1.7	6.9	2.4	7.4	2.9	7.8	2.9	8.1	2.5	8.2
PCM/Reseller	1.0	.1	1.9	.4	2.6	.5	2.3	.7	1.9	.6
OEM/Integrator	3.4	.2	6.5	12.0	8.4	20.3	11.9	25.7	13.1	29.3
TOTAL NON-U.S. REVENUES	6.1	7.2	10.8	19.8	13.9	28.6	17.1	34.5	17.5	38.1
WORLDWIDE RECAP										
Captive	7.3 +247.6%	7.3 --	13.2 +80.8%	7.8 +6.8%	24.1 +82.6%	8.2 +5.1%	31.2 +29.5%	8.4 +2.4%	38.0 +21.8%	8.5 +1.2%
PCM/Reseller	3.9 --	.1 --	7.0 +79.5%	.4 +300.0%	22.6 +222.9%	.5 +25.0%	26.6 +17.7%	.7 +40.0%	29.8 +12.0%	.6 -14.3%
OEM/Integrator	8.2 +41.4%	1.6 -52.9%	22.2 +170.7%	13.1 +718.8%	30.4 +36.9%	21.2 +61.8%	36.1 +18.8%	26.4 +24.5%	36.7 +1.7%	29.6 +12.1%
Total Revenues	19.4 +139.5%	9.0 +130.8%	42.4 +118.6%	21.3 +136.7%	77.1 +81.8%	29.9 +40.4%	93.9 +21.8%	35.5 +18.7%	104.5 +11.3%	38.7 +9.0%
ANNUAL SHARE, BY DIAMETER	68.4%	31.6%	66.7%	33.3%	72.2%	27.8%	72.7%	27.3%	73.1%	26.9%

Note: 5.25" includes 8" libraries.
12" includes 14" libraries.

TABLE 38

OPTICAL LIBRARIES, 1-39 DISKS

WORLDWIDE SHIPMENTS (UNITS)

BREAKDOWN BY DISK DIAMETER

	1990 Shipments		Forecast							
			1991		1992		1993		1994	
	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"
U.S. MANUFACTURERS										
U.S. Captive	160.0	8.0	384.0	8.0	964.0	8.0	1,419.0	7.0	1,972.0	6.0
PCM/Reseller	849.0	--	1,435.0	--	1,859.0	--	2,427.0	--	2,998.0	--
OEM/Integrator	618.0	47.0	1,946.0	37.0	3,679.0	28.0	4,934.0	19.0	6,028.0	8.0
TOTAL U.S. SHIPMENTS	1,627.0	55.0	3,765.0	45.0	6,502.0	36.0	8,780.0	26.0	10,998.0	14.0
NON-U.S. MANUFACTURERS										
Captive	62.0	142.0	88.0	151.0	106.0	160.0	111.0	166.0	104.0	168.0
PCM/Reseller	57.0	3.0	80.0	10.0	111.0	14.0	143.0	18.0	172.0	18.0
OEM/Integrator	109.0	7.0	292.0	681.0	444.0	1,190.0	773.0	1,512.0	1,158.0	1,832.0
TOTAL NON-U.S. SHIPMENTS	228.0	152.0	460.0	842.0	661.0	1,364.0	1,027.0	1,696.0	1,434.0	2,018.0
WORLDWIDE RECAP										
Captive	222.0	150.0	472.0	159.0	1,070.0	168.0	1,530.0	173.0	2,076.0	174.0
	+252.4%	--	+112.6%	+6.0%	+126.7%	+5.7%	+43.0%	+3.0%	+35.7%	+.6%
PCM/Reseller	906.0	3.0	1,515.0	10.0	1,970.0	14.0	2,570.0	18.0	3,170.0	18.0
	--	--	+67.2%	+233.3%	+30.0%	+40.0%	+30.5%	+28.6%	+23.3%	--
OEM/Integrator	727.0	54.0	2,238.0	718.0	4,123.0	1,218.0	5,707.0	1,531.0	7,186.0	1,840.0
	+100.8%	-61.4%	+207.8%	--	+84.2%	+69.6%	+38.4%	+25.7%	+25.9%	+20.2%
Total Shipments	1,855.0	207.0	4,225.0	887.0	7,163.0	1,400.0	9,807.0	1,722.0	12,432.0	2,032.0
	+326.4%	+36.2%	+127.8%	+328.5%	+69.5%	+57.8%	+36.9%	+23.0%	+26.8%	+18.0%
ANNUAL SHARE, BY DIAMETER	90.1%	9.9%	82.7%	17.3%	83.8%	16.2%	85.2%	14.8%	86.1%	13.9%

Note: 5.25" includes 8" libraries.
12" includes 14" libraries.

TABLE 39

OPTICAL LIBRARIES, 1-39 DISKS

WORLDWIDE SHIPMENTS (SINGLE UNITS)

ERASABLE/WRITE-ONCE DRIVE ANALYSIS

	1990 --Shipments--		Forecast -----1991----		-----1992----		-----1993----		-----1994----	
	Units	%	Units	%	Units	%	Units	%	Units	%
U.S. MANUFACTURERS										
Captive Total	168.0		392.0		972.0		1,426.0		1,978.0	
Write-Once	8.0	4.8	8.0	2.0	8.0	.8	7.0	.5	6.0	.3
Erasable	160.0	95.2	384.0	98.0	964.0	99.2	1,419.0	99.5	1,972.0	99.7
OEM/PCM Total	1,514.0		3,418.0		5,566.0		7,380.0		9,034.0	
Write-Once	472.0	31.2	638.0	18.7	728.0	13.1	780.0	10.6	764.0	8.5
Erasable	1,042.0	68.8	2,780.0	81.3	4,838.0	86.9	6,600.0	89.4	8,270.0	91.5
Total U.S.	1,682.0		3,810.0		6,538.0		8,806.0		11,012.0	
Write-Once	480.0	28.5	646.0	17.0	736.0	11.3	787.0	8.9	770.0	7.0
Erasable	1,202.0	71.5	3,164.0	83.0	5,802.0	88.7	8,019.0	91.1	10,242.0	93.0
NON-U.S. MANUFACTURERS										
Captive Total	204.0		239.0		266.0		277.0		272.0	
Write-Once	204.0	100.0	239.0	100.0	266.0	100.0	277.0	100.0	272.0	100.0
OEM/PCM Total	176.0		1,063.0		1,759.0		2,446.0		3,180.0	
Write-Once	80.0	45.5	772.0	72.7	1,306.0	74.3	1,644.0	67.3	1,962.0	61.8
Erasable	96.0	54.5	291.0	27.3	453.0	25.7	802.0	32.7	1,218.0	38.2
Total Non-U.S.	380.0		1,302.0		2,025.0		2,723.0		3,452.0	
Write-Once	284.0	74.8	1,011.0	77.7	1,572.0	77.7	1,921.0	70.6	2,234.0	64.8
Erasable	96.0	25.2	291.0	22.3	453.0	22.3	802.0	29.4	1,218.0	35.2
WORLDWIDE RECAP										
Total Worldwide Shipments	2,062.0		5,112.0		8,563.0		11,529.0		14,464.0	
	+251.2%		+147.9%		+67.5%		+34.6%		+25.4%	
Write-Once	764.0	37.1	1,657.0	32.4	2,308.0	27.0	2,708.0	23.5	3,004.0	20.8
	+60.1%		+116.8%		+39.2%		+17.3%		+10.9%	
Erasable	1,298.0	62.9	3,455.0	67.6	6,255.0	73.0	8,821.0	76.5	11,460.0	79.2
	--		+166.1%		+81.0%		+41.0%		+29.9%	

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

READ/WRITE OPTICAL LIBRARIES 40-69 CARTRIDGES

1991 DISK/TREND REPORT

READ/WRITE OPTICAL LIBRARIES, 40 - 69 CARTRIDGES

Coverage

Examples of optical disk libraries in this group include:

5.25" disk diameter

Document Imaging Systems	Docustore, 600, 675
DSM	48
Eastman Kodak	560
Hitachi	OL112-12, OL114, OL321
Matsushita Electric Industry	LF-J5000A, LF-J5080, LF-J7000
Mitsubishi Electric	MW-5G2-A
NKK	N-556E, N-556W, N-556MP
Ricoh	RJ5330E

8" disk diameter

Matsushita Graphic Commun.	LD-30

12" disk diameter

Cygnet	1820
DSM	48
Filenet	OSAR 64
NEC	N7921
Sony	WDA 3000, WDA 610

The libraries in this group are mainstream products for classical library uses in imaging and archiving systems. The 12" models are almost always used in multiuser systems because of their high storage capacities. The 5.25" libraries are usually found in multiuser systems also, but some are being used in free-standing document image filing systems.

Market status

Unit shipments of optical libraries for this group in 1990 were 1,253 units, up 112.4% from 1989. 5.25" units outstripped 12" units, capturing 71.8% of worldwide shipments. 1990 revenues climbed to $40.4 million, an increase of 31.6% above the 1989 level. 56.8% of worldwide revenues were

generated by 12" libraries as a result of higher average prices compared to 5.25" libraries. The number of library manufacturers in this product group has remained constant, but not all competitors manufacture libraries internally: Some are made by contract manufacturers on an exclusive basis.

Marketing trends

In 1994, forecasted unit shipments will grow to nearly 4,100 optical disk libraries in this product group. The 1994 balance between 12" and 5.25" drive use will have shifted heavily in favor of 5.25", with nearly 90% of shipments in the smaller size. However, 12" libraries will still hold 28% of total revenues. While an increasing number of manufacturers in the 5.25" segment is expected, the number of competitors in the 12" segment is expected to be constant or slowly declining.

The larger customers for archival applications now appear to desire systems with larger on-line capacity, so interest in 12" write-once drive based libraries is shifting out of this group into libraries with capacities of 70 cartridges or more. Organizations which have lower interest in archival storage are expected to shift to 5.25" based systems with multi-function drives.

While over 54% of the 1990 shipments of libraries in this group involved write-once drives, by 1993 relative equality between write-once and rewritable drives is anticipated. In 1994, rewritable drives are expected to account for about two thirds of worldwide shipments. The balance could shift more quickly if a true de facto standard for multi-function drives is achieved, but archival data storage applications should keep libraries with write-once drives in active demand.

Applications

Archival storage and on-line retrieval of document images are the two primary application areas for these mid-range libraries. Large financial institutions and government organizations are believed to be the most significant applications, followed by aerospace companies, large construction firms and geophysical exploration and production firms.

Multiple user microcomputers and minicomputers will be the most frequently found host systems for the medium scale optical library, followed by non-office systems and workstations.

Technical trends

The most significant changes are expected in several areas: An increasing number of drives per library to increase on-line data availability, an increased capacity per drive, and almost universal availability of dual cartridge elevator pickers on libraries in this class.

Specialized internal controllers will be increasingly replaced by personal computer processors packaged for the application. The basic electronic modules of a personal computer are fast enough and powerful enough to perform the necessary functions, and costs are low.

Forecasting assumptions

1. Archival applications will continue to favor write-once drives and media. Other applications will favor 5.25" rewritable or multifunction drive based optical libraries.

2. There are no immediate expectations in this product group for libraries using formats other than 12" and 5.25" format.

3. IBM, DEC, and other major system manufacturers will be marketing libraries of this class during the forecast period.

4. There will be no fundamental changes in technology affecting this group of libraries over the period of the forecast.

TABLE 40

OPTICAL LIBRARIES, 40-69 DISKS

REVENUE SUMMARY

	LIBRARY REVENUES, BY SHIPMENT DESTINATION ($M)									
	1990 Revenues		Forecast 1991		1992		1993		1994	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	6.2	9.6	1.6	2.4	.8	1.1	.7	.9	--	--
TOTAL U.S. CAPTIVE	6.2	9.6	1.6	2.4	.8	1.1	.7	.9	--	--
PCM/Reseller	--	--	1.0	1.0	1.6	1.6	2.1	2.3	2.6	2.9
OEM/Integrator	5.1	6.9	9.0	11.2	12.1	15.2	14.3	18.7	17.0	22.0
TOTAL U.S. NON-CAPTIVE	5.1	6.9	10.0	12.2	13.7	16.8	16.4	21.0	19.6	24.9
TOTAL U.S. REVENUES	11.3	16.5	11.6	14.6	14.5	17.9	17.1	21.9	19.6	24.9
Non-U.S. Manufacturers										
Captive	--	6.6	--	6.1	--	4.8	--	4.9	--	4.8
PCM/Reseller	1.9	4.2	3.7	7.3	5.5	10.2	6.1	11.7	7.2	13.2
OEM/Integrator	7.4	13.1	9.7	15.8	11.1	18.8	12.4	21.3	13.8	24.2
TOTAL NON-U.S. REVENUES	9.3	23.9	13.4	29.2	16.6	33.8	18.5	37.9	21.0	42.2
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	20.6	40.4	25.0	43.8	31.1	51.7	35.6	59.8	40.6	67.1
OEM Average Price ($000)		26.7		21.8		19.9		18.1		16.9

TABLE 41

OPTICAL LIBRARIES, 40-69 DISKS

UNIT SHIPMENT SUMMARY (SINGLE UNITS)

	LIBRARY UNIT SHIPMENTS, BY SHIPMENT DESTINATION									
	1990		Forecast							
	Shipments		1991		1992		1993		1994	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	39.0	60.0	10.0	15.0	5.0	7.0	4.0	5.0	--	--
TOTAL U.S. CAPTIVE	39.0	60.0	10.0	15.0	5.0	7.0	4.0	5.0	--	--
PCM/Reseller	--	--	71.0	74.0	116.0	116.0	154.0	166.0	197.0	223.0
OEM/Integrator	93.0	125.0	378.0	440.0	601.0	727.0	793.0	1,005.0	1,034.0	1,302.0
TOTAL U.S. NON-CAPTIVE	93.0	125.0	449.0	514.0	717.0	843.0	947.0	1,171.0	1,231.0	1,525.0
TOTAL U.S. SHIPMENTS	132.0	185.0	459.0	529.0	722.0	850.0	951.0	1,176.0	1,231.0	1,525.0
Non-U.S. Manufacturers										
Captive	--	179.0	--	140.0	--	141.0	--	148.0	--	159.0
PCM/Reseller	125.0	265.0	266.0	492.0	391.0	709.0	453.0	845.0	558.0	990.0
OEM/Integrator	322.0	624.0	491.0	797.0	585.0	983.0	711.0	1,200.0	821.0	1,424.0
TOTAL NON-U.S. SHIPMENTS	447.0	1,068.0	757.0	1,429.0	976.0	1,833.0	1,164.0	2,193.0	1,379.0	2,573.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	579.0	1,253.0	1,216.0	1,958.0	1,698.0	2,683.0	2,115.0	3,369.0	2,610.0	4,098.0
Cumulative Shipments (Single units)										
IBM	--	--	--	--	--	--	--	--	--	--
Non-IBM	840.0	1,843.0	2,056.0	3,801.0	3,754.0	6,484.0	5,869.0	9,853.0	8,479.0	13,951.0
WORLDWIDE TOTAL	840.0	1,843.0	2,056.0	3,801.0	3,754.0	6,484.0	5,869.0	9,853.0	8,479.0	13,951.0

TABLE 42

OPTICAL LIBRARIES, 40-69 DISKS

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1990 Revenues		Forecast							
			1991		1992		1993		1994	
	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"
U.S. MANUFACTURERS										
U.S. Captive	--	9.6	--	2.4	--	1.1	--	.9	--	--
PCM/Reseller	--	--	1.0	--	1.6	--	2.3	--	2.9	--
OEM/Integrator	--	6.9	4.6	6.6	8.7	6.5	11.6	7.1	14.4	7.6
TOTAL U.S. REVENUES	--	16.5	5.6	9.0	10.3	7.6	13.9	8.0	17.3	7.6
NON-U.S. MANUFACTURERS										
Captive	5.7	.9	4.8	1.3	3.8	1.0	4.1	.8	4.1	.7
PCM/Reseller	4.1	.1	7.1	.2	9.9	.3	11.4	.3	12.8	.4
OEM/Integrator	7.6	5.5	8.4	7.4	10.4	8.4	12.3	9.0	13.9	10.3
TOTAL NON-U.S. REVENUES	17.4	6.5	20.3	8.9	24.1	9.7	27.8	10.1	30.8	11.4
WORLDWIDE RECAP										
Captive	5.7 +103.6%	10.5 -27.1%	4.8 -15.8%	3.7 -64.8%	3.8 -20.8%	2.1 -43.2%	4.1 +7.9%	1.7 -19.0%	4.1 --	.7 -58.8%
PCM/Reseller	4.1 --	.1 --	8.1 +97.6%	.2 +100.0%	11.5 +42.0%	.3 +50.0%	13.7 +19.1%	.3 --	15.7 +14.6%	.4 +33.3%
OEM/Integrator	7.6 +171.4%	12.4 +15.9%	13.0 +71.1%	14.0 +12.9%	19.1 +46.9%	14.9 +6.4%	23.9 +25.1%	16.1 +8.1%	28.3 +18.4%	17.9 +11.2%
Total Revenues	17.4 +210.7%	23.0 -8.4%	25.9 +48.9%	17.9 -22.2%	34.4 +32.8%	17.3 -3.4%	41.7 +21.2%	18.1 +4.6%	48.1 +15.3%	19.0 +5.0%
ANNUAL SHARE, BY DIAMETER	43.2%	56.8%	59.2%	40.8%	66.6%	33.4%	69.8%	30.2%	71.8%	28.2%

Note: 5.25" includes 8" libraries
12" includes 14" libraries

TABLE 43

OPTICAL LIBRARIES, 40-69 DISKS

WORLDWIDE SHIPMENTS (UNITS)

BREAKDOWN BY DISK DIAMETER

	1990 Shipments		Forecast 1991		1992		1993		1994	
	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"
U.S. MANUFACTURERS										
U.S. Captive	--	60.0	--	15.0	--	7.0	--	5.0	--	--
PCM/Reseller	--	--	74.0	--	116.0	--	166.0	--	223.0	--
OEM/Integrator	2.0	123.0	315.0	125.0	597.0	130.0	851.0	154.0	1,137.0	165.0
TOTAL U.S. SHIPMENTS	2.0	183.0	389.0	140.0	713.0	137.0	1,017.0	159.0	1,360.0	165.0
NON-U.S. MANUFACTURERS										
Captive	154.0	25.0	120.0	20.0	125.0	16.0	136.0	12.0	148.0	11.0
PCM/Reseller	264.0	1.0	489.0	3.0	704.0	5.0	839.0	6.0	984.0	6.0
OEM/Integrator	479.0	145.0	593.0	204.0	738.0	245.0	944.0	256.0	1,148.0	276.0
TOTAL NON-U.S. SHIPMENTS	897.0	171.0	1,202.0	227.0	1,567.0	266.0	1,919.0	274.0	2,280.0	293.0
WORLDWIDE RECAP										
Captive	154.0	85.0	120.0	35.0	125.0	23.0	136.0	17.0	148.0	11.0
	+208.0%	-49.4%	-22.1%	-58.8%	+4.2%	-34.3%	+8.8%	-26.1%	+8.8%	-35.3%
PCM/Reseller	264.0	1.0	563.0	3.0	820.0	5.0	1,005.0	6.0	1,207.0	6.0
	--	--	+113.3%	+200.0%	+45.6%	+66.7%	+22.6%	+20.0%	+20.1%	--
OEM/Integrator	481.0	268.0	908.0	329.0	1,335.0	375.0	1,795.0	410.0	2,285.0	441.0
	+208.3%	+24.1%	+88.8%	+22.8%	+47.0%	+14.0%	+34.5%	+9.3%	+27.3%	+7.6%
Total Shipments	899.0	354.0	1,591.0	367.0	2,280.0	403.0	2,936.0	433.0	3,640.0	458.0
	+336.4%	-7.8%	+77.0%	+3.7%	+43.3%	+9.8%	+28.8%	+7.4%	+24.0%	+5.8%
ANNUAL SHARE, BY DIAMETER	71.8%	28.2%	81.4%	18.6%	85.1%	14.9%	87.2%	12.8%	88.9%	11.1%

Note: 5.25" includes 8" libraries
12" includes 14" libraries

TABLE 44

OPTICAL LIBRARIES, 40-69 DISKS

WORLDWIDE SHIPMENTS (SINGLE UNITS)

ERASABLE/WRITE-ONCE DRIVE ANALYSIS

	1990 --Shipments--		Forecast -----1991----		-----1992----		-----1993----		-----1994----	
	Units	%	Units	%	Units	%	Units	%	Units	%
U.S. MANUFACTURERS										
Captive Total	60.0		15.0		7.0		5.0		--	
Write-Once	60.0	100.0	15.0	100.0	7.0	100.0	5.0	100.0	--	--
OEM/PCM Total	125.0		514.0		843.0		1,171.0		1,525.0	
Write-Once	125.0	100.0	293.0	57.1	437.0	51.9	546.0	46.6	563.0	36.9
Erasable	--	--	221.0	42.9	406.0	48.1	625.0	53.4	962.0	63.1
Total U.S.	185.0		529.0		850.0		1,176.0		1,525.0	
Write-Once	185.0	100.0	308.0	58.3	444.0	52.3	551.0	46.9	563.0	36.9
Erasable	--	--	221.0	41.7	406.0	47.7	625.0	53.1	962.0	63.1
NON-U.S. MANUFACTURERS										
Captive Total	179.0		140.0		141.0		148.0		159.0	
Write-Once	117.0	65.5	64.0	45.7	28.0	19.9	22.0	14.9	19.0	11.9
Erasable	62.0	34.5	76.0	54.3	113.0	80.1	126.0	85.1	140.0	88.1
OEM/PCM Total	889.0		1,289.0		1,692.0		2,045.0		2,414.0	
Write-Once	569.0	64.1	727.0	56.5	837.0	49.5	843.0	41.2	841.0	34.8
Erasable	320.0	35.9	562.0	43.5	855.0	50.5	1,202.0	58.8	1,573.0	65.2
Total Non-U.S.	1,068.0		1,429.0		1,833.0		2,193.0		2,573.0	
Write-Once	686.0	64.3	791.0	55.5	865.0	47.2	865.0	39.4	860.0	33.4
Erasable	382.0	35.7	638.0	44.5	968.0	52.8	1,328.0	60.6	1,713.0	66.6
WORLDWIDE RECAP										
Total Worldwide Shipments	1,253.0		1,958.0		2,683.0		3,369.0		4,098.0	
	+112.3%		+56.2%		+37.0%		+25.5%		+21.6%	
Write-Once	871.0	69.6	1,099.0	56.2	1,309.0	48.8	1,416.0	42.0	1,423.0	34.7
	+54.4%		+26.1%		+19.1%		+8.1%		+.4%	
Erasable	382.0	30.4	859.0	43.8	1,374.0	51.2	1,953.0	58.0	2,675.0	65.3
	--		+124.8%		+59.9%		+42.1%		+36.9%	

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

READ/WRITE OPTICAL LIBRARIES 70 OR MORE CARTRIDGES

1991 DISK/TREND REPORT

READ/WRITE OPTICAL LIBRARIES, 70 OR MORE CARTRIDGES

Coverage

Examples of optical disk libraries in this group include:

5.25" disk diameter

Document Imaging Systems	675, 900
DSM	5100,5200,5500
Hewlett-Packard	C1715M
Mitsubishi Electric	MW-5G2-B, ME-5G2-C

12" and 14" disk diameter

Cygnet Systems	1800
Eastman Kodak	6800 ADL
Filenet	OSAR models 79GT, 144GT, 288

This group was pioneered by manufacturers of 12" libraries, which are typically used in large systems that manage image files for a complete business or major government department. Filenet started the 12" activity in this product group in 1985, and now battles with Cygnet for dominance. 5.25" libraries are starting to appear in increasing numbers, and are expected to be an area of increasing competition in the next few years.

Market status

In 1990, 271 units were shipped, a modest 7.1% increase that was restrained by economic conditions. All but 31 units (11.4%) were 12" models. Worldwide revenues rose 5.1% to $25.1 million, 73% of which was generated from sales in the U.S. This is a decrease from 1989, when 83% was generated from U.S. sales and reflects the slowdown in 1990 business activity within the U.S.

American manufacturers continue to dominate the product group, with Filenet, Cygnet and Hewlett-Packard the major players. Hewlett-Packard

announced two models in this product group in 1991 and was successful in capturing IBM as an OEM customer for these models. IBM's use of 5.25" technology for a mainstream product will influence the choices made by other system manufacturers and their customers and is expected to stimulate sales of 5.25" systems.

Nearly 74% of 1990 shipments were to the OEM/Integrator channel, with captive and small PCM/Reseller shipments providing the balance. U.S. firms shipped nearly 88% of the worldwide unit total, an increase over 1989, due to weak market presence by non-U.S. firms.

There is a low level of PCM/Reseller activity for the libraries in this group because the system integration and support requirements are very complex and the costs of the 12" libraries are a burden for the typical reseller. Reseller activity tends to concentrate in Europe where the typical reseller is more likely to be technically sophisticated and in the 5.25" subsystem area where complexity is less and carrying costs are lower.

Non-U.S. manufacturers will probably increase their participation in this product group. The most likely gains in share for the non-U.S. firms is expected to be in the 5.25" optical library segment.

It is also likely that the number of competitors in this product group will increase. The new entrants are most likely to specialize in libraries handling 5.25" disk cartridges.

Marketing trends

1994 worldwide shipments are forecasted to grow to 1,272 units, with 70% expected to occur in the U.S., reflecting an expanding market outside the U.S. 1994 revenue will grow to $84.9 million, 69% of which will be

generated in the U.S., reflecting a trend toward larger system configurations but a greater use of less expensive 5.25" systems.

12" libraries should be able to retain 57% of the unit shipments in 1994, all but a few of which will be using write-once media exclusively. The 5.25" libraries are more likely to use erasable or multifunction drives. The emphasis on archival storage applications on large systems in this product group and the desire of the archivist to minimize the number of media units favor the continued use of 12" write-once drives.

Over half of the libraries in this product group will be attached to multiuser micro or minicomputers and about a third will use a non-office technical system or workstation environment as its host system. Mainframe attachments may represent about 10% to 15% of the 1994 library sales.

Libraries using rewritable disk drives are expected to increase their share of the market from 1% in 1990 to 46% in 1994. Most, if not all, of the rewritable drives will be 5.25" diameter drives.

Applications

Financial and government institutions are, and will remain, the major users of optical libraries in this product group. It is possible that towards the end of the forecast period, optical library based mass storage systems designed to replace the IBM 3850 and other tape based mass storage systems for mainframe applications may appear in the market.

The IBM 3995 optical library introduced in 1991 (based on the Hewlett-Packard library) represents a near-term response to customer pressures for a library and the competitive pressure of Storage Technology's model 4400 tape-based library system. The 3995 library is not the expected replacement for the 3850 mass storage subsystem.

Technical trends

The large libraries that have appeared so far have used X-Y positioners accessing multiple bays of disk cartridge storage cells. Some of the new 5.25" models (those of Document Image Storage and DSM, for instance) offer the buyer the ability to configure the library with almost any combination of drives and storage cells. These same systems also offer multiple independently actuated positioner mechanisms. In the future, library designers may even attempt a silo design similar in concept to the tape cartridge library developed by Storage Technology. However, it is likely that such a design would make use of 5.25" or 3.5" media units rather than 12" media.

5.25" drives with higher capacities of 2 gigabytes (1 gigabyte per side) are expected to appear within the forecast period. As they appear, they will help 5.25" based optical libraries to compete more strongly against 12" drives, because fewer disk swaps will be required to support a given amount of stored data. 12" drive storage capabilities are also expected to increase, but probably will be an advantage only in archival applications or in smaller systems where multiple accesses for the same data are less likely to occur.

Forecasting assumptions

1. Governments, financial institutions and other large users will continue to be the primary market for libraries in this product group.
2. 12" will remain dominant format in the near term, but will be challenged by 5.25" libraries. Other formats are not expected to be significant in the forecast period.
3. U.S. suppliers will continue to dominate this segment of the library market due to their experience and strength in system integration skills.

4. There will be no significant changes in basic technology affecting these libraries over the period of the forecast.

5. IBM's adoption of 5.25" library technology will strongly reinforce a shift from 12" to 5.25" technology in this product group. The appearance of higher capacity 5.25" drives will also contribute to this shift.

TABLE 45

OPTICAL LIBRARIES, 70 OR MORE DISKS

REVENUE SUMMARY

	LIBRARY REVENUES, BY SHIPMENT DESTINATION ($M)									
	1990 Revenues		Forecast							
			1991		1992		1993		1994	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	5.8	8.9	10.2	15.4	15.7	24.1	21.6	32.8	26.0	38.3
TOTAL U.S. CAPTIVE	5.8	8.9	10.2	15.4	15.7	24.1	21.6	32.8	26.0	38.3
PCM/Reseller	--	--	--	--	--	--	--	--	--	--
OEM/Integrator	12.3	14.8	19.7	24.8	27.1	32.6	29.8	36.7	30.2	38.8
TOTAL U.S. NON-CAPTIVE	12.3	14.8	19.7	24.8	27.1	32.6	29.8	36.7	30.2	38.8
TOTAL U.S. REVENUES	18.1	23.7	29.9	40.2	42.8	56.7	51.4	69.5	56.2	77.1
Non-U.S. Manufacturers										
Captive	--	.2	.1	.4	--	.6	--	.7	--	1.0
PCM/Reseller	.1	.9	.1	1.6	.1	1.9	.1	2.1	.1	1.9
OEM/Integrator	.1	.3	.1	.3	.4	1.6	1.3	3.3	2.4	4.9
TOTAL NON-U.S. REVENUES	.2	1.4	.3	2.3	.5	4.1	1.4	6.1	2.5	7.8
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	18.3	25.1	30.2	42.5	43.3	60.8	52.8	75.6	58.7	84.9
OEM Average Price ($000)		75.5		66.6		53.6		49.8		46.2

TABLE 46

OPTICAL LIBRARIES, 70 OR MORE DISKS

UNIT SHIPMENT SUMMARY (SINGLE UNITS)

	LIBRARY UNIT SHIPMENTS, BY SHIPMENT DESTINATION									
	1990		Forecast							
	Shipments		1991		1992		1993		1994	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	32.0	49.0	60.0	87.0	94.0	140.0	143.0	205.0	192.0	268.0
TOTAL U.S. CAPTIVE	32.0	49.0	60.0	87.0	94.0	140.0	143.0	205.0	192.0	268.0
PCM/Reseller	--	--	--	--	--	--	--	--	--	--
OEM/Integrator	154.0	189.0	289.0	364.0	486.0	593.0	570.0	711.0	621.0	805.0
TOTAL U.S. NON-CAPTIVE	154.0	189.0	289.0	364.0	486.0	593.0	570.0	711.0	621.0	805.0
TOTAL U.S. SHIPMENTS	186.0	238.0	349.0	451.0	580.0	733.0	713.0	916.0	813.0	1,073.0
Non-U.S. Manufacturers										
Captive	--	7.0	2.0	11.0	--	17.0	--	21.0	--	28.0
PCM/Reseller	2.0	15.0	3.0	25.0	4.0	30.0	4.0	33.0	3.0	31.0
OEM/Integrator	3.0	11.0	4.0	13.0	15.0	45.0	42.0	93.0	73.0	140.0
TOTAL NON-U.S. SHIPMENTS	5.0	33.0	9.0	49.0	19.0	92.0	46.0	147.0	76.0	199.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	191.0	271.0	358.0	500.0	599.0	825.0	759.0	1,063.0	889.0	1,272.0
Cumulative Shipments (Single units)										
IBM	--	--	--	--	--	--	--	--	--	--
Non-IBM	390.0	524.0	748.0	1,024.0	1,347.0	1,849.0	2,106.0	2,912.0	2,995.0	4,184.0
WORLDWIDE TOTAL	390.0	524.0	748.0	1,024.0	1,347.0	1,849.0	2,106.0	2,912.0	2,995.0	4,184.0

TABLE 47

OPTICAL LIBRARIES, 70 OR MORE DISKS

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1990 Revenues		Forecast							
			1991		1992		1993		1994	
	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"
U.S. MANUFACTURERS										
U.S. Captive	--	8.9	.6	14.8	1.6	22.5	3.1	29.7	4.9	33.4
OEM/Integrator	.1	14.7	3.7	21.1	10.3	22.3	12.7	24.0	14.0	24.8
TOTAL U.S. REVENUES	.1	23.6	4.3	35.9	11.9	44.8	15.8	53.7	18.9	58.2
NON-U.S. MANUFACTURERS										
Captive	.2	--	.4	--	.6	--	.7	--	1.0	--
PCM/Reseller	.4	.5	.6	1.0	.7	1.2	.8	1.3	.9	1.0
OEM/Integrator	.3	--	.3	--	1.0	.6	2.3	1.0	3.1	1.8
TOTAL NON-U.S. REVENUES	.9	.5	1.3	1.0	2.3	1.8	3.8	2.3	5.0	2.8
WORLDWIDE RECAP										
Captive	.2 -33.3%	8.9 +6.0%	1.0 +400.0%	14.8 +66.3%	2.2 +120.0%	22.5 +52.0%	3.8 +72.7%	29.7 +32.0%	5.9 +55.3%	33.4 +12.5%
PCM/Reseller	.4 --	.5 --	.6 +50.0%	1.0 +100.0%	.7 +16.7%	1.2 +20.0%	.8 +14.3%	1.3 +8.3%	.9 +12.5%	1.0 -23.1%
OEM/Integrator	.4 --	14.7 +.7%	4.0 +900.0%	21.1 +43.5%	11.3 +182.5%	22.9 +8.5%	15.0 +32.7%	25.0 +9.2%	17.1 +14.0%	26.6 +6.4%
Total Revenues	1.0 +42.9%	24.1 +4.8%	5.6 +460.0%	36.9 +53.1%	14.2 +153.6%	46.6 +26.3%	19.6 +38.0%	56.0 +20.2%	23.9 +21.9%	61.0 +8.9%
ANNUAL SHARE, BY DIAMETER	4.0%	96.0%	13.2%	86.8%	23.4%	76.6%	26.0%	74.0%	28.3%	71.7%

Note: 5.25" includes 8" libraries.
12" includes 14" libraries.

TABLE 48

OPTICAL LIBRARIES, 70 OR MORE DISKS

WORLDWIDE SHIPMENTS (UNITS)

BREAKDOWN BY DISK DIAMETER

	1990 Shipments		Forecast							
	1991		1992		1993		1994			
	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"
U.S. MANUFACTURERS										
U.S. Captive	--	49.0	13.0	74.0	33.0	107.0	70.0	135.0	116.0	152.0
OEM/Integrator	1.0	188.0	89.0	275.0	292.0	301.0	374.0	337.0	445.0	360.0
TOTAL U.S. SHIPMENTS	1.0	237.0	102.0	349.0	325.0	408.0	444.0	472.0	561.0	512.0
NON-U.S. MANUFACTURERS										
Captive	7.0	--	11.0	--	17.0	--	21.0	--	28.0	--
PCM/Reseller	12.0	3.0	19.0	6.0	23.0	7.0	25.0	8.0	25.0	6.0
OEM/Integrator	11.0	--	13.0	--	36.0	9.0	78.0	15.0	112.0	28.0
TOTAL NON-U.S. SHIPMENTS	30.0	3.0	43.0	6.0	76.0	16.0	124.0	23.0	165.0	34.0
WORLDWIDE RECAP										
Captive	7.0	49.0	24.0	74.0	50.0	107.0	91.0	135.0	144.0	152.0
	-30.0%	+11.4%	+242.9%	+51.0%	+108.3%	+44.6%	+82.0%	+26.2%	+58.2%	+12.6%
PCM/Reseller	12.0	3.0	19.0	6.0	23.0	7.0	25.0	8.0	25.0	6.0
	--	--	+58.3%	+100.0%	+21.1%	+16.7%	+8.7%	+14.3%	--	-25.0%
OEM/Integrator	12.0	188.0	102.0	275.0	328.0	310.0	452.0	352.0	557.0	388.0
	-40.0%	+5.0%	+750.0%	+46.3%	+221.6%	+12.7%	+37.8%	+13.5%	+23.2%	+10.2%
Total Shipments	31.0	240.0	145.0	355.0	401.0	424.0	568.0	495.0	726.0	546.0
	+3.3%	+7.6%	+367.7%	+47.9%	+176.6%	+19.4%	+41.6%	+16.7%	+27.8%	+10.3%
ANNUAL SHARE, BY DIAMETER	11.4%	88.6%	29.1%	70.9%	48.7%	51.3%	53.5%	46.5%	57.2%	42.8%

Note: 5.25" includes 8" libraries.
12" includes 14" libraries.

TABLE 49

OPTICAL LIBRARIES, 70 OR MORE DISKS

WORLDWIDE SHIPMENTS (SINGLE UNITS)

ERASABLE/WRITE-ONCE DRIVE ANALYSIS

	1990 --Shipments--		Forecast							
			1991		1992		1993		1994	
	Units	%	Units	%	Units	%	Units	%	Units	%
U.S. MANUFACTURERS										
Captive Total	49.0		87.0		140.0		205.0		268.0	
Write-Once	49.0	100.0	74.0	85.2	107.0	76.5	135.0	66.0	152.0	56.8
Erasable	--	--	13.0	14.8	33.0	23.5	70.0	34.0	116.0	43.2
OEM/PCM Total	189.0		364.0		593.0		711.0		805.0	
Write-Once	189.0	100.0	279.0	76.7	307.0	51.9	346.0	48.7	373.0	46.3
Erasable	--	--	85.0	23.3	286.0	48.1	365.0	51.3	432.0	53.7
Total U.S.	238.0		451.0		733.0		916.0		1,073.0	
Write-Once	238.0	100.0	353.0	78.4	414.0	56.6	481.0	52.6	525.0	48.9
Erasable	--	--	98.0	21.6	319.0	43.4	435.0	47.4	548.0	51.1
NON-U.S. MANUFACTURERS										
Captive Total	7.0		11.0		17.0		21.0		28.0	
Write-Once	7.0	100.0	11.0	100.0	9.0	53.0	9.0	42.9	8.0	28.6
Erasable	--	--	--	--	8.0	47.0	12.0	57.1	20.0	71.4
OEM/PCM Total	26.0		38.0		75.0		126.0		171.0	
Write-Once	23.0	88.6	30.0	79.0	45.0	60.1	59.0	46.8	55.0	32.2
Erasable	3.0	11.4	8.0	21.0	30.0	39.9	67.0	53.2	116.0	67.8
Total Non-U.S.	33.0		49.0		92.0		147.0		199.0	
Write-Once	30.0	91.0	41.0	83.8	54.0	58.8	68.0	46.3	63.0	31.7
Erasable	3.0	9.0	8.0	16.2	38.0	41.2	79.0	53.7	136.0	68.3
WORLDWIDE RECAP										
Total Worldwide Shipments	271.0		500.0		825.0		1,063.0		1,272.0	
	+7.1%		+84.5%		+65.0%		+28.8%		+19.6%	
Write-Once	268.0	99.0	394.0	78.9	468.0	56.8	549.0	51.7	588.0	46.2
	+5.9%		+47.0%		+18.7%		+17.3%		+7.1%	
Erasable	3.0	1.0	106.0	21.1	357.0	43.2	514.0	48.3	684.0	53.8
	--		--		+236.7%		+43.9%		+33.0%	

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

1991 DISK/TREND REPORT

OPTICAL DISK DRIVE SPECIFICATIONS

Coverage: The following pages list optical disk drives intended for computer data storage which are now announced or in new production. In a few cases, products are listed for which only preliminary announcements have been made because they are judged to be significant indicators of industry direction in the production period shown.

Recording medium: The composition of the active layer of optical media is the one described by the drive manufacturer. Formulations of other manufacturers may not operate properly. Recording formats also differ, and for many products announced to date, recorded media is generally not interchangeable between systems. Where manufacturers specify that more than one type of media is usable, media type is indicated as "Various".

Operating mode: Rewritable (erasable) drives are indicated on the line describing the operating mode, with the technology type in parentheses.

Interface: Specific interfaces are listed for most of the drives. The abbreviation "PC" means the IBM PC/XT or PC/AT interface.

Speed control: Two abbreviations are used:

CAV = constant angular velocity.
CLV = constant linear velocity.

Capacities: Capacities are listed as "U" for unformatted and "F" for formatted. For optical drives that can access only one side of the media, the capacity given is in terms of one side, even if the drive uses two-sided media. As optical media is preformatted, the capacity given is the formatted capacity. Track capacity in CLV drives is variable, so this

parameter is given only for CAV drives. For CD-ROM drives, the capacity given is the mode 1 capacity, as drives are commonly used in that mode.

Servo type: Optical drive servo types are noted as:

Continuous: Continuous composite servo format
Sampled: Sampled servo format
Sector: Sampled servo format with RZ encoding

Positioner type: Many optical drives have multistage head positioners. A coarse movement positions the head in the vicinity of the track to be located. A fine, or vernier, actuator then moves the head to the desired track. Where appropriate, the abbreviation "Crs" is used for "coarse".

Accuracy: All of the information in this section has been checked for accuracy. Due to rapid changes in the industry, report users may need to make verbal inquiries of manufacturers for updates. Where data is not specified or otherwise unavailable, the abbreviation "NS" is used. Where a specification is not applicable, the abbreviation "N/A" appears.

1991 DISK/TREND optical disk product groups

For the 1991 report, products are classified in six groups.

Optical drives:

Group 10: Read-only optical disk drives.
Group 11: Read/write disk drives, less than 1 gigabyte.
Group 12: Read/write disk drives, more than 1 gigabyte.

Optical libraries:

Group 50: Read-only optical libraries
Group 51: Optical libraries with 1 to 39 cartridge capacity
Group 52: Optical libraries with 40 to 69 cartridge capacity
Group 53: Optical libraries with 70 or over cartridge capacity

MANUFACTURER	ATG GIGADISC	ATG GIGADISC	ATG GIGADISC	ATG GIGADISC	CANON
DRIVE	GD 1002	GD 6000	GD 6001	GD 9001	MO-5001S
DISK/TREND GROUP	12	12	12	12	11
MARKET	OEM	OEM	OEM	OEM	Captive, OEM
MEDIA: Nominal disk diameter	300 mm	300 mm	300 mm	300 mm	130 mm
Recording medium	Au-Cr-Polymer	Au-Cr-Polymer	Au-Cr-Polymer	Au-Cr-Polymer	Tb-Fe-Co
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Write Once	Write Once	Write Once	Write Once	Rewritable-(MO)
Interface	SCSI	SCSI	SCSI	SCSI, SCSI-2	SCSI
Speed control	CAV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 1,000	F: 3,200	F: 3,200	F: 4,500	F: 256
Capacity per track (Bytes)	F: 25,600	F: 52,428	F: 52,428	F: 73,726	F: 16,384
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	40000	62500	62500	62500	15728
Track density (TPI)	14514	25400	25400	25400	15875
Maximum linear density (BPI)	15200	28200	28200	39656	21082
Rotational speed (RPM)	1121.5	1143	1143	900	3000
PERFORMANCE					
Positioner type	Crs: Voice Coil Fine: Galvonom.	Crs: Linear Motor Fine: Galvonom.	Crs: Linear Motor Fine: Galvonom.	Crs: Linear Motor Fine: Galvonom.	Crs: Linear, Voice Coil Fine: Lens Actuator
Servo type	Sampled	Sampled	Sampled	Sampled	Continuous
Average positioning time (msec)	110	90	100	90	80
Within fine band (msec)	8	0.8	0.8	NS	18
Fine band capacity (Mbytes)	78	16	16	NS	1.0
Average rotational delay (msec)	26.7	26.2	26.2	33	10
Average access time (msec)	136.7	116.2	126.2	123	90
Data transfer rate (KBytes/sec)	480	1000	1000	1500	1138
FIRST CUSTOMER SHIPMENT	2Q88	3Q89	4Q90	1991	3/90
COMMENTS			Differs from GD 6000 in the cartridge (single operation loading)	Preliminary specification	SCSI controller available. Exchange coupled MO media. External mount

MANUFACTURER	CANON	CHEROKEE DATA SYSTEMS	CHEROKEE DATA SYSTEMS	CHINON	CHINON
DRIVE	OM-500D	M600 M610	M8820 M8822	CDA-431 CDC-431 CDN-431 CDS-431 CDX-431	CDS-430
DISK/TREND GROUP	11	11	11	10	10
MARKET	Captive, OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	130 mm	130 mm	130 mm	120 mm	120 mm
Recording medium	Bilayer RE-TM	Te-Ox	Te-Ox	Aluminum	Aluminum
Track format	Spiral	Spiral	Concentric	Spiral	Spiral
DRIVE: Operating mode	Rewritable-(MO)	Write Once	Write Once	Read Only	Read Only
Interface	Modified ESDI	SCSI	SCSI	SCSI	Proprietary
Speed control	CAV	CAV	CAV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 256	F: 320	F: 300	F: 550	F: 550
Capacity per track (Bytes)	F: 16,384	F: 17,408	F: 17,408	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	15728	18750	18260	20750	20750
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	21082	24924	24924	27600	27600
Rotational speed (RPM)	3000	1800	1613	500-200	500-200
PERFORMANCE					
Positioner type	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Rack & Pinion Fine: Lens Actuator	Crs: Rack & Pinion Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator	Crs: Motor Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	80	112	112	350	500
Within fine band (msec)	18	50	50	N/A	N/A
Fine band capacity (Mbytes)	2	1.7	1.7	N/A	N/A
Average rotational delay (msec)	10	16.5	18.6	110	110
Average access time (msec)	90	128.5	130.6	450	610
Data transfer rate (KBytes/sec)	1150	522	468	153.6	153.6
FIRST CUSTOMER SHIPMENT	4Q88	3/89	9/87	1Q90	1988
COMMENTS	SCSI controller available Exchange coupled MO media		Can be used in harsh environments	41.3 mm high External mount, except CDS-431 Audio output	External mount Audio output

MANUFACTURER	EASTMAN KODAK	FUJITSU	FUJITSU	FUJITSU	GOLDSTAR TELE-COMMUNICATION
DRIVE	6800	M2505B	F6443	M2502A/B	GCDR-200
DISK/TREND GROUP	12	11	12	12	10
MARKET	Captive, OEM	OEM	Captive	OEM	OEM
MEDIA: Nominal disk diameter	14"	130 mm	200 mm	12"	120 mm
Recording medium	Phase Change	Te Alloy	Tb-Fe-Co	Te Alloy	Aluminum
Track format	Spiral (Zone)	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Write Once	Write Once	Rewritable-(MO)	Write Once	Read Only
Interface	SCSI	ESDI, SCSI	Modified SMD	Mod. SMD, SCSI	Proprietary
Speed control	MCAV	CAV	CAV	CAV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 5,100	F: 300	F: 8,900	F: 1,800	F: 552
Capacity per track (Bytes)	F: N/A	F: 16,325	F: 24,576	F: 38,912	F: N/A
Data surfaces per spindle	1	1	16	1	1
Tracks per surface	87354	18320	23640	46260	20750
Track density (TPI)	21160	15875	15875	16383	15875
Maximum linear density (BPI)	21000	24924	19098	25133	27600
Rotational speed (RPM)	800-1600	1800	1800	900	535-200
PERFORMANCE					
Positioner type	Crs: Linear Fine: Lens Actuator	Crs: Stepping Motor Fine: Lens Actuator	Crs: Stepping Motor Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator
Servo type	Sampled	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	500	100	200*	190	600
Within fine band (msec)	100	NS	NS	NS	N/A
Fine band capacity (Mbytes)	N/A	NS	NS	NS	N/A
Average rotational delay (msec)	27	16.67	16.6	33.3	110
Average access time (msec)	527	116.67	216.6	223.3	710
Data transfer rate (KBytes/sec)	1000	693.6	979	816	153.6
FIRST CUSTOMER SHIPMENT	1991	9/87	6/89	1Q89	1990
COMMENTS			8 fixed disks per spindle. 2 actuators, 4 heads/spindle. *Media to media seek is 5 sec.	M2502A has SCSI interface	Audio output

MANUFACTURER	GOLDSTAR TELE-COMMUNICATION	GOLDSTAR TELE-COMMUNICATION	HEWLETT-PACKARD	HITACHI	HITACHI
DRIVE	GSO-5650R GSO-5650RS	GSO-5650WS	C1716C	CDR 1600S CDR 1650S	CDR 1700S CDR 1750S
DISK/TREND GROUP	11	11	11	10	10
MARKET	OEM	OEM	Captive,OEM,PCM	Captive,OEM,PCM	OEM, PCM
MEDIA: Nominal disk diameter	130 mm	130 mm	130 mm	120 mm	120 mm
Recording medium	Tb-Fe-Co	Te Alloy	Tb-Fe-Co	Aluminum	Aluminum
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Rewritable-(MO)	Write Once	Wr.Once,Rewrit.	Read Only	Read Only
Interface	ESDI	SCSI	SCSI-2	SCSI, Prop.	SCSI, Prop.
Speed control	CAV	CAV	CAV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 326.4	F: 326.4	F: 325	F: 552.9	F: 682
Capacity per track (Bytes)	F: 17,408	F: 17,408	F: 17,408	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	18751	18751	18751	20750	20750
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	24902*	24902	24902	27600	27600
Rotational speed (RPM)	2400	2400	3600	535-200	530-200
PERFORMANCE					
Positioner type	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: NS	Crs: Linear Motor Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	60	60	35	290	230
Within fine band (msec)	15	15	NS	N/A	NS
Fine band capacity (Mbytes)	3.3	3.3	NS	N/A	NS
Average rotational delay (msec)	12.5	12.5	8.3	110	110
Average access time (msec)	72.5	72.5	43.3	400	340
Data transfer rate (KBytes/sec)	680	680	1000	153.6	153.6
FIRST CUSTOMER SHIPMENT	1990	1990	1Q92	11/89	2Q91
COMMENTS	RS model is external mount *2,7 RLL Code	External mount	Single-ended & diff. synch. & asynch. Less than 3 sec spin-up. Embed. control.	CDR-1650S has SCSI interface	41.3 mm high CDR 1750S has SCSI interface

MANUFACTURER	HITACHI	HITACHI	HITACHI	HITACHI	HITACHI
DRIVE	CDR 3600 CDR 3600U CDR 3650	OD 101-1	OD 112-1	OD 301A-1	OD 321-1 OD 321-2
DISK/TREND GROUP	10	11	11	12	12
MARKET	Captive,OEM,PCM	Captive, OEM	Captive, OEM	Captive, OEM	Captive, OEM
MEDIA: Nominal disk diameter	120 mm	130 mm	130 mm	300 mm	300 mm
Recording medium	Aluminum	Te Alloy	Tb-Fe-Co	Te Alloy	Te Alloy
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Read Only	Write Once	Rewritable-(MO)	Write Once	Write Once
Interface	SCSI, Prop.	SCSI	SCSI	SCSI, GPIB, SMD	SCSI
Speed control	CLV	CAV	CAV	CAV	MCAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 682	F: 300	F: 322	F: 1,310	F: 3,500
Capacity per track (Bytes)	F: N/A	F: 16,400	F: 17,408	F: 31,700	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	18624	18751	41300	48035
Track density (TPI)	15875	16000	16000	16000	17000
Maximum linear density (BPI)	27600	24000	24000	19500	33200
Rotational speed (RPM)	535-200	1800	2400	600	1000
PERFORMANCE					
Positioner type	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: Galvonom.	Crs: Voice Coil Fine: Galvonom.	Crs: Voice Coil Fine: Galvonom.	Crs: Voice Coil Fine: Galvonom
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	290	93	62.5	200	120
Within fine band (msec)	N/A	NS	NS	NS	
Fine band capacity (Mbytes)	N/A	NS	NS	NS	
Average rotational delay (msec)	110	16.7	12.5	50	30
Average access time (msec)	450	109.7	75	250	150
Data transfer rate (KBytes/sec)	153.6	690	925	440	1160-2220
FIRST CUSTOMER SHIPMENT	10/89	2Q87	7/89	3Q85	1Q91
COMMENTS	41.3 mm high CDR 3650 has SCSI interface		ISO standard		Pit edge recording Glass substrate

MANUFACTURER	HONEYWELL	IBM	IBM	JVC	KAWASAKI STEEL
DRIVE	AN/MU-928	6450162	MD 3125A	XR-W1001	KHE640
DISK/TREND GROUP	11	11	11	11	11
MARKET	OEM	Captive	Captive	OEM	OEM
MEDIA: Nominal disk diameter	130 mm	86 mm	86 mm	120 mm	130 mm
Recording medium	Te Alloy	RE-TM Alloy	RE-TM Alloy	Organic Dye	RE-TM
Track format	Concentric	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Write Once	Rewrit/Read On.	Rewrit/Read On.	Write Once	Rewritable-(MO)
Interface	Modified SCSI	SCSI	SCSI	SCSI	SCSI
Speed control	CAV	CAV	CAV	CLV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 260	F: 127/122	F: 127/122	F: 580	F: 325
Capacity per track (Bytes)	F: 20,480	F:12,700/12,200	F:12,700/12,200	F: N/A	F: 16,384
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	12695	10000	10000	20750	19500
Track density (TPI)	NS	15900	15900	15875	16933
Maximum linear density (BPI)	NS	24400	24400	27600	24923
Rotational speed (RPM)	1800	1800	1800	530-200	1800
PERFORMANCE					
Positioner type	Crs: Stepping Motor Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine:	Crs: Linear, Voice Coil Fine: Lens Actuator
Servo type	Sector	Continuous	Continuous	Continuous	Sector
Average positioning time (msec)	125	66	66	300	53
Within fine band (msec)	NS	NS	NS	NS	8
Fine band capacity (Mbytes)	NS	1	1	NS	1
Average rotational delay (msec)	17	16.7	16.7	110	16.7
Average access time (msec)	142	82.7	82.7	410	69.7
Data transfer rate (KBytes/sec)	562	543.8	543.8	153.6	1500
FIRST CUSTOMER SHIPMENT	2Q89	4/91	4/91	1/92	3Q91
COMMENTS	Embedded controller Militarized	PS/2 series	Capacity is 122 MB with read only disks	41.3 mm high Embedded SCSI	

MANUFACTURER	KAWASAKI STEEL	LASER MAGNETIC STORAGE	LASER MAGNETIC STORAGE	LASER MAGNETIC STORAGE	LASER MAGNETIC STORAGE
DRIVE	KL1200S	CM 131 CM 132	CM 202 CM 214	CM 221	CM 231
DISK/TREND GROUP	11	10	10	10	10
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	130 mm	120 mm	120 mm	120 mm	120 mm
Recording medium	Te Alloy	Aluminum	Aluminum	Aluminum	Aluminum
Track format	Concentric	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Write Once	Read Only	Read Only	Read Only	Read Only
Interface	SCSI, PC	SCSI	SCSI, Serial	Serial	SCSI
Speed control	CAV	CLV	CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 630	F: 600	F: 600	F: 600	F: 600
Capacity per track (Bytes)	F: 20,480	F: N/A	F: N/A	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	31500	20750	20750	20750	20750
Track density (TPI)	36000 max.	15875	15875	15875	15875
Maximum linear density (BPI)	27000 max.	27600	27600	27600	27600
Rotational speed (RPM)	1800	500-200	500-200	500-200	500-200
PERFORMANCE					
Positioner type	Crs: Stepping Motor Fine: Galvonom.	Rotary Galvonometer	Rotary Galvonometer	Rotary Galvonometer	Rotary Galvonometer
Servo type	Sector	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	90	500	240	500	290
Within fine band (msec)	8	N/A	N/A	N/A	N/A
Fine band capacity (Mbytes)	4	N/A	N/A	N/A	N/A
Average rotational delay (msec)	16.7	110	110	110	110
Average access time (msec)	106.7	610	350	610	400
Data transfer rate (KBytes/sec)	600	153.6	153.6	153.6	153.6
FIRST CUSTOMER SHIPMENT	3Q89	8/88	1991	8/88	2Q89
COMMENTS	Grooveless tracking system	CM 132 is 2 drive package	41.3 mm high CM 202 has serial interface Embedded audio	41.3 mm high External mount	41.3 mm high External mount

MANUFACTURER	LASER MAGNETIC STORAGE	LASER MAGNETIC STORAGE	LASER MAGNETIC STORAGE	LASER MAGNETIC STORAGE	LITERAL
DRIVE	CM 50	510	1200E 1250E	LD 4100	525 GB+ 525 GBX2+
DISK/TREND GROUP	10	11	12	12	11
MARKET	OEM, PCM	OEM, PCM	OEM, PCM	Captive,OEM,PCM	OEM, PCM
MEDIA: Nominal disk diameter	120 mm	130 mm	12"	12"	130 mm
Recording medium	Aluminum	Te Alloy	Te Alloy	Te Alloy	Te Alloy
Track format	Spiral	Spiral	Spiral	Spiral	Concentric
DRIVE: Operating mode	Read Only	Write Once	Write Once	Write Once	Write Once
Interface	PC AT	SCSI	SCSI, ISI	SCSI-2	SCSI-2,Prop.,PC
Speed control	CLV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 553	F: 326.5	F: 1,049.6	F: 5,600	F: 640
Capacity per track (Bytes)	F: N/A	F: 16,384	F: 32,800	F: 49,808	F: 20,000
Data surfaces per spindle	1	1	1	2	1
Tracks per surface	20750	19928	32000	57219	32000
Track density (TPI)	15875	NS	15875	16925-23132	35000
Maximum linear density (BPI)	27600	NS	14111	NS	32000
Rotational speed (RPM)	500-200	2160	480	855	1800
PERFORMANCE					
Positioner type	Rotary Galvonometer	Linear, Voice Coil	Linear, Voice Coil	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Stepping Motor Fine: Lens Actuator
Servo type	Continuous	Sampled	Sampled	Sampled	Sector
Average positioning time (msec)	690	61.3	150	80	90
Within fine band (msec)	N/A	N/A	N/A	NS	8
Fine band capacity (Mbytes)	N/A	N/A	N/A	NS	4
Average rotational delay (msec)	110	13.7	62.5	35	16.7
Average access time (msec)	800	75	212.5	130*	106.7
Data transfer rate (KBytes/sec)	153.6	590	313	700	812.5
FIRST CUSTOMER SHIPMENT	11/90	4Q88	3Q83	2Q90	4/88
COMMENTS	External mount Top loading Gets power from bus adapter card		1250E is rack mounted Has Direct Read During Write	*Includes command latency Has Direct Read During Write	525 GBX2+ is external mount; dual drive available

MANUFACTURER	LITERAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL
DRIVE	S-525 MF	CR-501B CR-501S	CR-521B CR-521S	LK-MC501B LK-MC501S	LK-MC521B LK-MC521S
DISK/TREND GROUP	11	10	10	10	10
MARKET	OEM	OEM	OEM	Captive, OEM	Captive, OEM
MEDIA: Nominal disk diameter	130 mm	120 mm	120 mm	120 mm	120 mm
Recording medium	TeX/Tb-Fe-Co	Aluminum	Aluminum	Aluminum	Aluminum
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Wr.Once/Rewrit.	Read Only	Read Only	Read Only	Read Only
Interface	SCSI	SCSI	PC AT	SCSI	PC AT
Speed control	CAV	CLV	CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 326.4	F: 540	F: 540	F: 540	F: 540
Capacity per track (Bytes)	F: 17,920	F: N/A	F: N/A	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20000	20750	20750	20750	20750
Track density (TPI)	16900	15875	15875	15875	15875
Maximum linear density (BPI)	17662	27600	27600	27600	27600
Rotational speed (RPM)	1800	530-200	530-200	530-200	530-200
PERFORMANCE					
Positioner type	Crs: Linear, Voice Coil Fine: Galvonom.	Crs: DC Motor, Lead Screw Fine: Lens Actuator	Crs: DC Motor, Lead Screw Fine: Lens Actuator	Crs: DC Motor, Lead Screw Fine: Lens Actuator	Crs: DC Motor Lead Screw Fine: Lens Actuator
Servo type	Sampled	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	53	390	390	390	390
Within fine band (msec)	NS	N/A	N/A	N/A	N/A
Fine band capacity (Mbytes)	NS	N/A	N/A	N/A	N/A
Average rotational delay (msec)	16.7	110	110	110	110
Average access time (msec)	69.7	500	500	500	500
Data transfer rate (KBytes/sec)	475	153.6	153.6	153.6	153.6
FIRST CUSTOMER SHIPMENT	2Q91	1989	1989	6/91	6/91
COMMENTS	Pioneer mechanism	41.3 mm high S is external mount Embedded SCSI	41.3 mm high S is external mount Embedded AT	41.3 mm high S is external mount Embedded SCSI	41.3 mm high S is external mount Embedded AT

MANUFACTURER	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRONIC COMPONENTS
DRIVE	LF-5000 LF-5001	LF-5010 LF-5012 LF-5014 LF-5110 LF-5210	LF-7010 LF-7014 LF-7110	LF-9000 LF-9100	EMO-102
DISK/TREND GROUP	11	11	11	11	10
MARKET	OEM	OEM	Captive, OEM	OEM	OEM
MEDIA: Nominal disk diameter	130 mm	130 mm	130 mm	130 mm	120 mm
Recording medium	Te-Ox	Te-Ox	Ge-Te-Sb	Tb-Fe-Co	Aluminum
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Write Once	Write Once-(PC)	Rewritable-(PC)	Rewritable-(MO)	Read Only
Interface	SCSI	SCSI-2	SCSI-2	SCSI-2	Proprietary
Speed control	CAV	MCAV	MCAV	CAV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 200	F: 470	F: 500/470*	F: 326	F: 540
Capacity per track (Bytes)	F: 11,776	F: 25,600 avg.	F: NS	F: 17,408	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	17100	18360	19968/18360*	18727	20750
Track density (TPI)	15875	16925	16925	15875	15875
Maximum linear density (BPI)	21166	NS	30480	24937	27600
Rotational speed (RPM)	875	1200	1800	2400	530-200
PERFORMANCE					
Positioner type	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	190	90	90	62.5	540
Within fine band (msec)	45	45	45	13	N/A
Fine band capacity (Mbytes)	.588	NS	NS	1.6	N/A
Average rotational delay (msec)	34.3	25	16.7	12.5	110
Average access time (msec)	224.3	115	106.7	75	650
Data transfer rate (KBytes/sec)	171	861.25	990	925	153.6
FIRST CUSTOMER SHIPMENT	2Q88	3Q89	4Q90	1Q91	1Q87
COMMENTS		LF-5010 is external mount. LF-51XX series sold in Japan. LF-52XX series sold in Europe.	*Will operate with WORM media: 470 MB capacity. LF-7110 sold in Japan.	Glass substrate LF-9100 sold only in Japan	41.3 mm high

MANUFACTURER	MATSUSHITA ELECTRONIC COMPONENTS	MATSUSHITA ELECTRONIC COMPONENTS	MATSUSHITA ELECTRONIC COMPONENTS	MATSUSHITA GRAPHIC COMMUNICATION	MAXIMUM STORAGE
DRIVE	EMO-103	EMO-104	EMO-201	PF-10 PF-10B PF-3000	APX-3200
DISK/TREND GROUP	10	10	10	11	11
MARKET	OEM	OEM	OEM	Captive, OEM	OEM
MEDIA: Nominal disk diameter	120 mm	120 mm	120 mm	200 mm	130 mm
Recording medium	Aluminum	Aluminum	Aluminum	Te-Ox	Te Alloy
Track format	Spiral	Spiral	Spiral	Spiral	Concentric
DRIVE: Operating mode	Read Only	Read Only	Read Only	Write Once	Write Once
Interface	SCSI, PC	Proprietary	Centronics	Proprietary	Mod. ESDI, PC
Speed control	CLV	CLV	CLV	CLV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 540	F: 540	F: 540	F: 700	F: 122
Capacity per track (Bytes)	F: N/A	F: N/A	F: N/A	F: N/A	F: 8,192
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	20750	20750	23330	14901
Track density (TPI)	15875	15875	15875	23333	14100
Maximum linear density (BPI)	27600	27600	27600	15394	11400
Rotational speed (RPM)	530-200	530-200	530-200	900	1800
PERFORMANCE					
Positioner type	Crs: DC Motor Rack & Pinion Fine: Lens Actuator	Crs: DC Motor Rack & Pinion Fine: Lens Actuator	Crs: DC Motor Rack & Pinion Fine: Lens Actuator	Linear, Voice Coil	Crs: Stepping Motor Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Sampled	Sector
Average positioning time (msec)	1590	1590	1590	200	118
Within fine band (msec)	N/A	N/A	N/A	N/A	20
Fine band capacity (Mbytes)	N/A	N/A	N/A	N/A	1.31
Average rotational delay (msec)	110	110	110	33.3	16.7
Average access time (msec)	1700	1700	1700	233.3	134.7
Data transfer rate (KBytes/sec)	153.6	153.6	153.6	675	312.5
FIRST CUSTOMER SHIPMENT	3/89	3/89	6/89	2Q86	3Q87
COMMENTS	41.3 mm high Pop up loading model	41.3 mm high For automobile use (car navigator)	41.3 mm high Stand-alone model	Available only in Japan 30 disk library available	

MANUFACTURER	MAXIMUM STORAGE	MAXOPTIX	MAXOPTIX	MITSUBISHI ELECTRIC CORPORATION	MITSUBISHI ELECTRIC CORPORATION
DRIVE	APX-5100 APX-5200	Tahiti II Tahita II SD	Tahiti I	ME-5E1 ME-5U1	MW-5D1 MW-5U1
DISK/TREND GROUP	11	11	11	11	11
MARKET	OEM	OEM, PCM	OEM, PCM	OEM	OEM
MEDIA: Nominal disk diameter	130 mm	130 mm	130 mm	130 mm	130 mm
Recording medium	Te Alloy	RE-TM Alloy	RE-TM Alloy	Tb-Fe-Co	Te-Se
Track format	Concentric	Spiral, (Zone)	Spiral, (Zone)	Spiral	Spiral
DRIVE: Operating mode	Write Once	Rewritable-(MO)	Rewritable-(MO)	Rewritable-(MO)	Write Once
Interface	Modified ESDI	SCSI-2	SCSI	ESDI, SCSI	ESDI, SCSI
Speed control	CAV	CAV, MCAV	CAV, MCAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 501.8	F: 512/326.4	F: 512/326.4	F: 297/326.4	F: 297
Capacity per track (Bytes)	F: 16,384	F:25,000/17,408	F:25,000/17,408	F:15,872/17,408	F: 15,872
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	30626	25000	25000	18750	18750
Track density (TPI)	26458	16933	16933	15875	15875
Maximum linear density (BPI)	17665	25000*	25000*	25400*	25400*
Rotational speed (RPM)	1800	2200	2200	2400	1800
PERFORMANCE					
Positioner type	Crs: Stepping Motor Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator
Servo type	Sector	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	NS	35/25	35/25	35.5	63
Within fine band (msec)	NS	20.5/16	20.5/16	1.5	1.5
Fine band capacity (Mbytes)	NS	2	2	.317	.317
Average rotational delay (msec)	16.7	13.6	13.6	12.5	17
Average access time (msec)	NS	48.6	48.6	48	80
Data transfer rate (KBytes/sec)	625	1200/840	500/350	925	687.5
FIRST CUSTOMER SHIPMENT	10/89	1/91	11/89	2Q90	1Q88
COMMENTS	APX-5200 is external mount Rack & Pinion coarse positioner	SD version is for library use *2,7 RLL Code	*2,7 RLL Code	ME-5U1 is external mount *2,7 RLL Code	MW-5U1 includes controller; free standing package *2,7 RLL Code

MANUFACTURER	MITSUBISHI ELECTRIC CORPORATION	MITSUMI ELECTRIC	MITSUMI ELECTRIC	MITSUMI ELECTRIC	MITSUMI ELECTRIC
DRIVE	MW-5E3 MW-5U3	CRMC-FRO	CRMC-LUO	CRS-UF	CRS-XP
DISK/TREND GROUP	11	10	10	10	10
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	130 mm	120 mm	120 mm	120 mm	120 mm
Recording medium	Te-Se	Aluminum	Aluminum	Aluminum	Aluminum
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Write Once	Read Only	Read Only	Read Only	Read Only
Interface	SCSI	PC XT	PC XT	PC XT	PC XT
Speed control	CAV	CLV	CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 297/326	F: 540	F: 540	F: 540	F: 540
Capacity per track (Bytes)	F:15,872/17,408	F: N/A	F: N/A	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	18750	20750	20750	20750	20750
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	25400*	27600	27600	27600	27600
Rotational speed (RPM)	2400	500-200	500-200	500-200	500-200
PERFORMANCE					
Positioner type	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Motor Fine: Lens Actuator	Crs: Motor Fine: Lens Positioner	Crs: Fine:	Crs: Fine:
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	35.5	600	600	700	900
Within fine band (msec)	1.5	N/A	N/A	N/A	N/A
Fine band capacity (Mbytes)	0.317	N/A	N/A	N/A	N/A
Average rotational delay (msec)	12.5	110	110	110	110
Average access time (msec)	48	710	710	810	1010
Data transfer rate (KBytes/sec)	925	153.6	153.6	153.6	153.6
FIRST CUSTOMER SHIPMENT	4Q91	10/91	2/91	8/91	9/91
COMMENTS	MW-5U3 is external mount *2,7 RLL Code	73.5 mm high Front loading	41.3 mm high Top Loading	External model Front loading	Portable model Top loading

MANUFACTURER	MITSUMI ELECTRIC	MOST	MOUNTAIN OPTECH	MOUNTAIN OPTECH	MOUNTAIN OPTECH
DRIVE	CWS-3	RMD 5100-S	CS-400	CS-1000 R/W SE-1000 R/W	SEL-2C SEL-2-5AMS
DISK/TREND GROUP	11	11	11	11	11
MARKET	OEM	OEM, PCM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	120 mm	86 mm	130 mm	130 mm	130 mm
Recording medium	Dye Polymer	RE-TM Alloy	Te Alloy	RE-TM Alloy	Te Alloy
Track format	Spiral	Spiral	Concentric	Spiral (Zone)	Concentric
DRIVE: Operating mode	Write Once	Rewritable-(MO)	Write Once	Rewritable-(MO)	Write Once
Interface	SCSI	SCSI	SCSI, PC AT	SCSI	SCSI, PC AT
Speed control	CLV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 540	F: 128	F: 202	F: 512/326.4	F: 202
Capacity per track (Bytes)	F: N/A	F: 12,800	F: 10,752	F:25,000/17,408	F: 10,752
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	10000	18826	25000	18826
Track density (TPI)	15875	15875	15625	16933	15625
Maximum linear density (BPI)	27600	15875	14620	25000	14620
Rotational speed (RPM)	500-200	2400	1200	2200	1200
PERFORMANCE					
Positioner type	Crs: Voice Coil Fine: Lens Positioner	Crs: Voice Coil Fine: Lens Actuator	Crs: Stepping Motor Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator	Crs: Stepping Motor Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	500	35	170	35	170
Within fine band (msec)	N/A	3.5	15	20.5/16	15
Fine band capacity (Mbytes)	N/A	1.638	.32	2	.32
Average rotational delay (msec)	110	12.5	25	13.6	25
Average access time (msec)	600	47.5	195	48.6	195
Data transfer rate (KBytes/sec)	150	512	275	1250/880	275
FIRST CUSTOMER SHIPMENT	1992	4Q90	1986	2Q91	1987
COMMENTS	Preliminary specification		Mechanism from Shugart Corp.	Ruggedized version of Maxtor Tahiti SE-1000 is for military use	Ruggedized CS-400 MicroVax interface available

MANUFACTURER	MOUNTAIN OPTECH	MOUNTAIN OPTECH	NEC	NEC	NEC
DRIVE	SE-400M	SE-650-I	CDR-30	CDR-36	CDR-73 CDR-83
DISK/TREND GROUP	11	11	10	10	10
MARKET	OEM	OEM	Captive	OEM, PCM	OEM, PCM
MEDIA: Nominal disk diameter	130 mm	130 mm	120 mm	120 mm	120 mm
Recording medium	Te Alloy	Te Alloy	Aluminum	Aluminum	Aluminum
Track format	Concentric	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Write Once	Write Once	Read Only	Read Only	Read Only
Interface	SCSI, PC AT	SCSI	Proprietary	SCSI	SCSI
Speed control	CAV	CAV	CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 202	F: 326	F: 540	F: 540	F: 540
Capacity per track (Bytes)	F: 10,752	F: 17,408	F: N/A	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	18826	18272	20750	20750	20750
Track density (TPI)	15625	15625	15875	15875	15875
Maximum linear density (BPI)	14620	14620	27600	27600	27600
Rotational speed (RPM)	1200	1800	530-200	530-200	530-200
PERFORMANCE					
Positioner type	Crs: Stepping Motor Fine: Lens Actuator	Crs: NS Fine: Lens Actuator	Crs: Gear Mechanism Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	170	70	1390	390	300
Within fine band (msec)	15	50	N/A	N/A	N/A
Fine band capacity (Mbytes)	.32	1.74	N/A	N/A	N/A
Average rotational delay (msec)	25	16.6	110	110	110
Average access time (msec)	195	86.6	1500	500	410
Data transfer rate (KBytes/sec)	275	687.5	153.6	153.6	153.6
FIRST CUSTOMER SHIPMENT	2Q91	4Q92	12/88	4/91	4/91
COMMENTS	Designed to meet MIL-SPEC 883 for space applications	Ruggedized Preliminary specification	Used with NEC PC engine or PC-8801	Portable model	41.3 mm high CDR-73 is external mount

MANUFACTURER	NEC	NEC	NEC	NEC	NEC
DRIVE	CDR-90	PC-CD10	PC-CD103 N5267-38 N7914-81	N5267-37 N7915	ND-3605-13
DISK/TREND GROUP	10	10	10	11	11
MARKET	OEM	Captive	Captive	Captive	Captive
MEDIA: Nominal disk diameter	120 mm	120 mm	120 mm	130 mm	130 mm
Recording medium	Aluminum	Aluminum	Aluminum	Tb-Fe-Co	Te Alloy
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Read Only	Read Only	Read Only	Rewritable-(MO)	Write Once
Interface	SCSI	SCSI	SCSI	SCSI	SCSI
Speed control	CLV	CLV	CLV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 540	F: 540	F: 540	F: 305	F: 305
Capacity per track (Bytes)	F: N/A	F: N/A	F: N/A	F: 17,408	F: 17,408
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	20750	20750	18751	18751
Track density (TPI)	15875	15875	15875	15875	15375
Maximum linear density (BPI)	27600	27600	27600	25000	25000
Rotational speed (RPM)	535-200	530-200	530-200	1800	1800
PERFORMANCE					
Positioner type	Crs: Stepping Motor Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	500	1390	240	68	85
Within fine band (msec)	N/A	NS	N/A	NS	NS
Fine band capacity (Mbytes)	N/A	NS	N/A	NS	NS
Average rotational delay (msec)	110	110	110	16.7	16.6
Average access time (msec)	610	1500	350	84.7	101.6
Data transfer rate (KBytes/sec)	153.6	153.6	153.6	1500	1500
FIRST CUSTOMER SHIPMENT	2Q88	11/90	3Q90	8/89	7/90
COMMENTS	41.3 mm high Automotive use available in Japan only	External model for PC 9800 series			

MANUFACTURER	NEC	NEC	NEC	NIKON	NIPPON COLUMBIA
DRIVE	PC-CD102 PC-1137-04	N6513-20	N6513-23 N7913	MO-DD120C	DRD-251 DRD-253
DISK/TREND GROUP	11	12	12	12	10
MARKET	Captive	Captive	Captive	OEM	OEM
MEDIA: Nominal disk diameter	130 mm	12"	12"	12"	120 mm
Recording medium	Tb-Fe-Co	Te Alloy	Te Alloy	Tb-Fe,Gd-Fe-Co	Aluminum
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Rewritable-(MO)	Write Once	Write Once	Rewritable-(MO)	Read Only
Interface	SCSI	SCSI, Prop.	Prop., SCSI	SCSI	SCSI
Speed control	CAV	Zone CLV	MCAV	CAV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 305	F: 1,800	F: 2,500	F: 2,000	F: 553
Capacity per track (Bytes)	F: 17,408	F:29,500-56,500	F: NS	F: 44,444	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	18751	41000	49000	45000	20750
Track density (TPI)	15375	15875	16940	15875	15475
Maximum linear density (BPI)	25000	20000	25000	30600	26008
Rotational speed (RPM)	3000	600-330	600	1800	535-194
PERFORMANCE					
Positioner type	Crs: Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: Galvonom.	Linear, Voice Coil
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	60	650	150	70	300
Within fine band (msec)	NS	NS	NS	10	N/A
Fine band capacity (Mbytes)	NS	NS	NS	4.4	N/A
Average rotational delay (msec)	10	70	50	16.7	110
Average access time (msec)	70	720	200	86.7	410
Data transfer rate (KBytes/sec)	1500	452	900	1500	153.6
FIRST CUSTOMER SHIPMENT	1Q91	1Q87	6/90	--	3Q86
COMMENTS				Preliminary specification	41.3 mm high DRD-253 mounts externally

MANUFACTURER	NIPPON COLUMBIA	NIPPON COLUMBIA	NIPPON COLUMBIA	OPTIMEM	OPTIMEM
DRIVE	DRD-250 DRD-252	DRD-550 DRD-552 DRD-554	DRD-551 DRD-553 DRD-555	1000 1/2 1000 6/7	2400 1/2
DISK/TREND GROUP	10	10	10	12	12
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	120 mm	120 mm	120 mm	12"	12"
Recording medium	Aluminum	Aluminum	Aluminum	Te Alloy	Te Alloy
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Read Only	Read Only	Read Only	Write Once	Write Once
Interface	Proprietary	SASI, SCSI	Proprietary	SCSI, Prop.	SCSI
Speed control	CLV	CLV	CLV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 553	F: 553	F: 553	F: 1,000	F: 1,200
Capacity per track (Bytes)	F: N/A	F: N/A	F: N/A	F: 25,000	F: 25,000
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	20750	20750	40000	46900
Track density (TPI)	15475	15475	15475	14514	16933
Maximum linear density (BPI)	26008	26008	26008	15339	15339
Rotational speed (RPM)	535-194	535-194	535-194	1122	1122
PERFORMANCE					
Positioner type	Linear, Voice Coil	Linear, Voice Coil	Linear, Voice Coil	Crs: Voice Coil Fine: Galvonom.	Crs: Voice Coil Fine: Galvonom.
Servo type	Continuous	Continuous	Continuous	Sampled	Sampled
Average positioning time (msec)	300	190	190	150	150
Within fine band (msec)	N/A	N/A	N/A	3	3
Fine band capacity (Mbytes)	N/A	N/A	N/A	8.3	8.3
Average rotational delay (msec)	110	110	110	26.7	26.7
Average access time (msec)	410	300	300	176.7	176.7
Data transfer rate (KBytes/sec)	153.6	153.6	153.6	625	625
FIRST CUSTOMER SHIPMENT	3Q86	4Q85	4Q85	2Q84	4Q87
COMMENTS	41.3 mm high DRD-252 mounts externally	DRD-550 mounts in full height slot DRD-554 has audio output	External mount except for DRD-551 DRD-555 has audio output		2400 1 includes controller

MANUFACTURER	OPTIMEM	PENTAX TEKNOLOGIES	PHILIPS CONSUMER ELECTRONICS	PHILIPS CONSUMER ELECTRONICS	PHILIPS CONSUMER ELECTRONICS
DRIVE	4400	LW-S501	CDD401	CDD461	CDI601
DISK/TREND GROUP	12	11	10	10	10
MARKET	OEM	OEM	PCM	PCM	Captive
MEDIA: Nominal disk diameter	12"	130 mm	120 mm	120 mm	120 mm
Recording medium	Te Alloy	Te Alloy	Aluminum	Aluminum	Aluminum
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Write Once	Write Once	Read Only	Read Only	Read Only
Interface	SCSI	SCSI	Serial	Serial	Serial
Speed control	CAV	CAV	CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 1,979	F: 326	F: 540	F: 540	F: 540
Capacity per track (Bytes)	F: 40,960	F: 17,386	F: N/A	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	48333	18751	20750	20750	20750
Track density (TPI)	16900	15875	15875	15875	15875
Maximum linear density (BPI)	22088	24923	27600	27600	27600
Rotational speed (RPM)	1122	1800	500-200	500-200	500-200
PERFORMANCE					
Positioner type	Crs: Voice Coil Fine: Galvonom.	Crs: Linear, Voice Coil Fine: Galvonom.	Crs: Rotary Galvonometer Fine:	Crs: Rotary Galvonometer Fine:	Crs: Rotary Galvonometer Fine:
Servo type	Sampled	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	150	40	500	800	800
Within fine band (msec)	NS	NS	N/A	N/A	N/A
Fine band capacity (Mbytes)	NS	NS	N/A	N/A	N/A
Average rotational delay (msec)	26.7	16.7	110	110	110
Average access time (msec)	176.7	56.7	610	910	910
Data transfer rate (KBytes/sec)	723	530	153.6	153.6	153.6
FIRST CUSTOMER SHIPMENT	3Q89	1989	1990	4/91	1990
COMMENTS			External mount	External mount	External mount

MANUFACTURER	PIONEER	PIONEER	PIONEER	PIONEER	PIONEER
DRIVE	DRM-600/610	DD-M5101	DD-U5101	DDJ-U7001	DE-S7001 DE-U7001
DISK/TREND GROUP	10	11	11	11	11
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	120 mm	130 mm	130 mm	130 mm	130 mm
Recording medium	Aluminum	Cyanine Dye	Cyanine Dye	Cyanine Dye	Tb-Fe-Co/Dye
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Read Only	Write Once	Write Once	Write Once	Wr.Once/Rewrit.
Interface	SCSI	Proprietary	SCSI, Prop.	SCSI, Prop.	SCSI
Speed control	CLV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 3,240	F: 327	F: 327	F: 327	F: 327
Capacity per track (Bytes)	F: N/A	F: 16,384	F: 16,384	F: 16,384	F: 16,384
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	19958	19958	19958	19958
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	15875	15875	15875	15875
Rotational speed (RPM)	530-220	1800	1800	1800	1800
PERFORMANCE					
Positioner type	Crs: Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: Galvonom.	Crs: Voice Coil Fine: Galvonom.	Crs: Voice Coil Fine: Galvonom.	Crs: Linear, Voice Coil Fine: Galvonom.
Servo type	Continuous	Sampled	Sampled	Sampled	Sampled
Average positioning time (msec)	490	60	60	60	53.3
Within fine band (msec)	NS	NS	NS	NS	27
Fine band capacity (Mbytes)	NS	NS	NS	NS	.819
Average rotational delay (msec)	110	16.7	16.7	16.7	16.7
Average access time (msec)	600	76.7	76.7	76.7	70
Data transfer rate (KBytes/sec)	153.6	742.5	491	491	1875
FIRST CUSTOMER SHIPMENT	4Q89	2Q88	2Q88		6/90
COMMENTS	Integral with 6 disk changer. Disk change time is 7 sec. Includes audio output.	41.3 mm high Mechanism only. External SCSI controller board available		For use with optical libraries	DE-S7001 is external

MANUFACTURER	PIONEER	RICOH	RICOH	RICOH	RICOH
DRIVE	DEJ-U7001	RO-5030E RO-5030E-II	RO-5031E	RO-5042D	RO-5043
DISK/TREND GROUP	11	11	11	11	11
MARKET	OEM	Captive, OEM	OEM	Captive, OEM	Captive, OEM
MEDIA: Nominal disk diameter	130 mm	130 mm	130 mm	130 mm	130 mm
Recording medium	Tb-Fe-Co/Dye	RE-TM(Tb-Fe-Co)	Tb-Fe-Co	Tb-Fe-Co/Dye	Cyanine Dye
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Wr.Once/Rewrit.	Rewritable-(MO)	Rewritable-(MO)	Wr.Once/Rewrit.	Write Once
Interface	SCSI	SCSI	SCSI	SCSI	SCSI
Speed control	CAV	CAV	CAV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 327	F: 297/326	F: 297/326	F: 393/220	F: 393
Capacity per track (Bytes)	F: 16,384	F:15,872/17,408	F:15,872/17,408	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	19958	18750	18750	18750	18750
Track density (TPI)	15875	18875	15875	15900	15900
Maximum linear density (BPI)	15875	24902	24923	32200	32200
Rotational speed (RPM)	1800	1800	3600	1196-597*	668-334
PERFORMANCE					
Positioner type	Crs: Linear, Voice Coil Fine: Galvonom.	Crs: Voice Coil Fine: Voice Coil	Linear, Voice Coil	Crs: Voice Coil Fine: Voice Coil	Crs: Voice Coil Fine: Voice Coil
Servo type	Sampled	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	53.3	50	30	168/180	108
Within fine band (msec)	27	NS	NS	NS	NS
Fine band capacity (Mbytes)	.819	NS	NS	N/A	N/A
Average rotational delay (msec)	16.7	16.7	8.3	60/33	60
Average access time (msec)	70	66.7	38.3	228/213	168
Data transfer rate (KBytes/sec)	1875	625	1250	312.5	312.5
FIRST CUSTOMER SHIPMENT		1Q90	4Q91	2Q90	2Q90
COMMENTS	For use with optical libraries	Embedded SCSI controller E-II supports ISO and E format	Embedded SCSI controller Split optics	Non-ISO standard format *668-334 rpm in write once mode Embedded SCSI controller	41.3 mm high. SCSI controller included Cache controller

MANUFACTURER	SANYO	SANYO	SANYO	SANYO	SANYO
DRIVE	ROM-3000U ROM-3000US	ROM-3001U ROM-3001US	ROM-4005U	ROM-4006U	ROM-7006
DISK/TREND GROUP	10	10	10	10	10
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	120 mm	120 mm	120 mm	120 mm	120 mm
Recording medium	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Read Only	Read Only	Read Only	Read Only	Read Only
Interface	Proprietary	SCSI	Proprietary	SCSI	SCSI
Speed control	CLV	CLV	CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 540	F: 540	F: 540	F: 540	F: 540
Capacity per track (Bytes)	F: N/A	F: N/A	F: N/A	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	20750	20750	20750	20750
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	27600	27600	27600	27600
Rotational speed (RPM)	530-200	530-200	530-200	530-200	530-200
PERFORMANCE					
Positioner type	Crs: Linear Fine: Lens Actuator	Crs: Linear Fine: Lens Actuator	Crs: Linear Fine: Lens Actuator	Crs: Linear Fine: Lens Actuator	Crs: Linear Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	500	500	500	500	500
Within fine band (msec)	N/A	N/A	N/A	N/A	N/A
Fine band capacity (Mbytes)	N/A	N/A	N/A	N/A	N/A
Average rotational delay (msec)	108	108	108	108	108
Average access time (msec)	608	608	608	608	608
Data transfer rate (KBytes/sec)	153.6	153.6	153.6	153.6	153.6
FIRST CUSTOMER SHIPMENT	2/88	5/88	5/89	8/89	8/90
COMMENTS	S models have audio output External mount	S models have audio output External mount	41.3 mm high Internal mount Includes audio output	41.3 mm high Internal mount Includes audio output	41.3 mm high Preliminary specification. Optional XA format support

MANUFACTURER	SANYO	SHARP	SONY	SONY	SONY
DRIVE	ROM-PD1	JY-700	CDU-510	CDU-520	CDU-531
DISK/TREND GROUP	10	11	10	10	10
MARKET	OEM, PCM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	120 mm	130 mm	120 mm	120 mm	120 mm
Recording medium	Aluminum	RE-TM(Tb-Fe-Co)	Aluminum	Aluminum	Aluminum
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Read Only	Rewritable-(MO)	Read Only	Read Only	Read Only
Interface	PC AT/Centronic	SCSI	Proprietary	Proprietary	Proprietary
Speed control	CLV	CAV	CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 540	F: 297.4	F: 540	F: 540	F: 540
Capacity per track (Bytes)	F: N/A	F: 15,872	F: N/A	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	18751	20750	20750	20750
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	33200*	27600	27600	27600
Rotational speed (RPM)	530-200	2400	500-200	500-200	530-200
PERFORMANCE					
Positioner type	Crs: Fine:	Crs: Linear, Voice Coil Fine: Lens Actuator	Linear, Voice Coil	Crs: Linear, Voice Coil Fine: Lens Actuator	Linear, Voice Coil
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	900	60	390	390	270
Within fine band (msec)	--	NS	N/A	N/A	N/A
Fine band capacity (Mbytes)	--	NS	N/A	N/A	N/A
Average rotational delay (msec)	110	12.5	110	110	110
Average access time (msec)	1010	72.5	500	500	380
Data transfer rate (KBytes/sec)	153.6	925	153.6	153.6	153.6
FIRST CUSTOMER SHIPMENT	6/91	1/90	--	--	--
COMMENTS		512 byte sectors *2,7 RLL Code	41.3 mm high		Has audio output

MANUFACTURER	SONY	SONY	SONY	SONY	SONY
DRIVE	CDU-535	CDU-541	CDU-6100 CDU-6101 CDU-6110 CDU-6111	CDU-6150	CDU-6201
DISK/TREND GROUP	10	10	10	10	10
MARKET	OEM	OEM	OEM	OEM, PCM	OEM, PCM
MEDIA: Nominal disk diameter	120 mm	120 mm	120 mm	120 mm	120 mm
Recording medium	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Read Only	Read Only	Read Only	Read Only	Read Only
Interface	Proprietary	SCSI	SCSI, Prop.	Proprietary	Proprietary
Speed control	CLV	CLV	CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 540	F: 540	F: 540	F: 540	F: 540
Capacity per track (Bytes)	F: N/A	F: N/A	F: N/A	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	20750	20750	20750	20750
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	27600	27600	27600	27600
Rotational speed (RPM)	500-200	500-200	500-200	530-200	530-200
PERFORMANCE					
Positioner type	Crs: Linear, Voice Coil Fine: Lens Actuator	Linear, Voice Coil	Linear, Voice Coil	Linear, Voice Coil	Linear, Voice Coil
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	230	270	390	380	270
Within fine band (msec)	N/A	N/A	N/A	N/A	N/A
Fine band capacity (Mbytes)	N/A	N/A	N/A	N/A	N/A
Average rotational delay (msec)	110	110	110	110	110
Average access time (msec)	340	380	500	490	380
Data transfer rate (KBytes/sec)	153.6	153.6	153.6	153.6	153.6
FIRST CUSTOMER SHIPMENT	--	1989	--	--	--
COMMENTS	Has audio output and audio channel selector	Has audio output	External mount. CDU-6110 & 6111 have SCSI intf. CDU-6101 & 6111 have audio output.	External mount 2 drives in a single mount	External mount

MANUFACTURER	SONY	SONY	SONY	SONY	SONY
DRIVE	CDU-6205	CDU-6211	CDU-6250	CDU-7101	Data Discman
DISK/TREND GROUP	10	10	10	10	10
MARKET	OEM, PCM	OEM, PCM	OEM, PCM	Captive	Captive
MEDIA: Nominal disk diameter	120 mm	120 mm	120 mm	120 mm	80 mm
Recording medium	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Read Only	Read Only	Read Only	Read Only	Read Only
Interface	Proprietary	SCSI	Proprietary	IBM PC XT	Proprietary
Speed control	CLV	CLV	CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 540	F: 540	F: 540	F: 540	F: 184
Capacity per track (Bytes)	F: N/A	F: N/A	F: N/A	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	20750	20750	20750	9062
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	27600	27600	27600	27600
Rotational speed (RPM)	500-200	530-200	500-200	500-200	500-300
PERFORMANCE					
Positioner type	Crs: Linear, Voice Coil Fine: Lens Actuator	Linear, Voice Coil	Crs: Linear, Voice Coil Fine: Lens Actuator	Linear, Voice Coil	Crs: DC Motor Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	230	270	270	390	
Within fine band (msec)	N/A	N/A	N/A	N/A	N/A
Fine band capacity (Mbytes)	N/A	N/A	N/A	N/A	N/A
Average rotational delay (msec)	110	110	110	110	65
Average access time (msec)	340	380	380	500	
Data transfer rate (KBytes/sec)	153.6	153.6	153.6	153.6	153.6
FIRST CUSTOMER SHIPMENT	--	--	--	5/88	7/90
COMMENTS	External mount	External mount	External mount 2 drives in a single mount	External mount	

MANUFACTURER	SONY	SONY	SONY	SONY	SONY
DRIVE	CDW-W1	SMO-D301	SMO-D501 SMO-S501	SMO-E501	SMO-E511
DISK/TREND GROUP	11	11	11	11	11
MARKET	OEM	OEM	Captive, OEM	Captive, OEM	Captive, OEM
MEDIA: Nominal disk diameter	120 mm	86 mm	130 mm	130 mm	130 mm
Recording medium	NS	Tb-Fe-Co	Tb-Fe-Co	Tb-Fe-Co	Tb-Fe-Co
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Write Once	Rewritable-(MO)	Rewritable-(MO)	Rewritable-(MO)	Wr.Once/Rewrit.
Interface	Proprietary	SCSI, Prop.	SCSI, ESDI	SCSI, ESDI	SCSI
Speed control	CLV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 540	F: 128	F: 326.4	F: 326.4	F: 326.4
Capacity per track (Bytes)	F: N/A	F: 12,800	F: 17,408	F: 17,408	F: 17,408
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	10000	18751	18751	18751
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	24440	24902	24902	24902
Rotational speed (RPM)	NS	3000	2400	2400	2400
PERFORMANCE					
Positioner type	Crs: Linear, Voice Coil Fine:	Crs: Linear, Voice Coil Fine:	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	NS	40	90	70	70
Within fine band (msec)	NS	NS	20	20	20
Fine band capacity (Mbytes)	N/A	NS	22	22	22
Average rotational delay (msec)	NS	10	12.5	12.5	12.5
Average access time (msec)	NS	50	102.5	92.5	92.5
Data transfer rate (KBytes/sec)	153.6	625	680	680	680
FIRST CUSTOMER SHIPMENT	1990	1991	2Q88	3Q90	1991
COMMENTS	Sold only with mastering system Preliminary specification	41.3 mm high	ISO standard SMO-S501 is external mount	Embedded SCSI controller	Embedded SCSI controller

MANUFACTURER	SONY	SONY	TEXEL (SHINANO KENSHI)	TEXEL (SHINANO KENSHI)	TOSHIBA
DRIVE	WDD 3000	WDD-600	DM-3011 DM-3020 DM-5011 DM-5021	DM-3110 DM-3120 DM-5110 DM-5120	TXM-3201A
DISK/TREND GROUP	12	12	10	10	10
MARKET	Captive, OEM	Captive, OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	12"	12"	120 mm	120 mm	120 mm
Recording medium	Se-Sb, Bi-Te	Se-Sb, Bi-Te	Aluminum	Aluminum	Aluminum
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Write Once	Write Once	Read Only	Read Only	Read Only
Interface	SCSI	SCSI	SCSI	SCSI	SCSI
Speed control	CAV, CLV	CAV, CLV	CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 1,100/1,600	F: 2,180/3,275	F: 599	F: 599	F: 599
Capacity per track (Bytes)	F: 25,600/N/A	F: NS	F: N/A	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	43750	43750	20750	20750	20750
Track density (TPI)	15875	15875	15475	15475	15875
Maximum linear density (BPI)	24937	49874	26008	26008	27600
Rotational speed (RPM)	720/720-360	720/720-360	530-200	530-200	530-200
PERFORMANCE					
Positioner type	Crs: Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator	Crs: Lead Screw Fine: Lens Actuator	Crs: Linear Motor Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	250/620	180/400	340	700	240
Within fine band (msec)	25	20	N/A	N/A	N/A
Fine band capacity (Mbytes)	1.25	1.25	N/A	N/A	N/A
Average rotational delay (msec)	42/62.5	41/55	110	110	110
Average access time (msec)	292/682.5	221/455	450	570	350
Data transfer rate (KBytes/sec)	300	600	153.6	153.6	153.6
FIRST CUSTOMER SHIPMENT	1Q85	3Q89	2/90	2/90	1990
COMMENTS		Downward compatible with WDD 3000	41.3 mm high Uses Sony caddy DM-5XXX is external mount	41.3 mm high Uses Sony caddy DM-51XX is external mount	External mount Embedded SCSI controller and audio

MANUFACTURER	TOSHIBA	TOSHIBA	TOSHIBA	TOSHIBA	TOSHIBA
DRIVE	XM-2200A	XM-3201B	XM-3301B	XM-5100A	WM-D070 WM-S070
DISK/TREND GROUP	10	10	10	10	11
MARKET	OEM	OEM	OEM	OEM	Captive, OEM
MEDIA: Nominal disk diameter	120 mm	120 mm	120 mm	120 mm	130 mm
Recording medium	Aluminum	Aluminum	Aluminum	Aluminum	Te-C
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Read Only	Read Only	Read Only	Read Only	Write Once
Interface	SCSI	SCSI	SCSI-2	SCSI	SCSI, Prop.
Speed control	CLV	CLV	CLV	CLV	MCAV, CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 599	F: 599	F: 599	F: 599	F: 450/300
Capacity per track (Bytes)	F: N/A	F: N/A	F: N/A	F: N/A	F: 17,000(CAV)
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	20750	20750	20750	18750
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	27600	27600	27600	24900
Rotational speed (RPM)	530-200	530-200	530-200	530-200	900-1800
PERFORMANCE					
Positioner type	Crs: Linear Motor Fine: Lens Actuator	Crs: Linear Motor Fine: Lens Actuator	Crs: Rack & Pinion Fine: Lens Actuator	Crs: Linear Motor Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	240	240	215	270	90
Within fine band (msec)	N/A	N/A	N/A	N/A	.5
Fine band capacity (Mbytes)	N/A	N/A	N/A	N/A	50 (tracks)
Average rotational delay (msec)	110	110	110	110	16.7 (CAV)
Average access time (msec)	350	350	325	380	106.7 (CAV)
Data transfer rate (KBytes/sec)	153.6	153.6	153.6	153.6	528 (CAV)
FIRST CUSTOMER SHIPMENT	2Q89	4Q88	1Q91	2Q89	1Q89
COMMENTS	External mount Embedded SCSI controller and audio	41.3 mm high Embedded SCSI controller and audio	41.3 mm high Embedded SCSI controller and audio	External mount Embedded SCSI controller and audio	WM-S series is subsystem

MANUFACTURER	TOSHIBA	YAMAHA			
DRIVE	WM-S500A	YPR-102			
DISK/TREND GROUP	12	11			
MARKET	Captive, OEM	Captive			
MEDIA: Nominal disk diameter	12"	120 mm			
Recording medium	Te-C	Dye Polymer			
Track format	Spiral	Spiral			
DRIVE: Operating mode	Write Once	Write Once			
Interface	SCSI, Prop.	SCSI, Prop.			
Speed control	MCAV	CLV			
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 2,500	F: 620			
Capacity per track (Bytes)	F: 36,000 avg.	F: N/A			
Data surfaces per spindle	1	1			
Tracks per surface	45000	20750			
Track density (TPI)	15875	15875			
Maximum linear density (BPI)	22400	29870			
Rotational speed (RPM)	617	460-200			
PERFORMANCE					
Positioner type	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator			
Servo type	Continuous	Continuous			
Average positioning time (msec)	160	NS			
Within fine band (msec)	2	N/A			
Fine band capacity (Mbytes)	60 (tracks)	N/A			
Average rotational delay (msec)	48.8	110			
Average access time (msec)	208.8	NS			
Data transfer rate (KBytes/sec)	500-1000	153.6			
FIRST CUSTOMER SHIPMENT	4Q88	1991			
COMMENTS		Sold only as part of PDS system			

1991 DISK/TREND REPORT

OPTICAL LIBRARY SPECIFICATIONS

Coverage: The following pages list optical libraries intended for computer data storage which are now announced or in new production. In a few cases, products are listed for which preliminary announcements have been made because they are considered indicators of future industry direction.

Interface: Two interface specifications are given: One for the channel used to control the library and one for the channel(s) used to control the optical disk drives.

Import/export module: The number of disks which can be physically loaded into a library at once. Some libraries have a magazine containing multiple disks, allowing several disks to be inserted into the library at once.

Positioner type: The robotic positioner may be a single axis positioner, a two axis X-Y positioner, a rotary positioner or a carousel.

Pickers per positioner: Some positioning mechanisms can hold more than one disk at a time, permitting an exchange of disks without the need to immediately store the old disk.

Average media exchange: The average time needed for a library to remove a disk, store it, pick a new disk, and load it into a drive. It does not include spin-up or spin-down time. If the positioner has multiple pickers, only the disk fetch and exchange-at-drive times are included.

Non-queued access time: The average time required for a library to locate a cartridge, load it, spin-up the drive and be ready to read or write.

Drive data transfer rate: The data rate on the host drive interface channel. Throughput will be lower due to write verify or other delays and latencies.

Number of data paths: There may be a common I/O channel for the drives in a library or each may have its own connection to the host computer, depending upon the library design.

Accuracy: All of the information in this section has been checked for accuracy. Due to rapid changes in the industry, report users may need to make verbal inquiries of the manufacturers for updates. Where data is not specified or otherwise available, the abbreviation "NS" is used. Where a specification is not applicable, the abbreviation "N/A" appears.

1991 DISK/TREND optical disk product groups

For the 1991 report, products are classified in six groups.

Optical drives:

Group 10: Read-only optical disk drives.
Group 11: Read/write disk drives, less than 1 gigabyte.
Group 12: Read/write disk drives, more than 1 gigabyte.

Optical libraries:

Group 50: Read-only optical libraries
Group 51: Optical libraries with 1 to 39 cartridge capacity
Group 52: Optical libraries with 40 to 69 cartridge capacity
Group 53: Optical libraries with 70 or over cartridge capacity

See the previous specification section for optical disk drive data.

MANUFACTURER	ACCESS	AISIN SEIKI	CYGNET	CYGNET	CYGNET
LIBRARY	ODSR	JC2000	5250/W	1800/A1	1800/A2
DISK/TREND GROUP	51	51	51	53	53
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	12"	130 mm	130 mm	12"	12"
Nominal disk capacity (MB)	2,000	600-650	650	2,000	6,400
Cartridge type	LMSI	ANSI/ISO	ANSI/ISO, Other	ATG	ATG
DRIVE: Type	Write Once	Wr.Once,Rewrit.	Write Once	Write Once	Write Once
Drive models	LMSI LD 1250E	Sony SMO D501 Hitachi OD101 Toshiba 0070	LMS LD510	ATG GD 1002	ATG GD 6001
LIBRARY MECHANISM					
Minimum disk capacity (units)	16*	20	25	61	61
Maximum disk capacity (units)	20	20	25	141	141
Number of drives: Maximum	2	2	2	5	5
Interface: Library Drive	RS232C SCSI	SCSI Drive dependent	RS232C, SCSI SCSI	RS232C, SCSI SCSI	RS232C, SCSI SCSI
Library capacity (Gbytes) (with maximum disk capacity)	40	12-13	16.25	282	902.4
Import/export module (disks)	1	1	1	1	1
PERFORMANCE					
Positioner type	Y axis	Y axis	Rotary, with sliding disk tray	Y axis	Y axis
Pickers per positioner	1	1	2	2	2
Average media exchange time (sec)	9	5	4	18	7.5
Spin-up + drive ready time (sec)	3	Drive dependent	5.9	NS	3.6
Spin-down time (sec)	3	Drive dependent	1.9	NS	2.0
Average drive access time (msec)	212.5	Drive dependent	75	227	116
Non-queued access time (sec)	12	Drive dependent	8	15	7.4
Drive data transfer rate (KB/s)	1500	Drive dependent	1250	3830	1500
Number of drive data paths: Max.	2	1 or 2	2	5 (1 per drive)	5 (1 per drive)
FIRST CUSTOMER SHIPMENT	--	2Q88	4Q88	1987	1/91
COMMENTS	*With 2 drives				

MANUFACTURER	CYGNET	CYGNET	CYGNET	CYGNET	CYGNET
LIBRARY	1800/H	1800/L1	1800/L2	1800/0	1800/S
DISK/TREND GROUP	53	53	53	53	53
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	12"	12"	12"	12"	12"
Nominal disk capacity (MB)	2,600	2,000	5,600	2,400	6,550
Cartridge type	Proprietary	LMSI	LMSI	Optimem	Sony
DRIVE: Type	Write Once	Write Once	Write Once	Write Once	Write Once
Drive models	Hitachi OD301A1	LMSI LD1250	LMSI 4100	Optimem 2400 Optimem 4400	Sony WDD 600
LIBRARY MECHANISM					
Minimum disk capacity (units)	61	42	61	61	61
Maximum disk capacity (units)	141	95	141	141	141
Number of drives: Maximum	5	5	5	5	5
Interface: Library Drive	RS232C, SCSI SCSI	RS232C, SCSI SCSI	RS232C, SCSI SCSI	RS232C, SCSI SCSI	RS232C, SCSI SCSI
Library capacity (Gbytes) (with maximum disk capacity)	366.6	190.0	789.6	338.4/549.9	923.55
Import/export module (disks)	1	1	1	1	1
PERFORMANCE					
Positioner type	Y axis	Y axis	Y axis	Y axis	Y axis
Pickers per positioner	2	2	2	2	2
Average media exchange time (sec)	8	8.7	7.2	8.7	8
Spin-up + drive ready time (sec)	4.5	4	3.5	5	3.8
Spin-down time (sec)	3.5	4	1.5	5	2.1
Average drive access time (msec)	250	212.5	115	177	221
Non-queued access time (sec)	10	10	7.1	11	9
Drive data transfer rate (KB/s)	1200	1200	1000	1200	1000
Number of drive data paths: Max.	5 (1 per drive)	5 (1 per drive)	5 (1 per drive)	5 (1 per drive)	5 (1 per drive)
FIRST CUSTOMER SHIPMENT	1987	1987	7/91	1987	2Q89
COMMENTS					

MANUFACTURER	CYGNET	DOCUMENT IMAGING SYSTEMS CORP.	DOCUMENT IMAGING SYSTEMS CORP.	DOCUMENT IMAGING SYSTEMS CORP.	DOCUMENT IMAGING SYSTEMS CORP.
LIBRARY	1800/T	D64-1	D1200-R	D2200-1	D300-2
DISK/TREND GROUP	53	52	53	53	53
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	12"	130 mm	130 mm	130 mm	130 mm
Nominal disk capacity (MB)	5,000	650	650	650	650
Cartridge type	Toshiba WM7500	ANSI/ISO	ANSI/ISO	ANSI/ISO	ANSI/ISO
DRIVE: Type	Write Once	Wr.Once,Rewrit.	Wr.Once,Rewrit.	Wr.Once,Rewrit.	Wr.Once,Rewrit.
Drive models	Toshiba WMS500A	Various	Various	Various	Various
LIBRARY MECHANISM					
Minimum disk capacity (units)	53	34	690	1185	174
Maximum disk capacity (units)	124	64	1270	2370	314
Number of drives: Maximum	5	4	30	50	8
Interface: Library Drive	RS232C, SCSI SCSI	RS232C, SCSI SCSI	RS232C, SCSI SCSI	RS232C, SCSI SCSI	RS232C, SCSI SCSI
Library capacity (Gbytes) (with maximum disk capacity)	620	41.6	825.5	1540.5	204.1
Import/export module (disks)	1	1	1	1	1
PERFORMANCE					
Positioner type	Y axis	X-Y axis	X-Y axis	X-Y axis	X-Y axis
Pickers per positioner	2	2	2	2	2
Average media exchange time (sec)	8.7	5	7	7	7
Spin-up + drive ready time (sec)	5 max.	Drive dependent	Drive dependent	Drive dependent	Drive dependent
Spin-down time (sec)	5 max.	Drive dependent	Drive dependent	Drive dependent	Drive dependent
Average drive access time (msec)	160	Drive dependent	Drive dependent	Drive dependent	Drive dependent
Non-queued access time (sec)	11	Drive dependent	Drive dependent	Drive dependent	Drive dependent
Drive data transfer rate (KB/s)	1250	Drive dependent	Drive dependent	Drive dependent	Drive dependent
Number of drive data paths: Max.	5 (1 per drive)	1-4	1-5	1-5	1-4
FIRST CUSTOMER SHIPMENT	1Q90	9/90	1991	1991	1991
COMMENTS			1 positioner version available as D600-1	1 positioner version available as D1100-1	1 positioner version available as D150-1

MANUFACTURER	DOCUMENT IMAGING SYSTEMS CORP.	DOCUMENT IMAGING SYSTEMS CORP.	DSM GMBH & CO.	DSM GMBH & CO.	DSM GMBH & CO.
LIBRARY	D600-2	D75-1	20/27/30	28/38	48
DISK/TREND GROUP	53	53	51	51	52
MARKET	OEM	OEM	Captive, OEM	Captive, OEM	Captive, OEM
MEDIA: Nominal disk diameter	130 mm	130 mm	12"	12"	12"
Nominal disk capacity (MB)	650	650	2,000	Drive dependent	Drive dependent
Cartridge type	ANSI/ISO	ANSI/ISO	Proprietary	Proprietary	Proprietary
DRIVE: Type	Wr.Once,Rewrit.	Wr.Once,Rewrit.	Write Once	Write Once	Write Once
Drive models	Various	Various	LMSI 1200	ATG, Optimem Sony, Toshiba, LMSI 4100	ATG Gigadisc Optimem LMSI 4100
LIBRARY MECHANISM					
Minimum disk capacity (units)	394	49	20	28	48
Maximum disk capacity (units)	674	79	30 (2 drives)	28	48
Number of drives: Maximum	15	4	2	2	2
Interface: Library Drive	RS232C, SCSI SCSI	RS232C, SCSI SCSI	RS232C SCSI	RS232C SCSI	RS232C SCSI
Library capacity (Gbytes) (with maximum disk capacity)	438.1	51.4	60	Drive dependent	Drive dependent
Import/export module (disks)	1	1	1	1	1
PERFORMANCE					
Positioner type	X-Y axis	X-Y axis	Y axis	Y axis	Y axis
Pickers per positioner	2	2	2	2	2
Average media exchange time (sec)	7	6	6	8	8
Spin-up + drive ready time (sec)	Drive dependent	Drive dependent	Drive dependent	Drive dependent	Drive dependent
Spin-down time (sec)	Drive dependent	Drive dependent	Drive dependent	Drive dependent	Drive dependent
Average drive access time (msec)	Drive dependent	Drive dependent	Drive dependent	Drive dependent	Drive dependent
Non-queued access time (sec)	Drive dependent	Drive dependent	6 + spin-up	8 + spin-up	8 + spin-up
Drive data transfer rate (KB/s)	Drive dependent	Drive dependent	Drive dependent	Drive dependent	Drive dependent
Number of drive data paths: Max.	1-4	1-4	2	2	2
FIRST CUSTOMER SHIPMENT	11/90	1991	4/90	11/89	11/89
COMMENTS	1 positioner version available as D300-1		Model 27 has 1 drive, 27 disks	Model 38 has 1 drive, 38 disks	

MANUFACTURER	DSM GMBH & CO.	DSM GMBH & CO.	EASTMAN KODAK	EASTMAN KODAK	FILENET
LIBRARY	100-2000	5100 5200 5300 5400 5500	560	6800 ADL	Model 0140 OSAR GTX
DISK/TREND GROUP	53	53	52	53	53
MARKET	Captive, OEM	Captive, OEM	Captive, OEM	Captive, OEM	Captive, OEM
MEDIA: Nominal disk diameter	12"	130 mm	130 mm	14"	12"
Nominal disk capacity (MB)	Drive dependent	Drive dependent	654	10,200	7,000
Cartridge type	Proprietary	ANSI/ISO	Various	Proprietary	Hitachi
DRIVE: Type	Write Once	Wr.Once,Rewrit.	Wr.Once,Rewrit.	Write Once	Write Once
Drive models	ATG, Optimem, Sony, Hitachi, LMSI	Various	Various	Kodak 6800	Hitachi OD 301
LIBRARY MECHANISM					
Minimum disk capacity (units)	104	24 (5100)	36	50	96
Maximum disk capacity (units)	329	134 (5500)	60	100	125
Number of drives: Maximum	10	8 (5300-5500)	5	2	6
Interface: Library Drive	RS232C SCSI	RS232C SCSI	RS232C SCSI	RS232C SCSI	RS232, RS422 SCSI
Library capacity (Gbytes) (with maximum disk capacity)	Drive dependent	Drive dependent		1020	875
Import/export module (disks)	4 or 5	1	1	1	1
PERFORMANCE					
Positioner type	Y axis	X-Y axis	Y axis	Y axis	X-Y axis
Pickers per positioner	2	2	2	2	2
Average media exchange time (sec)	12	6-7	5	6.5	4.0
Spin-up + drive ready time (sec)	Drive dependent	Drive dependent	Drive dependent	2.5	3.0
Spin-down time (sec)	Drive dependent	Drive dependent	Drive dependent	1.5	2.5
Average drive access time (msec)	Drive dependent	Drive dependent	Drive dependent	570	150
Non-queued access time (sec)	8 + spin-up	Drive dependent	Drive dependent	7.0	6.0
Drive data transfer rate (KB/s)	Drive dependent	Drive dependent	Drive dependent	1000	4000
Number of drive data paths: Max.	2	2 to 8	5 (1 per drive)	2 (1 per drive)	6
FIRST CUSTOMER SHIPMENT	9/87	11/89	1Q91	3Q88	6/91
COMMENTS				Expandable in modules of 50 disks	Maximum capacity with 2 drives

MANUFACTURER	FILENET	FILENET	FILENET	HEWLETT-PACKARD	HEWLETT-PACKARD
LIBRARY	Model 0150 OSAR 107/144 GT	Model 0161 OSAR 288 X	OSAR 340	C1710M-105 Model 10GB/M	C1710A Model 20GB/M
DISK/TREND GROUP	53	53	53	51	51
MARKET	Captive, OEM	Captive, OEM	Captive, OEM	Captive,OEM,PCM	Captive,OEM,PCM
MEDIA: Nominal disk diameter	12"	12"	12"	130 mm	130 mm
Nominal disk capacity (MB)	5,600	7,000	5,600	650	650
Cartridge type	LMSI	Hitachi	LMSI	ANSI/ISO	ANSI/ISO
DRIVE: Type	Write Once	Write Once	Write Once	Rewritable	Rewritable
Drive models	LMSI LD 4100	Hitachi OD 321	LMSI LD 4100	Sony SMO-D501	Sony SMO-D501
LIBRARY MECHANISM					
Minimum disk capacity (units)	107	288	340	16	32
Maximum disk capacity (units)	144	288	340	16	32
Number of drives: Maximum	6	4	4	1	2
Interface: Library Drive	RS232, RS422 SCSI	RS232, RS422 SCSI	RS232, RS422 SCSI	SCSI-2 SCSI	SCSI-2 SCSI
Library capacity (Gbytes) (with maximum disk capacity)	806	2,016	1,904	10.4	20.8
Import/export module (disks)	1	1	1	1	1
PERFORMANCE					
Positioner type	X-Y axis	X-Y axis	X-Y axis	X-Y axis	X-Y axis
Pickers per positioner	2	2	2	1	1
Average media exchange time (sec)	4.0	8.3	7.8	7	7
Spin-up + drive ready time (sec)	3.0	3.0	3.0	6.4	6.4
Spin-down time (sec)	1.5	2.5	4.5	3.6	3.6
Average drive access time (msec)	130	150	130	102.5	102.5
Non-queued access time (sec)	6.0	9.5	9.3	9.9	9.9
Drive data transfer rate (KB/s)	4000	4000	4000	1200	1200
Number of drive data paths: Max.	6	4	4	1	2
FIRST CUSTOMER SHIPMENT	3/91	7/91	--	1Q91	11/89
COMMENTS	Maximum capacity with 2 drives		Special order		

MANUFACTURER	HEWLETT-PACKARD	HEWLETT-PACKARD	HITACHI	HITACHI	HITACHI
LIBRARY	C1715M-105 Model 60GB/M	C1715M Model 100GB/M	OL101-11 OL101-21	OL112-11 OL112-21	OL301-11 OL301-21
DISK/TREND GROUP	53	53	51	51	51
MARKET	Captive,OEM,PCM	Captive,OEM,PCM	Captive, OEM	Captive, OEM	Captive, OEM
MEDIA: Nominal disk diameter	130 mm	130 mm	130 mm	130 mm	12"
Nominal disk capacity (MB)	650	650	600	644	2,620
Cartridge type	ANSI/ISO	ANSI/ISO	ANSI/ISO	ANSI/ISO	Proprietary
DRIVE: Type	Rewritable	Rewritable	Write Once	Rewritable-(MO)	Write Once
Drive models	Sony SMO-D501	Sony SMO-D501	Hitachi OD101	Hitachi OD112-1	Hitachi OD301A1
LIBRARY MECHANISM					
Minimum disk capacity (units)	88	144	24	24	16
Maximum disk capacity (units)	88	144	24	24	16
Number of drives: Maximum	4	4	2	2	2
Interface: Library Drive	SCSI-2 SCSI	SCSI-2 SCSI	SCSI SCSI	SCSI SCSI	SCSI SCSI
Library capacity (Gbytes) (with maximum disk capacity)	57.2	93.6	14.4	15	42
Import/export module (disks)	1	1	1	1	1
PERFORMANCE					
Positioner type	X-Y axis	X-Y axis	Y axis	Y axis	Y axis
Pickers per positioner	1	1	1	1	1
Average media exchange time (sec)	8	8	7.7	7.7	8.7
Spin-up + drive ready time (sec)	6.4	6.4	2.5	4.0	4.3
Spin-down time (sec)	3.6	3.6	2.5	3.5	3.5
Average drive access time (msec)	102.5	102.5	110	70	250
Non-queued access time (sec)	10.9	10.9	7.8	7.8	8.8
Drive data transfer rate (KB/s)	1200	1200	1500	1500	1500
Number of drive data paths: Max.	4	4	1	1	1
FIRST CUSTOMER SHIPMENT	1Q91	1Q91	1987	1989	1985
COMMENTS	Single-ended or differential SCSI	Single-ended or differential SCSI	-11 has single ended interface -21 has differential interface	-11 has single ended interface -21 has differential interface	-11 has single ended interface -21 has differential interface. IEEE-488 interface avail

MANUFACTURER	HITACHI	HITACHI	HITACHI	HITACHI	HITACHI
LIBRARY	OL301-12 OL301-22	OL101-12 OL101-22	OL112-12 OL112-22	OL114-11 OL114-21	OL321-22
DISK/TREND GROUP	51	52	52	52	52
MARKET	Captive, OEM	Captive, OEM	Captive, OEM	Captive, OEM	Captive, OEM
MEDIA: Nominal disk diameter	12"	130 mm	130 mm	130 mm	12"
Nominal disk capacity (MB)	2,620	600	644	644	7000
Cartridge type	Proprietary	ANSI/ISO	ANSI/ISO	ANSI/ISO	Proprietary
DRIVE: Type	Write Once	Write Once	Rewritable-(MO)	Wr.Once/Rewrit.	Write Once
Drive models	Hitachi OD301A1	Hitachi OD101	Hitachi OD112-1	Hitachi	Hitachi OD321
LIBRARY MECHANISM					
Minimum disk capacity (units)	32	48	48	48	47
Maximum disk capacity (units)	32	48	48	48	47
Number of drives: Maximum	2	4	4	4	4
Interface: Library Drive	SCSI SCSI	SCSI SCSI	SCSI SCSI	SCSI SCSI	SCSI SCSI
Library capacity (Gbytes) (with maximum disk capacity)	83.9	28.8	30	30	329
Import/export module (disks)	1	1	1	1	1
PERFORMANCE					
Positioner type	Y axis	Y axis	Y axis	Y axis	Y axis
Pickers per positioner	1	1	1	1	2
Average media exchange time (sec)	8.7	7.7	7.7	7.7	6.5
Spin-up + drive ready time (sec)	4.3	2.5	3.7	4.0	3
Spin-down time (sec)	3.5	2.5	2.7	3.5	3
Average drive access time (msec)	250	110	70	70	150
Non-queued access time (sec)	8.8	7.8	7.8	7.8	8.5
Drive data transfer rate (KB/s)	1500	1500	1500	1500	1500/4000
Number of drive data paths: Max.	1	2	1	4	2
FIRST CUSTOMER SHIPMENT	1985	1987	1989	1991	1Q91
COMMENTS	-12 has single ended interface -22 has differential interface. IEEE-488 interface avail	-12 has single ended interface -22 has differential interface	-12 has single ended interface -22 has differential interface	-11 is single-ended SCSI -21 is differential SCSI	Dual picker

MANUFACTURER	HITACHI	INTERNATIONAL DATA ENGINEERING	INTERNATIONAL DATA ENGINEERING	INTERNATIONAL DATA ENGINEERING	KUBIK ENTERPRISES
LIBRARY	OL321-32	7000 7100	9000	Micro Library	DDC-240
DISK/TREND GROUP	52	51	51	51	50
MARKET	Captive, OEM	OEM, PCM	OEM, PCM	OEM, PCM	OEM
MEDIA: Nominal disk diameter	12"	130 mm	130 mm	130 mm	120 mm
Nominal disk capacity (MB)	7000	654	654	654	550
Cartridge type	Proprietary	ANSI/ISO	ANSI/ISO	ANSI/ISO	N/A
DRIVE: Type	Write Once	Wr.Once,Rewrit.	Wr.Once,Rewrit.	Rewritable	Read Only
Drive models	Hitachi OD321	Various	Various	Maxoptix Ricoh Sony	LMSI, Sony
LIBRARY MECHANISM					
Minimum disk capacity (units)	64	10	20	5	240
Maximum disk capacity (units)	64*	10*	20*	5	240
Number of drives: Maximum	2	1	2	1	1
Interface: Library Drive	SCSI SCSI	SCSI-2 SCSI	SCSI-2 SCSI	SCSI-2 SCSI	RS232C SCSI
Library capacity (Gbytes) (with maximum disk capacity)	448	6.5	13.1	3.3	132
Import/export module (disks)	1	1	1	5	1
PERFORMANCE					
Positioner type	Y axis	Y axis	X-Y axis	X axis	Rotary
Pickers per positioner	2	1	1	1	1
Average media exchange time (sec)	6.5	6	7	7	7
Spin-up + drive ready time (sec)	3	Drive dependent	Drive dependent	Drive dependent	1
Spin-down time (sec)	3	Drive dependent	Drive dependent	Drive dependent	1
Average drive access time (msec)	150	Drive dependent	Drive dependent	Drive dependent	Drive dependent
Non-queued access time (sec)	8.5	Drive dependent	Drive dependent	Drive dependent	NS
Drive data transfer rate (KB/s)	1500/4000	Drive dependent	Drive dependent	Drive dependent	153.6
Number of drive data paths: Max.	2	1	1	1	1
FIRST CUSTOMER SHIPMENT	1Q91	1/90	3Q91	3Q91	1990
COMMENTS	*With 1 drive Dual picker	*11 with Panasonic drive 7100 is ruggedized version	105 MB Winchester buffer is optional	Preliminary specification	

MANUFACTURER	KUBIK ENTERPRISES	LASER MAGNETIC STORAGE	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA GRAPHIC COMMUNICATION
LIBRARY	MULTI-SERVER	LF 4500 RapidChanger	LF-J5000A LF-J5080	LF-J7000A	LD-30 TQ-3050
DISK/TREND GROUP	50	51	52	52	52
MARKET	OEM	OEM, PCM	Captive, OEM	Captive, OEM	Captive, OEM
MEDIA: Nominal disk diameter	120 mm	12"	130 mm	130 mm	210 mm
Nominal disk capacity (MB)	550	5,600	940/1,000*	940/1,000*	1,200
Cartridge type	N/A	LMSI	ANSI/ISO	ANSI/ISO	Proprietary
DRIVE: Type	Read Only	Write Once	Wr.Once,Rewrit.	Wr.Once/Rewrit.	Write Once
Drive models	LMSI, Sony	LMSI LD 4100	MEI LF-5012 LF-7010	MEI LF-5012 LF-7010	MCGS LD-10
LIBRARY MECHANISM					
Minimum disk capacity (units)	240	5	50	50	30
Maximum disk capacity (units)	240	5	50	50	30
Number of drives: Maximum	5	1	2	2	2
Interface: Library	RS232C	SCSI-2	SCSI-2	SCSI-2	Proprietary
Drive	SCSI	SCSI-2	SCSI-2	SCSI-2	Proprietary
Library capacity (Gbytes) (with maximum disk capacity)	132	28	47/50*	47/50*	36
Import/export module (disks)	1	5	1	1	1
PERFORMANCE					
Positioner type	Rotary	Moving Magazine	Y axis	Y axis	X-Y axis
Pickers per positioner	1	N/A	1	1	1
Average media exchange time (sec)	7	3	10	8	12
Spin-up + drive ready time (sec)	1	2.5	5	3.5	2
Spin-down time (sec)	1	1.5	5	3.5	2
Average drive access time (msec)	Drive dependent	130*	115	115	220
Non-queued access time (sec)	NS	5.5	10	10	7
Drive data transfer rate (KB/s)	153.6	1800**	1500	1500	675
Number of drive data paths: Max.	5	1	1	1/2	1
FIRST CUSTOMER SHIPMENT	--	2Q90	1/90	1991	1984
COMMENTS	Preliminary specification	*Includes command overhead **Asynchronous mode	*With LF-7010 rewritable drive	*With LF-7010 rewritable drive	

MANUFACTURER	MITSUBISHI ELECTRIC CORPORATION	MITSUBISHI ELECTRIC CORPORATION	MITSUBISHI ELECTRIC CORPORATION	MITSUBISHI ELECTRIC CORPORATION	MITSUBISHI ELECTRIC CORPORATION
LIBRARY	ME-5G2-Z	ME-5G2-A	MW-5G2-A	ME-5G2-B	ME-5G2-C
DISK/TREND GROUP	51	52	52	53	53
MARKET	Captive, OEM	Captive, OEM	Captive, OEM	Captive, OEM	Captive, OEM
MEDIA: Nominal disk diameter	130 mm	130 mm	130 mm	130 mm	130 mm
Nominal disk capacity (MB)	297/326	297/326	600	297/326	297/326
Cartridge type	Proprietary	Proprietary	Proprietary	Proprietary	Proprietary
DRIVE: Type	Rewritable-(MO)	Rewritable-(MO)	Write Once	Rewritable-(MO)	Rewritable-(MO)
Drive models	Mitsub. ME-5E1	Mitsub. ME-5E1	Mitsub. MW-5D1	Mitsub. ME-5E1	Mitsub. ME-5E1
LIBRARY MECHANISM					
Minimum disk capacity (units)	24	54	54	150	134
Maximum disk capacity (units)	24	54	54	150	134
Number of drives: Maximum	2	2	2	2	4
Interface: Library	SCSI	SCSI	SCSI	SCSI	SCSI
Drive	SCSI	SCSI	SCSI	SCSI	SCSI
Library capacity (Gbytes) (with maximum disk capacity)	14	32	32	90	80
Import/export module (disks)	1	1	1	1	1
PERFORMANCE					
Positioner type	Y axis	X-Y axis	X-Y axis	X-Y axis	X-Y axis
Pickers per positioner	1	1	1	1	1
Average media exchange time (sec)	5.5	6.5	7.5	8.5	8.5
Spin-up + drive ready time (sec)	3.5	3.5	3	3.5	3.5
Spin-down time (sec)	3.0	3.0	2.5	3.0	3.0
Average drive access time (msec)	58	58	85	58	58
Non-queued access time (sec)	6	7	7	8	8
Drive data transfer rate (KB/s)	620	620	480	620	620
Number of drive data paths: Max.	2	2	1	2	4
FIRST CUSTOMER SHIPMENT	2Q91	2Q91	3Q90	2Q91	3Q91
COMMENTS	Sold only in Japan	Sold only in Japan		Sold only in Japan	Sold only in Japan

MANUFACTURER	MITSUBISHI ELECTRIC CORPORATION	MITSUBISHI ELECTRIC CORPORATION	NEC	NEC	NEC
LIBRARY	MW-5G2-B	MW-5G2-C	N7923	N7925	ND3605-19
DISK/TREND GROUP	53	53	51	52	52
MARKET	Captive, OEM	Captive, OEM	Captive	Captive	Captive
MEDIA: Nominal disk diameter	130 mm	130 mm	12"	130 mm	130 mm
Nominal disk capacity (MB)	600	600	5,000	610	610
Cartridge type	Proprietary	Proprietary	Proprietary	ANSI/ISO	ANSI/ISO
DRIVE: Type	Write Once	Write Once	Write Once	Rewritable-(MO)	Write Once
Drive models	Mitsub. MW-5D1	Mitsub. MW-5D1	NEC N7913	NEC N7915	NEC ND3605-13
LIBRARY MECHANISM					
Minimum disk capacity (units)	150	134	36	67	46
Maximum disk capacity (units)	150	134	36	67	60
Number of drives: Maximum	2	4	2	4	4
Interface: Library Drive	SCSI SCSI	SCSI SCSI	NEC Proprietary	SCSI SCSI	SCSI SCSI
Library capacity (Gbytes) (with maximum disk capacity)	90	80	180	40	36.6
Import/export module (disks)	1	1	1	1	1
PERFORMANCE					
Positioner type	X-Y axis	X-Y axis	Y axis	Y axis	Y axis
Pickers per positioner	1	1	2	2	2
Average media exchange time (sec)	9.5	9.5	14	10	10
Spin-up + drive ready time (sec)	3	3	8	3.5	3.5
Spin-down time (sec)	2.5	2.5	8	3.5	3.5
Average drive access time (msec)	85	85	200	84.7	84.7
Non-queued access time (sec)	8	8	15	9	9
Drive data transfer rate (KB/s)	480	480	900	1500	1500
Number of drive data paths: Max.	1	1	2	1	1
FIRST CUSTOMER SHIPMENT	3Q90	3Q90	6/90	1990	9/90
COMMENTS					

MANUFACTURER	NEXT TECHNOLOGY	NKK	NKK	NKK	NKK
LIBRARY	Voyager	N-556E	N-556MP	N-556MS	N-556W
DISK/TREND GROUP	50	52	52	52	52
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	120 mm	130 mm	130 mm	130 mm	130 mm
Nominal disk capacity (MB)	550	654	654	650	900
Cartridge type	N/A	ANSI/ISO	ANSI/ISO	ANSI/ISO	ANSI/ISO
DRIVE: Type	Read Only	Rewritable	Wr.Once,Rewrit.	Wr.Once,Rewrit.	Write Once
Drive models	Sony 541 or user selected	Sony SMO-D501	Pioneer DEJ-U7001	Sony SMO-E511	Toshiba D070
LIBRARY MECHANISM					
Minimum disk capacity (units)	90	56	56	56	56
Maximum disk capacity (units)	270	56	56	56	56
Number of drives: Maximum	8	2	2	2	2
Interface: Library	RS232C	SCSI	SCSI	SCSI	RS232C, SCSI
Drive	SCSI	SCSI	SCSI	SCSI	SCSI
Library capacity (Gbytes) (with maximum disk capacity)	148.5	36	36.6	36.4	50
Import/export module (disks)	1	16	16	16	16
PERFORMANCE					
Positioner type	X-Y axis	Y axis	Y axis	Y axis	Y axis
Pickers per positioner	2	1	1	1	1
Average media exchange time (sec)	5	5	5	5	5
Spin-up + drive ready time (sec)	Drive dependent	7	6	7	7
Spin-down time (sec)	Drive dependent	4	3	4	5
Average drive access time (msec)	Drive dependent	100	70	100	100
Non-queued access time (sec)	Drive dependent	9.5	8.5	9.5	9.5
Drive data transfer rate (KB/s)	153.6	1200	491	1200	1200
Number of drive data paths: Max.	8 (1 per drive)	1/2	1/2	1/2	1/2
FIRST CUSTOMER SHIPMENT	3Q89	12/89	3Q91	3Q91	1/90
COMMENTS					

MANUFACTURER	NSM	PIONEER	RICOH	RICOH	SONY
LIBRARY	CDR-100	DRM-600 DRM-600A DRM-610	RJ5160	RJ5330E	WDA 3000
DISK/TREND GROUP	50	50	51	52	52
MARKET	OEM	OEM	OEM	OEM	Captive, OEM
MEDIA: Nominal disk diameter	120 mm	120 mm	130 mm	130 mm	12"
Nominal disk capacity (MB)	600	550	800	646	3,200
Cartridge type	NSM	N/A	Proprietary	ANSI/ISO	Proprietary
DRIVE: Type	Read Only	Read Only	Write Once	Rewritable	Write Once
Drive models	Philips NEC	Pioneer (integrated with drive)	Ricoh RO-5040WL	Ricoh RO-5030EII	Sony WDD 3000
LIBRARY MECHANISM					
Minimum disk capacity (units)	100	6	20	56	50
Maximum disk capacity (units)	100	6	20	56	50
Number of drives: Maximum	1	1	2	2	2
Interface: Library	SCSI, RS422	SCSI	SCSI	SCSI	SCSI
Drive	SCSI	SCSI	SCSI	SCSI	SCSI
Library capacity (Gbytes) (with maximum disk capacity)	60	3.3	16	36.2	160
Import/export module (disks)	50/1	6	1	16	1
PERFORMANCE					
Positioner type	X-Y axis	NS	Y axis	Y axis	Y axis
Pickers per positioner	2	1	1	1	1
Average media exchange time (sec)	5.5	NS	7	5	7
Spin-up + drive ready time (sec)	1.5	NS	.5	9.0	2.5
Spin-down time (sec)	1.0	NS	.5	5.0	2.5
Average drive access time (msec)	500	600	168	67	500
Non-queued access time (sec)	9	NS	8.2	11.5	4
Drive data transfer rate (KB/s)	153.6	NS	1400	1400	300
Number of drive data paths: Max.	1	1	1/2	1/2	1
FIRST CUSTOMER SHIPMENT	3/91	4Q89	2Q88	4Q89	1/85
COMMENTS			Can attach 7 units to 1 SCSI port		Can attach 7 units to 1 SCSI port

MANUFACTURER	SONY	TOSHIBA	TOSHIBA		
LIBRARY	WDA-610	WM-A012	WM-A320		
DISK/TREND GROUP	52	51	51		
MARKET	Captive, OEM	Captive	Captive		
MEDIA: Nominal disk diameter	12"	130 mm	12"		
Nominal disk capacity (MB)	6,550	800	5,000		
Cartridge type	Proprietary	Proprietary	Proprietary		
DRIVE: Type	Write Once	WORM	WORM		
Drive models	WDD 600	Toshiba WM-D050	Toshiba WM-S500		
LIBRARY MECHANISM					
Minimum disk capacity (units)	50	20	25		
Maximum disk capacity (units)	50	20	25		
Number of drives: Maximum	2	2	2		
Interface: Library Drive	SCSI SCSI	SCSI SCSI	SCSI SCSI		
Library capacity (Gbytes) (with maximum disk capacity)	327.5	16	125		
Import/export module (disks)	1	1	1		
PERFORMANCE					
Positioner type	Y axis	Y axis	Y axis		
Pickers per positioner	1	1	1		
Average media exchange time (sec)	5	26	15		
Spin-up + drive ready time (sec)	2.5	NS	5		
Spin-down time (sec)	2.5	NS	3		
Average drive access time (msec)	400	180	208		
Non-queued access time (sec)	3.0	16	12.5		
Drive data transfer rate (KB/s)	600	693	500-1000		
Number of drive data paths: Max.	1	2	2		
FIRST CUSTOMER SHIPMENT	9/89	1985	1984		
COMMENTS	Can attach 7 units to 1 SCSI port	Sold only in Japan	Sold only in Japan		

MANUFACTURER PROFILES

1991 DISK/TREND REPORT

MANUFACTURER PROFILES

All manufacturers now producing optical disk drives or optical disk libraries, or those which are expected to eventually enter the market, are listed in this section. DISK/TREND normally estimates the annual volume of disk drive sales by manufacturers. Because few companies had a high level of optical library or disk drive sales in 1990, this figure is reported explicitly only for firms with major 1990 sales. "1990 total net sales" covers the fiscal year ending in 1990 for each firm unless noted otherwise, or for the parent company if the disk drive or library manufacturer is a subsidiary. The fiscal year of listed firms ends on December 31, 1990, unless otherwise noted.

Manufacturers located in the United States that have majority owners headquartered in other countries are grouped in the geographical area in which the owner's home office is located.

Exchange rates

The exchange rates used in converting the financial data of non-U.S. manufacturers to dollars are given below. The average exchange rate for 1990 is used, as cited by the Federal Reserve Bulletin.

Country	Currency	Currency units/U.S. dollar
France	Franc	5.45
Japan	Yen	145.0
Netherlands	Guilder	1.82
South Korea	Won	711.0
Germany	Deutschmark	1.61

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

U.S. Manufacturers

ACCESS CORPORATION
1101 Glendale-Milford Road
Cincinnati, Ohio 45215

Access is a manufacturer of digital and micrographic image management and distribution systems. The company was founded in 1963. As an adjunct to its systems business, Access, in conjunction with Laser Magnetic Storage, designed a 12" optical library unit which it supplied exclusively to LMSI for a few years. Access now supplies the library to its own end users and on an OEM basis to system vendors. The Access libraries incorporate drives from LMSI.

BERNOULLI OPTICAL SYSTEMS CO.
Subsidiary of Iomega Corporation
5700 Flatiron Parkway
Boulder, CO 80301

BOSCO developed a 5.25", half-high write-once drive using flexible media which it now is willing to license to other companies. Target capacity was 1.3 gigabytes on two sides of the cartridge, with average access time in the 40-50 millisecond range. The BOSCO design was the first 5.25" optical drive to have dual optical heads and independent actuators. Media was to be supplied by ICI, which had invested in BOSCO and now shares the rights to the drive design. A prototype drive and media were shown at the 1989 AIIM show and at subsequent events, but there are no current plans to produce the drive.

CHEROKEE DATA SYSTEMS
1880 S. Flatiron Court
Boulder, CO 80301

Cherokee was founded in March, 1984. Key founders include managers previously with Storage Technology Corporation and Sperry Corporation. The firm has designed a 300 megabyte ruggedized 5.25" write-once drive that it supplies to customers in the defense and mineral resources industries. Shipments began in 1988. The first major customer for the Cherokee drive was Lockheed Corporation, which announced in April of 1986 that it had invested $2,000,000 in Cherokee and intended to modify the product for potential use in airborne electronic navigation systems for fighter aircraft. Later investments brought Lockheed's share of ownership to 36%. Cherokee shipped a modest number of drives in 1988 and 1989. Increased government purchasing activity is expected by Cherokee to gradually improve shipments. A non-ruggedized version of the drive became available in late 1989, which is expected by Cherokee to increase in shipment volume.

COLORADO TECH DESIGNS, INC.
4755 Walnut Street
Boulder, CO 80301

Founded in 1986, Colorado Tech Designs specializes in mass storage subsystems. Current products are heavily oriented toward tape libraries, although a few optical libraries were built several years ago on a custom contract basis. The company is one of the few to employ a rotary mechanism in its libraries, rather than the more conventional elevator mechanism. Future plans include optical libraries using small diameter drives, but no specific timetable has been announced.

CYGNET SYSTEMS, INC.
2560 Junction Avenue
San Jose, CA 95134

Cygnet was founded in 1983 to develop systems to serve the image storage market. Its primary line of business is a series of optical libraries that use various 12" and 5.25" optical drives, plus supporting software. As one of the early entrants into the optical library arena, Cygnet enjoys a substantial share of the available business. The first commercial shipments of 12" based libraries began in 1987. Shipments of libraries with 5.25" drives began in late 1988, although the unusual design of the 5.25" library has caused some drive integration problems delaying manufacturing ramp up. Cygnet decided in mid-1990 to offer its 5.25" library only with the LMSI write-once drive, but is considering adding a rewritable drive in the future.

Cygnet has licensed Eastman Kodak to manufacture some of its products.

DIGITAL EQUIPMENT CORPORATION
146 Main Street
Maynard, MA 01754

1990 total net sales: $12,942,523,000 (FY ending 6/30/90 Net income: $74,393,000

DEC was the first major system supplier to offer the CD-ROM as a system peripheral. The CD-ROM product is based upon a drive supplied by Philips, and is interfaced and supported on the highly successful Micro-VAX product line. A long-time manufacturer of both rigid and floppy magnetic disk drives, DEC is a logical candidate for internal production of its own optical drives at some future time. In 1988, DEC announced the RV20, which incorporates a 12", 1 gigabyte per side, write-once drive supplied by Laser Magnetic Storage. DEC also announced the RV64 jukebox (externally procured), which can handle up to four 12" drives, in 1989.

DOCUMENT IMAGING SYSTEMS CORPORATION
543 Weddell Drive
Sunnyvale, CA 94089

DISC was founded in 1986 specifically to develop and manufacture customized optical libraries. The firm's products are built around a modular concept of configuring a system with an appropriate number of 5.25" optical drives, disk storage slots and picker mechanisms to meet customer performance needs. Tradeoffs may be made between the number of drives (up to 110), pickers (up to 24) and disk storage slots (up to 2290). The first commercial showing of the systems was at the 1990 AIIM conference.

EASTMAN KODAK COMPANY
343 State Street
Rochester, NY 14650

1990 total net sales: $18,908,000,000 Net income: $703,000,000

Eastman Kodak has had two publicly announced optical disk drive production efforts, one a very high capacity 14" write-once optical disk drive and the other a low-end 3.5" magneto-optical drive. The latter product originated at Verbatim Corporation, acquired by Eastman Kodak in 1985, and is now associated with Literal Corporation in which Eastman Kodak has a 26% interest. In the spring of 1989, Eastman Kodak purchased a 40% ownership in Laserdrive and transferred the 3.5" drive development to Laserdrive. Verbatim, which was sold to Mitsubishi Kasei in 1990, retained optical media and head development responsibilities. Laserdrive was merged into Literal Corporation in 1990.

The 14" drive began its production run in 1987, but relatively few have been shipped to date. It uses a zoned format and employs proprietary dye/polymer media. The drive is used in Eastman Kodak's KIMS series image storage product lines and is also offered on an OEM basis as a computer peripheral. The company also purchases 12" optical drives from Hitachi and 5.25" optical drives from Literal for use in the KIMS product line.

Eastman Kodak produces automated library units for use with its own 14" drive as well as a 5.25" library for use with purchased drives. Both libraries are also sold on an OEM basis. The firm also purchases library units for systems using 12" drives from other manufacturers.

FILENET CORPORATION
3565 Harbor Boulevard
Costa Mesa, CA 92626

1990 total net sales: $102,871,000 Net income: $3,759,000

Filenet, founded in 1982, is a producer of document image storage systems and subsystems including optical libraries. Systems are sold primarily to end users, but 12" libraries are also sold on an OEM basis. OEM Customers for libraries have included IBM, N. V. Philips, Eastman Kodak and others.

International system sales are handled by foreign subsidiaries and by distributors, most notably Olivetti in Europe and Australia and Toyo Officemation, a Mitsui subsidiary, in Japan.

Production of optical libraries began in 1985. The Filenet product line is built around 12" drives, and offers some of the largest storage capacities available in a non-customized optical library. Up to 288 disks can be stored in the largest Filenet system. Filenet has a major share of the 12" optical library market, with claimed cumulative shipments of over 400 systems, mostly 12", as of mid-1991. The firm also sells 5.25" libraries to its end user customers, but these are purchased from other sources.

Filenet is shifting the thrust of its product development activities to libraries able to store larger numbers of disks and to the development of complete systems and software for document imaging, processing and storage.

HEWLETT-PACKARD COMPANY
3000 Hanover Street
Palo Alto, CA 94303

1990 total net sales: $13,233,000,000 (FY ending 10/31/90) Net income: $739,000,000

Hewlett-Packard announced a high performance 5.25" magneto-optic disk drive in 1991 for volume delivery in early 1992. The drive will be produced in the Greeley, Colorado facility which has been producing optical libraries since 1989. Some related work on optical and rigid drive technology is being done at H-P Laboratories.

In 1989, H-P announced that it would sell the Sony 5.25" rewritable drive as an OEM or end user system peripheral in both standalone and jukebox configurations. The new H-P optical drive is expected to gradually displace the Sony drive in H-P system and subsystem products.

In September of 1987, the firm announced it would distribute technical documentation for its computer systems on CD-ROM, and followed that up in June of 1988 with distribution of UNIX support information on CD-ROM.

HONEYWELL, INC.
Optical Storage Systems Operation
19019 North 59th Avenue
Glendale, AZ 85308

Honeywell purchased Sperry's Optical Products Group and Aerospace Group at the time that Sperry and Burroughs merged to form Unisys, and combined them to form the Sperry Space Division. At the same time, Honeywell obtained Sperry's 9% share of ownership in ISI, now renamed as Literal Corp. Honeywell is continuing development of a militarized drive based on Literal technology. Small quantities of a 300 megabyte 5.25" write-once drive began shipping in 1989 for use in a USAF system.

INTERNATIONAL BUSINESS MACHINES CORPORATION
Route 22
Armonk, NY 10504

1990 total net sales: $69,018,000,000 Net income: $6,020,000,000

Since May, 1986, IBM has demonstrated CD-ROM subsystems with various personal computers, and in 1990 CD-ROM drives were announced as options on the IBM RS/6000 system as well as on some PS/2 systems. IBM relies on outside purchases of CD-ROM drives at present and is unlikely to manufacture its own.

At the 1989 Microsoft CD-ROM conference, IBM indicated support of both the XA architecture and the Intel DVI format, and has continued to indicate support of these formats. In other forums, IBM has indicated interest in future multimedia products for small systems and various applications.

In April, 1987, IBM announced the model 3363 write-once drive for use with its personal computers. The mechanism for this drive was obtained from Matsushita Electric; IBM supplied the electronics, software, and final assembly and test. The product has been unsuccessful, and shipments of mechanisms to IBM ceased in 1988. The 3363 was finally withdrawn from marketing in 1991.

In the spring of 1991, IBM announced a 3.5" 128 megabyte magneto-optic drive that had been designed at its Fujisawa facilities. The drive, which can also function as a read-only drive, will be sold with PS/2 systems and on an OEM basis. IBM's entry into the 3.5" drive marketplace is expected to encourage other firms to announce similar optical disk drives in the 1991-1992 time period.

IBM has been purchasing 12" optical drives and library modules for integration into subsystems since 1988, and in 1991 announced the 3995, a family of 5.25" libraries with write-once drives. Hewlett-Packard is the supplier of the library mechanisms, while Mitsubishi drives have been shown with the libraries. The company offers optical library systems as attachments to large and mid-range systems used in image management applications.

While IBM has not revealed its future product plans, it is widely believed in the industry that IBM is working on 5.25" erasable optical technology for use with high performance workstations and optical library subsystems. As a result of a mid-1988 reorganization, IBM's future optical products may be made in a location other than Tucson, but development staff and laboratories remained in Tucson. Further development of 3.5" drives is also under way in Fujisawa, Japan.

INTERNATIONAL DATA ENGINEERING
6214 Bury Drive
Eden Prairie, MN 55346

Privately held IDE was founded in 1987. Originally the firm was involved

in making data cartridge duplicators and tape cartridge stacker mechanisms, but in 1988 started developing a small optical library. The resulting products are tabletop libraries offering modest performance and capable of holding ten 5.25" cartridges and a single 5.25" drive. A 20 cartridge, 2 drive model was introduced in 1990. The libraries are being remarketed by subsystem producers and some optical drive producers. Because of the library's very low OEM and distributor prices, the firm was able to sell more libraries in 1990 than any other producer. A five cartridge version is planned for introduction in 1991.

KUBIK ENTERPRISES, INC.
18873 Allandale Avenue
Saratoga, CA 95070

Kubik is a start-up company that is producing optical libraries for CD and CD-ROM subsystems. Philips/LMSI CD-ROM mechanisms are used. The products are unusual in that they employ a rotary mechanism, not unlike that used in many slide projectors, to store disks. Shipment levels remain low while the company seeks strategic alliances.

LITERAL CORPORATION
2768 Janitell Road
Colorado Springs, CO 80906

Literal began life as Information Storage, Inc. (ISI), in 1983 when it was founded by executives from Optical Peripherals Laboratory, the original Philips and Control Data joint venture for optical drive development. Among the early investors in ISI were CPT (20%) and Tallgrass (20%). Sperry, now incorporated into Unisys, also became a significant investor, and acquired rights to ISI technology for use in military systems. This product area, along with Sperry's investment, was subsequently sold to Honeywell. A funds shortage in early 1986 required scaling back the size of the company, but ISI was successful in attracting additional investment from local and foreign sources, in some cases by licensing its design. In 1986, ISI licensed two other firms, Maximum Storage, Inc., and Kawatetsu Advantech, to use ISI technology and designs. Both firms are currently in low volume production. Kawatetsu is a subsidiary of Kawasaki Steel, which is a current investor in Literal.

In 1990, Literal was formed by combining the operations of ISI and Laserdrive, which was jointly owned by Olivetti and Eastman Kodak. Laserdrives' operations were transferred to Colorado Springs by mid-1990. Olivetti and Eastman Kodak each own about 26% of Literal, and Kawasaki Steel holds about 21%. The remainder is held by earlier ISI investors.

The initial ISI product was a 5.25" write-once drive of 122 megabyte capacity, aimed at the personal computer and small system peripherals market. Limited production began in the fourth quarter of 1985. In February, 1988, ISI announced a 600 megabyte per side, 5.25" write-once drive for volume delivery in late 1988. The drive uses a technique called track compression to achieve the higher capacity.

Literal's current efforts are heavily oriented to ramping up production of newer optical drives, and developing device drivers for various operating systems. Development on a small diameter magneto-optic drive is proceeding based upon the Verbatim technology obtained from Laserdrive.

MAXIMUM STORAGE, INC.
5025 Centennial Boulevard
Colorado Springs, CO 80919

Privately held, MSI was founded in September, 1986, by Paul Schroeder, one of the founders of INMOS. Start-up has been rapid, as MSI licensed technology from ISI and began producing a 5.25" write-once drive having specifications similar to the ISI drive in early 1987. MSI has designed its drives for use with IBM PC and PC-compatible computers, and has developed its own software to optimize data throughput in write-once drives.

MAXOPTIX CORPORATION
Joint venture of Maxtor Corporation and Kubota, Ltd.
2520 Junction Avenue
San Jose, CA 95134

In March of 1989, Maxtor and Kubota, Ltd. formed Maxoptix, a joint venture 75% owned by Maxtor. Maxoptix designs, produces and markets rewritable optical disk drives. Kubota has worldwide manufacturing rights and exclusive sales rights in Japan for Maxoptix products.

Maxtor, with manufacturing facilities in California and Singapore, is a supplier of high performance 3.5" and 5.25" rigid disk drives. In 1986, Maxtor entered into an agreement with Ricoh in which Maxtor acquired exclusive U.S. OEM marketing rights for the Ricoh 5.25" write-once optical disk drive. Because of Maxtor's strong market penetration in the OEM community, this was a successful effort for both parties, although shipment volume of the write-once drives has since declined.

In May, 1988, Maxtor announced a 5.25" magneto-optic rewritable drive offering 35 millisecond average seek time, the industry's fastest at the time. Evaluation units began shipping in late 1988, and volume production began in late 1989. Maxtor also announced a 3.5" erasable drive to be supplied by Seiko Epson, but this product was later withdrawn. The rewritable drive program was turned over to Maxoptix for further development and eventual manufacturing. An improved version with similar specifications but improved electronics was introduced in 1991.

Maxoptix leverages its optical program through Maxtor's subsystem subsidiary Storage Dimensions, which serves the personal computer and system integrator markets. U.S. Design, a firm specializing in storage subsystems for the DEC market was also acquired by Maxtor and subsequently merged into Storage Dimensions. Storage Dimensions accounts for a substantial fraction of Maxtor and Maxoptix optical and rigid disk drives.

In 1990, Digirede, a Maxtor licensee in Brazil, indicated its intent to assemble the Maxoptix magneto-optic drive in Brazil, but the current economic and political uncertainties in Brazil's economy make a starting date uncertain.

MOUNTAIN OPTECH, INC.
4775 Walnut Street
Boulder, CO 80301

Mountain Optech, founded in 1985, specializes in optical disk drives for ruggedized and military applications. Its first product was a modified version of the Optotech 5.25" write-once drive, delivered in 1986. The modified drives are used in harsh environments such as seismic survey, aircraft maintenance, and manned spacecraft. The mechanism and electronics have been modified for ruggedized or militarized requirements.

The firm has begun designing its own drives which will include advanced features such as digitally adaptive read/write electronics. A militarized write-once drive for use in an airborne digital mapping system was delivered in late 1990. An upgraded ISO-compatible version is planned for 1991 production, as is a ruggedized version of a currently available 5.25" magneto-optic rewritable drive.

OPTIMEM
Subsidiary of Archive Corporation
435 Oakmead Parkway
Sunnyvale, CA 94086

1990 total net sales: $293,234,000 Net income: $11,537,000

Optimem began in 1980 when a Xerox technology program was transferred to Shugart Associates, then a Xerox subsidiary. The Optimem Division of Shugart functioned until Shugart ceased operations, at which time Optimem itself became a Xerox subsidiary company. In mid-1986, control of Optimem was acquired from Xerox by Cipher Data Products. Xerox retained a 10% minority ownership position. 3M Company subsequently acquired a small ownership position.

The Optimem products were 12", 1 and 1.2 gigabyte drives. Work on a 5.25" drive capable of using read-only, write-once or magneto-optical erasable media was discontinued in 1987 and Optimem relied upon other manufacturers for its 5.25" product line. The 12" Optimem drive found applications in image processing and in document storage and retrieval systems.

Optimem was hurt in 1987 by the departure of most of its senior management, and though the firm weathered the changes it was unable to recover its former strength. Despite Optimem's partial recovery, Archive elected to discontinue new drive manufacturing operations in the summer of 1991. Service and support for existing customers will be maintained.

Asian Manufacturers

(All fiscal years end in March, 1990, unless otherwise noted. All firms are in Japan unless otherwise noted.)

AISIN SEIKI CO., LTD.
2-1 Asahi-cho, Kariya-shi
Aichi 448

1990 total net sales: $4,732,317,000 Net income: $445,931,000

Aisin Seiki, a member of the Toyota Group, was established in 1949. The firm's primary activity, about 70% of revenues, is the production of automotive components for Toyota, but it also produces home and industrial appliances, air conditioning equipment, and cryogenic pumps. Electronic products, including optical libraries, are an area of diversification.

Optical libraries are produced under Aisin's own name and are also produced for other firms on a contract basis. At present, only library units with 5.25" drives are produced. Both write-once and rewritable drives are used. Production started in 1988, but the first libraries with rewritable drives were shipped in 1990.

ALPS ELECTRIC CO., LTD.
1-7, Yukigaya Otsuka-cho
Ohta-ku, Tokyo 145

1990 total net sales: $2,777,841,000 Net income: $4,903,000

Alps Electric is a major manufacturer of electronic components and subassemblies for audio, television, instrument and computer applications. Peripheral devices, including printers, floppy and rigid disk drives, accounted for 15% of revenues in 1990. Alps has been working with other companies wishing to supply CD-ROMs and is able to supply design assistance, components, and to manufacture on a contract basis.

CANON INC.
2-7-1 Nishi-Shinjuku
Shinjuku-ku, Tokyo 163

1990 total net sales: $11,916,883,000 (FY ending 12/31/90) Net income: $423,503,000

Canon is a major supplier of business machines, copiers, and cameras, but about 27% of the firm's business is in computer peripherals and another 22% is in other data and communications equipment. Disk drive products include flexible and erasable optical drives. Canon's rewritable drive and media were announced in 1988 when it was revealed that Canon had an exclusive agreement with NeXT to supply a 256 megabyte 5.25" magneto-optic drive. Shipments began in 1988, making Canon, along with Sony, one of the few major suppliers of rewritable drives. In 1989, Canon acquired a 16% interest in NeXT. In 1991, Canon is shipping most of its optical drives for use in its own document management systems.

CHINON INDUSTRIES INC.
21-17 1 Chome, Takashima
Suwa City, Nagano 392

1990 total net sales: $334,766,000 Net income ($386,000)

Chinon is best known for its cameras and audio equipment, but 53% of its sales come from floppy disk drives, printers and other equipment for information systems. Eastman Kodak holds approximately 12.3% ownership through Kodak Japan. Chinon has been producing head assemblies for CD equipment and in 1988 began supplying CD-ROM drives to Atari as a custom product. A similar drive has since appeared under Chinon's own label for use with IBM and Apple personal computers.

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

1990 total net sales: $17,584,641,000 Net income: $598,331,000

Fujitsu is Japan's largest producer of computer systems and also manufactures a wide variety of other electronic equipment. Computer products represent about 70% of Fujitsu's sales.

Fujitsu announced a write-once 12" drive for use in document storage systems in 1984. The product is currently marketed only in Japan. In 1986, the company added a similar product for sale in Japan on an OEM basis. The head for the drive was developed in a joint effort with Olympus Optical Company, the industry's leading supplier of optical read/write heads. Media was developed in a joint program with Asahi Chemical. In October, 1986, Fujitsu announced a 5.25" write-once drive with 300 megabyte capacity for delivery in mid-1987. Fujitsu has a development program for erasable optical disk drives and media, and has made a technology announcement of rewritable media using phase change techniques, but has not announced a phase change drive as of mid-1990. However, an 8", non-removable M-O rewritable drive with 8.9 gigabyte capacity was introduced in 1989. It, also, is offered only in Japan.

In 1989, Fujitsu began to ship a computer system with a bundled CD-ROM drive, one of the first companies anywhere to take such a step. It is currently available only in Japan, but has been displayed in the U.S. and elsewhere. The CD-ROM drive is purchased from another firm.

At the 1991 Tokyo Business Show, Fujitsu showed a preliminary version of a 5.25" optical library and a non-operating version of a high performance 5.25" rewritable drive being jointly developed with NTT.

GOLDSTAR CO., LTD.
20, Yoido-dong
Yongdungpogu, Seoul
Korea

1989 total net sales: $3,663,836,000 Net income: $25,368,000

Goldstar, founded in 1959, is one of Korea's leading manufacturers of home appliances and electronics. About 67% of revenues are derived from electronic products. In 1989, Goldstar announced a CD-ROM drive, but sales to date have been modest.

GOLDSTAR TELECOMMUNICATION CO., LTD.
20, Yoido-dong
Yongdungpogu, Seoul
Korea

1989 total net sales: $221,911,000 Net income: ($17,945,000)

Goldstar Telecommunications is a joint venture between the Lucky Goldstar Group (6.8%) and several other firms, including the German firms, Siemens (20%) and DEG (6.8%). About 14% of total sales is computer related equipment. Goldstar announced a rewritable drive in 1989, but few have shipped.

HITACHI, LTD.
6-2, Otemachi 2-chome
Chiyoda-ku, Tokyo 100

1990 total net sales: $48,812,743,000 Net income: $1,454,917,000

Hitachi remains Japan's largest manufacturer of electrical and electronic equipment and a major producer of computer systems. It manufactures rigid disk drives and other peripherals as well as processors.

Hitachi was one of the earlier entrants in the optical disk drive market, and the firm's CD-ROM and read/write drives are available in the U.S. as well as in Japan. Hitachi's first write-once 12" optical disk drive has a capacity of 1.3 gigabytes, and began shipping in 1984.

The CD-ROM drives began shipping in 1985, and since 1987 Hitachi has been a leading high performance CD-ROM drive producer. The CD-ROM product line was expanded in 1986 and 1987 to include 5.25" form factor drive packaging and some new features.

In early 1986, Sperry announced that the Hitachi 12" write-once optical drive was available as a peripheral device on its mainframes -- the first optical drive offered by a mainframe vendor. A 5.25" continuous servo write-once drive with a capacity of 300 megabytes was announced at COMDEX in 1986. A sampled servo version offering 320 megabytes per side was introduced in late 1987, but this drive was not successful.

In early 1988, Hitachi made a technology announcement of a 3.5" erasable drive under development in its Central Research Laboratory, but the first Hitachi rewritable drive to be announced was a 322 megabyte, 5.25" model in March of 1989.

Hitachi also offers automated library storage units for use with 12" and 5.25" drive designs and has successfully marketed its libraries on an OEM and captive basis. Media for Hitachi drives is made by Hitachi Maxell.

JVC (VICTOR COMPANY OF JAPAN, LTD.)
1-4 Nihonbashi-Honcho
Chuo-ku, 103 Tokyo

1990 total net sales: $5,976,207,000 Net profit: $127,055,000

JVC, as it is commonly known, is a major producer of consumer audio equipment, including CD players. Video tape recorders accounted for 47% of JVC sales in 1990, but JVC has been expanding into computer peripherals and has been shipping rigid disk drives since 1985. Computer related products now account for about 9% of revenues. The firm introduced CD-ROM drives and went into low volume production in the last half of 1987, but has since withdrawn from the CD-ROM market. A CD-WO drive first shown at the 1990 Fall COMDEX conference is scheduled to go into production in late 1991.

KAWATETSU ADVANTECH CO. LTD.
Subsidiary of Kawasaki Steel Corporation
14-4 Nihonbashi Kodemma-cho
Chuo-ku, Tokyo 103

1990 total net sales: $8,374,455,000 Net income: $385,303,000

Kawatetsu Advantech is a smaller company specializing in electronic instrumentation. The firm began producing 5.25" write-once optical disk drives at its Nishinomiya plant in December of 1986 under license from ISI, now Literal Corporation. Kawatetsu Advantech markets the drives to OEM customers in Asian markets through Kanto Denshi, a trading company, and may act as a source of supply to Literal as demand warrants.

In 1988, Kawatetsu Advantech, Kawasaki Steel and four private investors established Advansys Corporation, which is chartered to develop components for optical disk drives. Advantech holds 50% ownership and Kawasaki Steel an additional 25%. Kawatetsu Advantech is maintaining its relationship with Literal, and has begun shipping 5.25" drives based on the ISI 600 megabyte design.

MATSUSHITA ELECTRONIC COMPONENTS CO., LTD.
Subsidiary of Matsushita Electric Industrial Co,. LTD.
1006, Kadoma City
Osaka, 571

MACO, as the company is often known, produces a wide variety of electronic items, including audio/visual equipment, appliances, communications and data processing equipment, and instrumentation. Data storage products include CD-ROM drives and floppy disk drives. Half-high CD-ROMs began shipping in 1987, mostly to customers in Japan.

MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.
1006, Kadoma City
Osaka, 571

1990 total net sales: $41,398,524,000 Net income: $1,624,559,000

MEI's Panasonic, National, Technics, and Quasar brands are among the most widely known in the world for appliances, consumer electronics, and communications equipment. The firm also developed an 8" write-once drive for use by Matsushita Graphics Communication Systems in captive document storage systems.

Matsushita-Kotobuki Electronics produces CD-ROM drives for sale by MEI. High volume production commenced in 1991.

In April, 1987, IBM announced a 200 megabyte write-once disk drive whose mechanism is made for IBM by Matsushita Electric's Disk Division. The product was not a commercial success, although MEI is offered similar product under its own brand. The company also has an active program in rewritable optical drives and media, and is noted for its advanced work in rewritable phase change media.

In 1989, the Disk Division of MEI acquired the responsibility for manufacturing and marketing of the Matsushita Communication Industrial optical disk drive product line, adding rewritable drives and optical libraries to the MEI product line. Production of a 470 megabyte 5.25" write-once drive began in the fall of 1989.

In 1990, Matsushita announced the first commercially available rewritable phase change drive and media at the Spring COMDEX conference. This 5.25" drive will also accept write-once media, making it a multifunction drive as well. Because no overwrite pass is required, write throughput of this drive exceeds that of magneto-optic rewritable drives.

MATSUSHITA GRAPHIC COMMUNICATION SYSTEMS
3-8 Shimomeguro 2-chome
Meguro-ku, Tokyo 104

MGCS is best known for facsimile systems, but has, for the past three years, marketed a line of office automation equipment. These include

document storage systems using an 8" write-once optical drive developed by MGCS' parent, Matsushita Electric Industrial Company. MGCS now manufactures the drive itself along with an 8" library unit for use in the Panafile series of document storage systems. These systems were marketed only in Japan, and the 8" line is now being phased out in favor of 5.25" products produced by other Matsushita divisions.

MITSUBISHI ELECTRIC CORPORATION
2-2-3, Marunouchi
Chiyoda-ku, Tokyo 100

1990 total net sales: $20,527,034,000 Net income: $529,628,000

Mitsubishi is most noted for heavy machinery production, but is also active in defense electronics and consumer electronics. Data and communication systems represent 36% of sales. In 1987, Mitsubishi introduced a 5.25" 300 megabyte write-once optical drive with 80 millisecond average access time. The drive is sold as part of an optical storage library system that can contain as many as two drives and 152 disks. Higher performance 5.25" M-O type rewritable drives began to ship in the second quarter of 1990 and an improved version of the write-once drive is expected in the first quarter of 1991. All of Mitsubishi's library products are configured with 5.25" drives.

A Mitsubsishi write-once drive using a mechanism similar to its rewritable drive was shown by IBM as part of its optical library subsystem in the spring of 1991.

MASS OPTICAL STORAGE TECHNOLOGIES (MOST)
Subsidiary of Nakamichi Corporation
23832 Rockfield Boulevard
Lake Forest, CA 92630

MOST was formed in 1987. The firm is engaged in the design and manufacture of 3.5" M-O rewritable disk drives. Sales to the VAR/VAD distribution channel are made (non-exclusively) through Ocean Microsystems, another Nakamichi subsidiary. Production of a 128 megabyte 3.5" drive developed by MOST and Nakamichi began in late 1990.

NAKAMICHI CORPORATION
1-153, Suzuki-cho
Kodaira City, Tokyo 187

1990 total net sales: $166,531,000 (FY ending 2/28/90) Net income: $3,795,000

Best known for its top of the line audio equipment, Nakamichi has had an optical disk drive development program for several years, as well as laboratory equipment for optical disk drive development. About 11% of 1990 sales were computer related items. Nakamichi established or pur-

chased several organizations in the United States, including MOST, Mountain Computer, and Ocean Microsystems. Ocean Microsystems is responsible for marketing optical subsystems using the MOST drive. In September, 1990, Nakamich established Nakamichi Peripherals Corporation, a holding company that will supervise the operations of MOST, Mountain, and Ocean.

Responsibility for Nakamichi's line of optical disk test equipment has been transferred to Mountain Computer, which manufactures a variety of test and certification equipment. A 128 megabyte 3.5" rewritable drive developed by MOST and Nakamichi, appeared in 1990, the first 128 megabyte 3.5" M-O drive to reach the marketplace.

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

1990 total new sales: $23,752,945,000 Net income: $587,717,000

NEC has defined its product area as communications and computers, with computer products accounting for about 45% of annual revenues. The firm has the largest share of the Japanese personal computer market. NEC makes a variety of data storage products, including floppy, rigid and optical disk drives. The firm's first optical drive, which was introduced in 1983, was a 1 gigabyte, 12" unit used primarily for NEC captive document storage systems, but also sold on an OEM basis. A 1.8 gigabyte drive was marketed in 1987 and a 2.5 gigabyte drive was introduced in 1990. A 5.25" M-O rewritable drive started production in mid-1989. NEC offers optical libraries with 12" drives and with 5.25" drives.

NEC Home Electronics is producing CD-ROM drives for both captive use and worldwide OEM sale, but has had its greatest success with a modified CD audio drive as a CD-ROM add-on to its popular PC Engine consumer system. While an attempt to market a similar product in the U.S. was not successful in 1989 or 1990, NEC has hopes for 1991.

NIKKYO CORPORATION
480 Minoridai
Matsudo-shi, Chiba 271

Nikkyo was founded in 1947 and started as a producer of metal parts. Starting in 1956, the company diversified into the production of electrical and electronic components and equipment.

Optical libraries are produced for the data processing and entertainment markets. Videodisk changers proved to be an entry into similar products for computer applications. The computer related products include both 12" and 5.25" libraries manufactured on a contract basis for a number of system producers. Nikkyo is one of Japan's highest volume producers of optical libraries for computer use and one of Japan's two major producers of libraries for videodisks.

NIKON CORPORATION
3-2-3, Marunouchi
Chiyoda-ku, Tokyo 100

1990 total net sales: $1,961,510,000 Net income: $129,345,000

Nikon, a member of the Mitsubishi group, is best known for its popular line of cameras and other optical equipment. The firm is also a significant supplier of semiconductor production equipment, medical optical instruments, microscopes and telescopes, and other optical instruments. As a way of expanding its scope of business, Nikon is developing a 12" erasable optical drive, but the real opportunity for Nikon may lie in an innovative media design that solves the overwrite problem experienced by current magneto-optic media designs. However, it will take several years for Nikon to fully commercialize the technology, and commercial availability prior to 1992 is unlikely. Nikon's media development is targeted to small diameter media -- 5.25" and less.

NIPPON COLUMBIA CO., LTD.
4-14-14, Akasaka
Minato-ku, Tokyo 107

1990 total net sales: $845,462,000 Net income: $25,683,000

Primarily known as a producer of CD disks, phonograph records, consumer electronics and audio equipment under the "DENON" brand, Nippon Columbia is leveraging its CD audio player experience to gain an entry in the CD-ROM market. CD-ROM hardware production in limited quantities began in the fourth quarter of 1985, and half high models are now available. The firm has yet to establish strong marketing channels for the drives and shipments remain at moderate levels. The company is also developing phase change technology media, but has not yet committed to development of a write-once or rewritable drive.

NKK CORPORATION
1-1-2 Marunouchi
Chiyoda-ku, Tokyo 100

1990 total net sales: $9,992,400,000 Net income: $270,303,000

NKK, founded in 1912, originally was a steel pipe producer. It is now one of Japan's largest steel producers and is diversifying into other areas such as electronics, automation, CAD/CAM systems, biotechnologies advanced materials and urban development. Steel represents about 79% of the firm's revenues. The electronics division, which is responsible for libraries, was started in 1988.

NKK is offering an optical library with both 5.25" write-once and rewritable drives. The library unit was developed jointly with another manufacturing company. First shown in 1989 at the Spring COMDEX show, it is being marketed on a worldwide basis and has appeared in numerous

document management systems. A variety of write-once and erasable drives are offered in the library, with the most recent addition being Pioneer's multifunction 5.25" drive.

OLYMPUS OPTICAL CO., LTD.
22-2, Nishi-Shinjuku 1-chome
Shinjuku-ku, Tokyo

1990 total net sales: $1,511,690,000 Net income: $57,772,000

Founded in 1919, Olympus Optical company is known primarily for its cameras and optical instruments. In recent years the company has broadened its activities to include electronics and some specialty products, including optical heads for disk drives. Development of optical disk drive technology began in 1981 when Olympus and Fujitsu began a joint project that resulted in one of the first commercial write-once optical disk drives. The firm's optical electronic products include optical heads, an optical card reader compatible with the Drexler Lasercard and a 5.25" erasable optical disk drive announced in November, 1987. The disk drive, which has a capacity of 326 megabytes per side, was provided in sample quantities as of mid-1988, and the mechanism was adopted by Ricoh as the basis of its own rewritable drive.

PENTAX TEKNOLOGIES CORPORATION
Subsidiary of Asahi Optical Co., Ltd.
880 Interlocken Parkway
Broomfield, CO 80020

Pentax Teknologies was founded in 1985. Products include optical components, heads and a write-once drive, a 5.25" 326 megabyte per side unit introduced in late 1988. Drives became available for delivery in 1989. The Pentax drive is unusually fast for a write-once drive, having a specified average seek time of 40 milliseconds.

PIONEER ELECTRONIC CORPORATION
4-1, Meguro 1-chome
Meguro-ku, Tokyo 153

1990 total net sales: $3,528,979,000 Net income: $203,145,000

98% of Pioneer's 1990 revenues came from sales of audio and video equipment. The firm is especially strong in the laserdisc and automotive audio CD markets.

Pioneer and Ricoh have had a joint development program on an 8" 750 megabyte optical write-once disk drive, with Ricoh being Pioneer's most significant customer for the product. First shipments began in late 1985, and Pioneer has established a separate division to make and sell the product. Pioneer has also developed a 5.25" write-once drive and displayed media for it at the Japan COMDEX show in early 1986. Drive ship-

ments commenced in mid-1988. The media used in these drives is a cyanine dye based type that appears to offer superior resistance to corrosion. The active layer is placed on the PMMA substrate by spin coating, a relatively inexpensive production process. Pioneer's media is the first commercial version of dye based media to be brought to market. In 1989, Pioneer introduced a CD-ROM drive integral to an automatic library mechanism. The library contains up to six disks and is derived from a design developed for use with audio CD players and disks. This library was the best selling CD-ROM library in 1990.

In 1990, Pioneer introduced a multi-function drive using dye or M-O media interchangeably. The drive uses sampled servo format. This drive and other Pioneer 5.25" drives are being resold by certain drive producers who have not yet put their own designs into production.

RICOH CO., LTD.
15-1, Minami-Aoyama 1-chome
Minato-ku, Tokyo 107

1990 total net sales: $5,761,821,000 Net income: $109,455,000

Copiers, photographic equipment, and sensitized papers provide most of Ricoh's revenues, but the firm also produces a growing line of data processing equipment which now accounts for 27% of sales. This product line, which was started in 1979, includes floppy disks and a cartridge-type rigid disk licensed from DMA Systems. Ricoh has been Pioneer's partner in the development of an 8" write-once optical drive which Ricoh uses in a document storage system, and the firm showed a prototype OEM 8" write-once drive at the 1986 NCC show. However, Ricoh has concentrated upon developing optical disk drives in the 5.25" form factor, rather than expending further effort on an 8" product. In early 1987, Ricoh and Maxtor entered an agreement whereby Maxtor is the exclusive marketing agent for Ricoh OEM 5.25" write-once optical disk drives in the United States. Ricoh is marketing subsystems containing optical drives in the U.S., an activity permitted under the terms of the Ricoh-Maxtor agreement. Since 1987, Ricoh has supplied more write-once drives than any other manufacturer, largely as a result of its collaboration with Maxtor. The Ricoh-Maxtor agreement for write-once drives continues, even though Maxtor went its own way with rewritable drives. Ricoh has also announced two generations of 5.25" optical libraries, the newer of which is made for Ricoh on a contract basis.

In 1988, a half high version of its original 5.25" optical disk drive design was announced. Also in 1988, Ricoh adopted a rewritable drive mechanism supplied by Olympus on an exclusive basis, and, supplying the required electronics and packaging, began shipping a rewritable 5.25" 300 megabyte per side optical drive in the second quarter of 1989. In early 1990, Ricoh announced a multifunction drive capable of using M-O rewritable media with 220 megabyte capacity per side and 393 megabyte per side write-once media. An ISO-standard high performance 5.25" rewritable drive was introduced in 1991.

SANYO ELECTRIC CO., LTD.
2-18 Keihan-Hondori
Moriguchi, Osaka 570

1990 total net sales: $10,317,828,000 (FY ending 11/30/90) Net income: $120,683,000

Sanyo is a major supplier of facsimile equipment, consumer electronics, appliances, batteries and components such as solar cells, and is one of Japan's more active offshore manufacturers. The firm began development of DRAM in 1989. About 27% of sales are computing and business equipment. Sanyo is actively involved in CD equipment and media production and introduced a CD-ROM drive in 1987. Shipments began in 1988. Half high drives began shipping in 1989, and a portable version was introduced in 1991.

SEIKO EPSON CORPORATION
80 Hirooka
Shiojiri-shi, Nagano 399-07

Epson is a member of the privately held Suwa Seikosha/Epson group owned by members of the Hattori family, which also control Japan's Seiko companies, known for watches and electronics. Epson is best known for its line of printers, but also manufactures a portable computer, displays, paper tape equipment, and floppy and rigid disk drives. In 1988, Epson agreed to supply Maxtor with a 160 megabyte 3.5" erasable optical disk drive and media then under development. While plans to deliver such a drive to Maxtor have been terminated, industry expectations are for Seiko Epson to be an entrant in the 3.5" rewritable drive market.

SHARP CORPORATION
22-22 Nagaike-cho
Abeno-ku, Osaka 545

1990 total net sales: $9,433,903,000 Net income: $287,724,000

Founded in 1935, Sharp was originally a producer of mechanical pencils. Sharp is now a supplier of electrical and electronic equipment. About 47% of sales are derived from computer or computer related products, including desktop and transportable personal computers. Sharp has been actively developing magneto-optic disk drives and media for several years and has made several technology announcements during this period. In mid-1987, the firm announced a 5.25" 190 megabyte erasable optical drive. An improved 325 megabyte version began production in 1990.

SHINANO KENSHI (TEXEL)
1078 Kami-maruko
Maruko-machi, Chiisagata-gun
Nagano-ken

Shinano Kenshi, founded in 1918 as a silk spinning company, is perhaps

best known under the name of its sales subsidiary, Texel. The company has produced CD players, printers, and floppy disk drives under contract for other companies. In 1989, the firm began selling a CD-I encoding system. CD-ROM drives bearing the firms own label first shipped in 1990.

SONY CORPORATION
6-7-35, Kitashinagawa
Shinagawa-ku, Tokyo 141

1990 total net sales: $20,312,014,000 Net income: $709,021,000

Sony is a leader in consumer electronics and has also earned a position as the major supplier of 3.5" floppy disk drives. TV, VCR, and audio products make up 82% of revenues.

Sony is fielding a product line of CD-ROM, write-once and rewritable optical drives. The write-once product line includes 12" drives with up to 3.2 gigabyte capacity, while the rewritable drives are 5.25" and 3.5" ISO standard models. The rewritable drive product line is being aggressively developed. An 8" write-once drive produced earlier has been discontinued. To support its write-once drives, Sony offers an automated library unit, first shown at COMDEX in the fall of 1985.

Sony is vertically integrated and supplies its own media. The company is currently the largest producer of magneto-optic media. Because of its strong position in the audio CD player market, Sony is very competitive in the CD-ROM marketplace with products aimed at the personal computer and small systems market. Sony, together with Philips, has been a moving force in establishing standards for CD and CD-ROM devices and in the CD-I multimedia standards effort. Sony showed a writable CD format drive as part of a CD-ROM mastering system at the 1990 Microsoft Conference but does not intend, at least for the moment, to sell the drive separately. In mid-1990, Sony introduced the Data Discman, a portable CD-ROM system using the first 3.15" CD-ROM drive to go into production. The product may be introduced in the U.S. in late 1991 if software is available in time.

In 1987, Sony announced an erasable 5.25" optical drive using magneto-optical technology. Evaluation units were first shipped in late 1987, and additional improved evaluation units were shipped in mid-1988. Production units were shipped in late 1988, and Sony has been successful in capturing several OEM accounts for its rewritable drive. In 1989 and 1990, Sony was the largest supplier of rewritable optical disk drives, and claimed over 100,000 cumulative shipments by mid-1991.

Sony introduced a 3.5" 128 megabyte rewritable drive in mid-1991. The drive has a specified average seek time of 40 milliseconds and rotates at 3,000 RPM, among the fastest optical drives. Another 1991 Sony announcement concerned a 2.5" magneto-optic drive intended for use in a portable audio recorder. The Sony announcement was a technology announcement, and drive availability is not expected until 1992. The new drive, which does not require a separate erase pass before recording, will also read CD-like read-only disks.

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

1990 total net sales: $29,323,814,000 Net income: $909,214,000

Toshiba is a major factor in consumer electric and electronic products, and also has a leading position in the office computer market in Japan. About 56% of sales in 1990 were related to data communications or computer products. Optical, rigid and floppy drives are produced by Toshiba, which was one of the first firms to market a 12" write-once drive. A 12" 2.5 gigabyte drive began shipments in 1988. Toshiba shipped production level 5.25" write-once optical disk drives in early 1989, although it began shipping samples of its 5.25" write-once drive in 1986. However, 5.25" drive shipments have not been emphasized due to the lack of a well developed market. Toshiba showed a 3.5" rewritable drive rotating at 3600 RPM at the 1991 Tokyo Business show, but this was a preliminary announcement only.

CD-ROM shipments also began in 1986, with half high drives scheduled for the latter half of 1987. Toshiba's later CD-ROM models have unusually short seek times for CD-ROM drives, and this has helped Toshiba capture a significant and growing market share. The drives are particularly favored by system integrators building file servers incorporating CD-ROM, and in 1990, Toshiba CD-ROM drives appeared in the product lines of major system manufacturers, including IBM.

Toshiba has made and sold optical libraries on a captive basis since the mid-eighties, but they are sold only in Japan and in small quantities.

YAMAHA CORPORATION
10-1 Nakazawa-machi
Hamamatsu, Shizuoka

1990 total net sales: $3,439,559,000 Net income: $42,517,000

Yamaha is the world's largest manufacturer of musical instruments, which account for 57% of the firm's sales. The firm is also emerging as a major supplier of thin film heads for rigid disk drives.

Among more recent activities is the development of a CD format system capable of recording on write-once media. The media is supplied by Fuji Photo Film. The Yamaha system is intended for use in situations where fast preparation of a master disk is required or where relatively few copies are needed. It contains the first commercial write-once CD format drive. The drive is not available as a separate item. The write-once system is remarketed by companies specializing in CD-ROM authoring tools and systems.

European Manufacturers

ATG GIGADISC
1270 Avenue General Eisenhower
31047 Toulouse
France

Beginning as the optical disk operation of Thomson-CSF, ATG was formed as a joint venture in 1984 when CIT-Alcatel, a maker of image processing systems, joined with Thomson-CSF, Rhone-Poulenc, Bull, and several other French companies to form Alcatel-Thomson-Gigadisc. A major drive and media production facility in Toulouse was brought on-stream in early 1986. ATG was one of the first firms to get into limited production of optical drives, but media shortages hampered its growth. The new facility alleviated this problem, but disappointing sales caused Alcatel to decide to withdraw from the venture, and for a short time ATG was dormant while new investors were found. Now officially Art Tech Gigadisc, the firm prefers to be known as ATG Gigadisc. While ATG Gigadisc markets its products internationally, it has its strongest market presence in Europe. In 1991, the company was purchased by Optix S.A., a French holding company owned by private investors. Optix also owns Dorotech, a French systems integrator of optical subsystems.

ATG Gigadisc products include 3.2 gigabyte and 4.5 gigabyte 12" write-once drives; small diameter drives are also under development. The firm designed a library storage unit for 12" media, but has elected to market Cygnet's line of library units in order to concentrate its resources on drive development and manufacturing.

DETERNER STEURERUNGS UND MACHINENBAU GMBH & CO.
Birkenstrasse 2
D-2951 Deternerlehe
West Germany

DSM, established in 1987, is a small, specialty products engineering firm. It has produced a small number of custom optical libraries which can be configured with various numbers of drives and cartridge storage slots. Some standard configurations are also available. Library configurations with either 12" WORM and 5.25" drives of any type are produced. Drives from most manufacturers are supported in the library system. DSM announced capabilities include optical libraries with up to 2100 storage slots for disks.

LASER MAGNETIC STORAGE INTERNATIONAL
Subsidiary of N.V. Philips
4425 ArrowsWest Drive
Colorado Springs, CO 80907

LMSI was formed in 1986 through the combination of Optical Storage International, Computer Peripherals International, and Philips' CD-ROM opera-

tions. Philips owns 51% of the company. CPI was a CDC and NCR joint venture that produced tape drives. OSI, formed in 1984, was a joint venture of Philips and Control Data. The organization originally was managed by Control Data and combined two earlier joint ventures, Optical Peripherals Laboratory in Colorado and Optical Media Laboratory in the Netherlands. The entire U.S. operation, at one time split between California and Colorado, was consolidated at the Colorado facility in early 1986. In the spring of 1986, Philips assumed management responsibility for LMSI and in 1990 purchased Control Data's interest.

LMSI makes optical disk drives and also produces tape drives, which are the firm's most profitable products. LMSI optical disk drives currently include CD-ROM drives, a 12" write once drive, 12" automated libraries, and a 5.25" write-once drive using sampled servo tracking. The 5.25" drive was introduced at the Fall COMDEX conference in 1987 and went into production in late 1988. In 1990, LMSI introduced the first optical disk drive with two independently operating heads scanning both sides of the media. The drive uses 12" media and is available as a freestanding drive or as part of a jukebox unit containing the drive and five disks. Production of the new 12" products was delayed until the spring of 1991. LMSI has also begun marketing a rewritable 5.25" drive made by a Japanese company and 5.25" libraries from Hewlett-Packard.

Media is obtained from an LMSI manufacturing operation sharing Philips media manufacturing facilities at Blackburn in the UK. Philips and Dupont Optical (PDO) also is a qualified media supplier.

ING. C. OLIVETTI & C., S.P.A.
Via G. Jervis 77
10015 Ivrea
Italy

1990 total net sales: $7,542,700,000 Net income: $50,400,000

Olivetti's major participation in the optical drive business is through its 40% equity in Laserdrive, now merged into Literal Corp. The firm had an 80% share of Laserdrive, but sold half of its holdings to Eastman Kodak in 1989. Olivetti retains a 26% interest in Literal.

While Olivetti had major internal disk storage projects under development, a change of emphasis in 1988 resulted in the formation of joint ventures with other firms. A joint venture with Conner Peripherals has absorbed Olivetti's magnetic disk drive manufacturing and development in Italy. Some optical recording research projects have been continued. Olivetti has negotiated some optical technology sharing agreements with Toshiba.

NSM AKTIENGESELLSCHAFT
Im Tiergarten 20-30, D 6530
Bingen am Rhein
Germany

NSM introduced an optical library for CD-ROM drives in 1991. The company has produced many libraries with audio drives in them in previous years. The NSM design can handle up to 100 disks, which can be inserted in magazines holding up to 50 disks for convenient loading and unloading. NSM markets primarily in Europe.

NEXT TECHNOLOGY CORPORATION LIMITED
St. Johns Innovation Centre
Cambridge CB4 4WS
England

Next Technology (no relationship to NeXT Computer) is a producer of optical libraries using CD-ROM drives. Up to 270 disks may be routed to as many as 8 drives by the mechanism. Shipments began in early 1990, although a few evaluation and test units were released in 1989.

N. V. PHILIPS
5600 MD Eindhoven
The Netherlands

1990 total net sales: $30,639,560,000 Net income: $2,329,670,000

The Philips organization, established in 1891 as a manufacturer of electrical equipment, has been active for many years in the development of optically based information systems. Initial development work was spun off to joint ventures with Control Data. Philips' initial digital optical developments were a 12" write-once drive and the CD-ROM. Philips, together with Sony, has been instrumental in establishing standards for CD and CD-ROM drives. The Philips CD-ROM has the distinction of being the first CD-ROM to be accepted by a major system OEM: Digital Equipment Corporation offered it as a peripheral on its Micro-Vax line. Philips and Sony continue to innovate standards for CD-ROM, including CD-I and CD-ROM XA.

In 1986, OSI, a joint venture between Philips and Control Data, was reorganized as Laser Magnetic Storage and charged with the responsibility of manufacturing and marketing the Philips CD-ROM, write once optical disk drives designed by OSI using Philips-developed technology, and magnetic tape drives previously produced by another CDC joint venture. Philips owned 51% of LMS; Control Data held the other 49%. In 1990, Philips purchased Control Data's share and is now the sole owner of LMSI.

Philips Consumer Electronics Company, a division of North American Philips, has been developing CD-I players and is planning to bring them to market in late 1991. The players will be marketed under the Magnavox brand name. The firm is also selling free-standing CD-ROM drive subsystems bundled with software.

Philips is involved in a joint effort with Sun Microsystems to develop CD-ROM and CD-I authoring systems using Sun workstations. Philips is a producer of CD media through its Polygram operation and several joint ventures with Japanese companies. In 1985, Philips also entered into a joint venture with DuPont named Philips and DuPont Optical (PDO) to produce optical media of various types in large quantities. PDO did not meet financial expectations and, as of mid-1991, was up for sale.

SOCIETE D'APPLICATIONS GENERALES D'ELECTRICITE ET DE MECANIQUE (SAGEM)
La Ponant,27, rue Leblanc
75512 Paris CEDEX 15
France

SAGEM is a French high technology company specializing in electronic products. About 25% of revenues are obtained from military and avionic systems, 31% from industrial telecommunications products and 44% from data processing and related telecommunications products. The firm makes small quantities of militarized rigid disk drives for use in harsh environments.

SAGEM is involved with other European commercial and academic organizations in a consortium directed toward the development of magneto-optic disk drives, drive components and media, but there is no near term production planned. SAGEM has drive development responsibilities, and media is to be developed by Hoechst. The long-term target is a 5 gigabyte 5.25" magneto-optic drive.

DISK/TREND ON DISK

1991 DISK/TREND REPORT

INTRODUCTION

DISK/TREND ON DISK is a set of floppy disks containing the statistical tables and specification tables from the annual DISK/TREND Reports. The disk files have been prepared in a format usable on IBM or IBM-compatible computers running under the MS-DOS or PC-DOS operating system. A system with a hard disk is highly recommended, but a system with two floppy disks can be used if necessary. All DISK/TREND ON DISK files contain data only -- manipulation of data is the user's responsibility. Because some of the files can be very large, system memory of 640K or more is recommended.

A file translation program, AutoImport, is available from DISK/TREND to assist in converting the data supplied to the formats of several popular spreadsheet programs.

Two types of diskette files are supplied for each DISK/TREND disk drive report. The first type contains the statistical tables in ASCII format. File names are keyed to the table numbers in the report for easy identification. The second type contains the specification section in a Lotus 1-2-3 data base format. Multiple disks of each type are provided where the files are too numerous or too large to fit on a single floppy disk. The color used on the label of each floppy disk is similar to the color used on the cover of the corresponding report for ease in identification.

Because the statistical tables are provided in ASCII format, they can be used with any spreadsheet program that can import ASCII text files. However, the specification tables have been prepared specifically in Lotus 1-2-3 format to allow them to be searchable using Lotus 1-2-3 data base commands. If you are using a spreadsheet program other than Lotus 1-2-3 that can translate Lotus WK1 formatted files to its own format, it may be able to import the specification tables.

The authors of this manual assume that you are familiar with personal computers, Lotus 1-2-3 or other spreadsheets, and MS-DOS, and do not cover their operation in this manual. This manual deals specifically with how to load and use the files supplied on the floppy disks.

One copy of AutoImport is provided automatically at no extra charge to DISK/TREND subscribers who have purchased an original copy of DISK/TREND ON DISK but is provided only in the first year DISK/TREND ON DISK is purchased. Updates to AutoImport may be provided in following years at DISK/TREND's discretion. Extra copies of AutoImport may be purchased at any time. If you have not purchased DISK/TREND ON DISK, but would find AutoImport useful with other file translation tasks, it may be purchased independently from DISK/TREND or White Crane Systems, Inc.

Note: Please read the license information on the following page.

DISK/TREND ON DISK
Information License

DISK/TREND supplies diskettes containing selected information from the 1991 DISK/TREND Report as a separately purchased option to subscribers to the corresponding 1991 DISK/TREND Report volume.

YOU MAY:

1. Install and use the information on a single computer system, provided that you or the organization by which you are employed has purchased at least one copy of the DISK/TREND report volume associated with the information.

2. Make backup copies of the information for your own use. Such backup copies may be used only on the computer on which the information is installed. You must reproduce the copyright notice on any copies.

3. Reproduce the information, but not the associated programs or documentation, contained in the Product for use within internal documents distributed within the organization by which you are employed.

YOU MAY NOT:

1. Install, or allow the use of, the information on more than a single computer system.

2. Transfer the information through or within a computer network.

3. Distribute the information or any portion thereof in any form outside the organization by which you are employed or modify the information for purposes of distribution.

4. Transfer this license to another party.

AUTOIMPORT

Use of AutoImport is subject to the terms and conditions provided by White Crane Systems, Inc.

Trademarks

IBM is a trademark of International Business Machines Corporation.

Lotus and Lotus 1-2-3 are trademarks of Lotus Development Corporation.

MS-DOS is a trademark of Microsoft Corporation.

AutoImport is a trademark of White Crane Systems, Inc.

Getting started

The first thing you should do is to make working copies of the original DISK/TREND diskettes. Place the originals in a safe location and use only the working copies for day-to-day operations. This procedure will help to protect your data from inadvertent destruction or loss due to a malfunction of the computer or its operator. We also recommend that you place a write protect tab on the working copies (after you create them) for the same reason. Use the hard disk or another floppy disk copy for day-to-day manipulations of the files.

The statistical tables are provided in ASCII text format. This allows you to use any word processor to edit the file prior to importing it into Lotus 1-2-3. Appropriate editing removes any material you don't wish to work with and allows you to add figures or text to the data tables. You may also embed the data in internal documents or reports you are preparing for use within your company.

To convert the statistical tables to a spreadsheet you may use the Auto-Import utility software, which is probably quicker and easier than the typical text file import and conversion procedure provided with spreadsheet programs. One copy of AutoImport is provided automatically at no extra charge to each DISK/TREND subscriber who has purchased an original copy of DISK/TREND ON DISK and is provided in the first year DISK/TREND ON DISK is purchased. Updates to AutoImport may be provided in following years at DISK/TREND's discretion. Extra copies of AutoImport may be purchased at any time.

DISK/TREND ON DISK is normally shipped on 1.2 megabyte 5.25" floppy disks, but is also available on 1.44 3.5" megabyte disks if requested.

STATISTICAL TABLES

Loading and Installation

1. Place the floppy disk marked 'Tables' in a floppy disk drive able to read your size disks. This is usually drive A, but if you are using a dual floppy only system, use drive B and put the Lotus 1-2-3 system disk in drive A. Use the DOS 'DIR' command to examine the file directory on the 'Tables' disk. If there are any special instructions, they will be in a file named READ.ME. To see these instructions, at the DOS prompt type:

   TYPE A:READ.ME (Use the appropriate drive letter if not A)

   If you wish to print the instructions, turn on your printer and type:

   TYPE A:READ.ME>PRN

2. Do this step if you have a hard disk. Log into the hard disk directory in which Lotus 1-2-3 normally stores worksheet files. Using the DOS 'COPY' command, copy all the statistical table files to the hard disk. This can be done in one step using the copy command as follows:

   COPY A:?T*.*

   Several utility files should also be copied. The command is:

   COPY A:*.PRN

   The utility file names are of the form FORMLIN?.PRN. The files are specific to use with Lotus 1-2-3 data parsing if you prefer not to use AutoImport for file translation.

   Installing AutoImport: If you have a hard disk, create a directory named AIMP (You could use other names if you prefer). Now place AutoImport disk 1 in drive A and type: A:INSTALL C:\AIMP and then ENTER. Follow any instructions appearing on the screen until installation is complete. To make AutoImport accessible from any directory, place C:\AIMP in your AUTOEXEC.BAT file's 'PATH' statement. See your MS-DOS instruction manual for information about this step.

   If you are using a floppy-only system, copy the AutoImport disks and use only the copies in following steps. In a floppy-only system, AutoImport disk 1 should be in drive A when AutoImport is in use for file translation.

3. If you are using AutoImport (highly recommended) for translation of files to spreadsheet format, do the translation at this point. See the following section on using AutoImport for details.

4. Now you are ready to start your spreadsheet. If you are using a two floppy system, place the DISK/TREND disk in drive B and the spreadsheet

system disk in drive A. If you are using a rigid disk system, place a copy of the spreadsheet system disk in floppy drive A if required by the security provisions of your spreadsheet program. Now start your spreadsheet as usual. After obtaining the blank spreadsheet image on the screen, use the appropriate file retrieval command to select a file. An example of a Lotus 1-2-3 command is:

/FR<filename>

The file names are in the format XTYY.WK1, where:

X= Type of data
F (Flexible disk drive data)
R (Rigid disk drive data)
O (Optical disk drive data)

YY= Table number, as shown in the appropriate report volume

ZZ= Year of Report.

Examples:
File RT10.WK1 is Rigid Disk Drive Report Table 10
File FT2.WK1 is Flexible Disk Drive Report Table 2
File OT1.WK1 is Optical Disk Drive Report Table 1

The file selected will be loaded as a worksheet. If this is the first time the file has been loaded, you may want to create your own formulas linking the cells of the spreadsheet. See your spreadsheet reference manual for details on numerical manipulations and graphics.

If you don't use AutoImport

If you don't use AutoImport but still want to translate ASCII files to your spreadsheet format, you will have to use spreadsheet tools such as the Lotus 1-2-3 Data Parse commands. They allow the user to convert a table which has been imported in the form of a block of text to a form in which the individual numbers and labels can be manipulated as spreadsheet elements or used to prepare graphics. Let's take Lotus 1-2-3 as an example. Before proceeding, it would be useful to read the Lotus reference manual on this subject if you are not a regular user of the Data Parse commands.

The trickiest and most time-consuming part of using the Data Parse commands is setting up the format line. Several utility files have been provided on the tables disk to make this process easier. These are used with various table formats encountered in the DISK/TREND Reports and correspond with the precomputed masks provided for use with AutoImport:

- FORMLINA.PRN — Used with Tables 1 and 2 and the Revenue and Unit Shipment tables found in the product group sections of all DISK/TREND reports.

- o FORMLINB.PRN — Used with Tables 3 and 4.
- o FORMLINF.PRN — Used with Tables 5 through 12.
- o FORMLIND.PRN — Used with Application tables.
- o FORMLINE.PRN — Used with Drive Height, Drive Capacity and Track Density tables in Flexible Disk Drive Report.

There are no FORMLIN format files for disk diameter tables or market share tables, as these are variable in format. You will have to construct the format line directly, but after you have seen how it is done for the other tables, this should not be too big a job.

After you have used spreadsheet tools to translate a file, you will understand why we recommend AutoImport for this function.

Using AutoImport:

Using AutoImport is a two-step process. Step one is creation of a translation mask for each format used in files to be converted. The typical DISK/TREND Report uses 5 to 7 standard mask designs (which have been precomputed and included on your Statistical Tables disk) plus additional masks that are dependent upon table content, as some table types have variable numbers of columns. You will have to create your own masks for such tables, but this can be done easily as shown below.

Step two is the translation process. Once the mask has been created, it can be used with any table matching the mask format. See the table below which relates table types to specific masks.

MASK TABLE

Mask File Name	Rigid Report	Flexible Report	Optical Report
MASKA	<-------- Table 1--------->		Tables 1,2
	<------------ Product Group Revenue ---------->		
	<------------ Product Group Shipment ---------->		
MASKB	<-------- Table 2 -------->		Tables 3,4
MASKC	Tables 3 to 8	Tables 3,4	Tables 5 to 12
MASKD	<----- All Product Group Application Tables ------->		
MASKE	N/A	Drive Height, Track Density, Drive Capacity	Write-Once/ Erasable Analysis
MASKF	N/A	Applications Summary	N/A
MASKG	N/A	Product Group Market Share	N/A

TABLE NUMBER TO MASK CROSS-REFERENCE

Table Number	1990 Rigid Report	1990 Flexible Report	1991 Optical Report
1	MASKA	MASKA	MASKA
2	MASKB	MASKB	MASKA
3	MASKC	MASKC	MASKB
4	MASKC	MASKC	MASKB
5	MASKC	--	MASKC
6	MASKC	--	MASKC
7	MASKC	MASKF	MASKC
8	MASKC	MASKA	MASKC
9	--	MASKA	MASKC
10	--	MASKE	MASKC
11	MASKA	MASKD	MASKC
12	MASKA	MASKG	MASKC
13	--	MASKA	--
14	--	MASKA	--
15	MASKD	MASKE	--
16	--	MASKE	--
17	MASKA	MASKD	MASKA
18	MASKA	MASKG	MASKA
19	--	MASKA	--
20	--	MASKA	--
21	MASKD	--	MASKD
22	MASKA	--	--
23	MASKA	MASKE	MASKA
24	--	MASKE	MASKA
25	--	MASKD	--
26	MASKD	MASKG	--
27	--	MASKA	MASKE
28	MASKA	MASKA	MASKD
29	MASKA	--	--
30	--	--	MASKA
31	--	MASKD	MASKA
32	MASKD	MASKG	MASKD
33	--		MASKA
34	MASKA		MASKA
35	MASKA		MASKA
36	--		MASKA
37	--		--
38	MASKD		--
39	--		MASKE
40	MASKA		MASKA
41	MASKA		MASKA
42	--		--
43	--		--
44	MASKD		MASKE
45	--		MASKA
46	MASKA		MASKA
47	MASKA		--

Cross reference (continued)

Mask File Name	1990 Rigid Report	1990 Flexible Report	1991 Optical Report
48	--		--
49	--		MASKE
50	MASKD		
51	--		
52	MASKA		
53	MASKA		
54	--		
55	--		
56	MASKD		
57	--		
58	MASKA		
59	MASKA		
60	--		
61	--		
62	--		
63	MASKD		
64	--		

-- indicates that the format of this table is variable. Create a mask using AutoImport if a spreadsheet is needed.

Translation using precomputed masks

1. First, copy the files you wish to translate to the AIMP directory from DISK/TREND ON DISK floppy disk. Go to the AIMP directory, insert the floppy disk in drive A and type the following commands:

   ```
   COPY A:?T*.*
   COPY A:*.MSK
   ```

   These commands copy the data files and mask files you need.

   If you are using a two floppy disk system, copy the files you want to translate to a second floppy disk along with the mask files. Make sure that no more than half of the floppy disk is filled, because you will need space for the converted files.

2. Now start AutoImport. When the opening screen appears, select the 'TRANSLATE' menu item using the arrow keys or just type 'T'. (The AutoImport menu system works just like the menus in Lotus 1-2-3.)

3. When the next screen appears, enter the name of the mask to use on the top line where the highlighted space is. If a standard mask is being used, see the mask table above to choose the mask file name to enter. If you used a mask previously, the system defaults to the last mask named. Press 'ENTER'.

4. Select the output file name. Type OFT (Output:File:Type-in)

   Enter the name of the file. The file name form recommended is ?Tnn, where ? is the type of report (R, F, or O), T is just that, and nn is the DISK/TREND Report table number matching the file being translated. You should not enter the file name extension as the system adds it automatically for you. Press 'ENTER'.

   Examples: RT4 FT12 OT14

5. Enter the input file name using the same file naming convention as above. Type IT (Input:Type-in)

   Enter the name of the file, including the extension, which will be of the form yy? where yy is the year of the report and ? is the report type as above.

   Examples: RT4.90R FT12.90F OT14.900

6. The default spreadsheet type to which the translation is made is Lotus 1-2-3 version 2.x. If you wish to translate to a different spreadsheet format you may choose it by typing /TS and then selecting your preference from the menu of choices displayed.

7. You are ready to translate. Type 'G' for 'GO' or select 'GO' using the arrow keys. You will see the file being translated scroll by as the translation proceeds.

8. If you want to do more translations, repeat from step 3.

9. When you are done translating, leave AutoImport by typing /Q (Quit) to return to the AutoImport main menu and then /E (Exit) to leave AutoImport and return to DOS. It will save you some keystrokes if you copy your new spreadsheet files to your spreadsheet directory. If you are using a two floppy system, just remove the AutoImport disk from drive A and substitute your spreadsheet disk.

Mask Generation

1. Start AutoImport as above. When the opening screen appears, select 'Mask' using the arrow keys or type 'M'.

2. Name the file you will use as the template to create the mask. The file name will be of the form ?Tnn.yy?, where ? is the type of report (R, F, or O), nn is the table number and yy is the report year.

   Example: OT50.910

   To name the file, type /FIT (File:Input:Type-in). When the highlighted blank space appears, fill it in with the file name and press 'Enter'. The contents of the file will now appear on the screen.

3. Next define the header lines. These are lines that are translated to the spreadsheet as a single cell of text. Place the cursor at the top of the header area, normally at the left top of the report table. Now type /LH (Line:Header). Using the down arrow key, expand the highlighted area until it extends to just above the first row of numerical data. Press 'Enter'. If there are any footnotes at the bottom, the lines in which they appear can be treated the same way by locating the header at the left margin of the first footnote line, typing /LH, extending the highlight area over the note and pressing 'Enter'.

4. Next, locate the longest left margin label (excluding the header lines) in the table. Position the cursor so that it is at the left margin of the line containing the longest label. Type /AY (Auto:Yes). This step actually creates the mask. Check to be sure all figures have been delineated properly. If not, see below.

   In a few cases, the automatic feature may be confused by a table layout and all values will not be picked for conversion. In these unusual cases, you may be able to get the overlooked values included by repeating this step on another line.

   Another unusual case can occur in which the right-hand part of a label is somehow included in a value occurring in the next column to the right. Deal with this rare case as follows:

   - Place cursor in left margin of offending line. Type /CW to adjust width and then use arrow keys to move right column margin clear of the column of values.

   - Set cursor on last position of column to the right of the left margin labels. Type /DCO to delete this one column from the mask.

   - Now place cursor in first space to the right of the left margin label column. Type /C and then adjust the column width to encompass all places in the values column you have been working with. This will restore the mask column, also.

5. Save the mask in a mask file. Type /FMS (File:Mask:Save). Fill in the name of the mask file.

   Example: OT50MSK

6. Save the output file. Type /FOT (File:Output:Type-in). Now enter the file name.

   Example: OT50. You don't need to enter the file extender.

7. To make more masks, repeat from step 2. To quit the mask function, type /Q (quit). This returns you to the AutoImport main menu. To leave AutoImport, type /E.

Other AutoImport Functions

AutoImport can do much more than the functions described above, which are those concerned with a basic understanding of how to create spreadsheets from DISK/TREND ON DISK files. See the separate AutoImport manual provided for details of these other functions.

SPECIFICATION TABLES

Loading

1. Place the floppy disk marked 'Specifications' in a floppy disk drive able to read your size disks. This is usually drive A, but if you are using a dual floppy only system, use drive B and put the spreadsheet system disk in drive A. Use the DOS 'DIR' command to examine the file directory on the 'Tables' disk. If there are any special instructions, they will be in a file named READ.ME. To see these instructions, at the DOS prompt type:

   TYPE A:READ.ME (Use the appropriate drive letter if not A)

   If you wish to print the instructions, turn on your printer and type:

   TYPE A:READ.ME>PRN

2. Do this step if you have a hard disk. Log into the hard disk directory in which your spreadsheet normally stores worksheet files. Using the DOS 'COPY' command, copy all the specification table files to the hard disk. This can be done in one step using the copy command as follows:

   COPY A:?S*.*

3. Now you are ready to start Lotus 1-2-3 or other spreadsheet. If you are using a two floppy system, place the DISK/TREND disk in drive B and the Lotus spreadsheet system disk in drive A. If you are using a rigid disk system, place the spreadsheet system disk in floppy drive A. If your spreadsheet is not Lotus 1-2-3, you will have to translate the data from Lotus 1-2-3 to your format. Almost all spreadsheet packages of recent vintage are able to do this translation. After translation, if needed, start your spreadsheet as usual. After obtaining the blank spreadsheet image on the screen, use the spreadsheet File Retrieve command to select a file. The equivalent Lotus 1-2-3 command is:

   /FR<filename>

   The file names are in the format XSYZZ.WK1 or XSYZZ.WKS, depending upon which version of Lotus 1-2-3 you are using. X,Y, and Z are:

   X= F (Flexible disk drive data)
      O (Optical disk drive data)
      R (Rigid disk drive data)

Y= Table number. Usually, there is only one table, but if the specification file is so large as to need multiple disks to hold it, there may be several.

ZZ= Year of report.

Example: OS191 Optical disk specification table
LS191 Optical library specification table

Note that the specification tables load directly as a data base. You can use the data base functions of Lotus 1-2-3 to sort, count or otherwise manipulate the data for purposes of special analysis. Other spreadsheets may have similar capabilities.

Using the specification data base

Introduction: If you have not used the Lotus 1-2-3 /DATA QUERY commands, it will be helpful for you to review the sections of the Lotus 1-2-3 reference manual that pertain to their use before proceeding further.

The specification data base fits into a worksheet format of 25 to 30 columns, depending upon whether rigid, optical or floppy drives are involved, and a row count of up to 500 rows. Each row represents a specific record, and is equivalent to a single column in the Specifications section of the DISK/TREND report. Each column represents a specific specification parameter, and is equivalent to one row of the DISK/TREND report.

The data base has been set up for data extraction using Lotus 1-2-3 commands. The Input, Output and Criterion ranges have been predefined, but you, the user, will have to decide how you want the extracted data manipulated and place the appropriate Lotus functions, such as @COUNT, in the appropriate cells. Some rows between the bottom of the input range and the top of the output range have been left empty so that you can do this easily. When the database is first loaded, you will see the top of the input range, showing the first column (manufacturer name) for the first several manufacturers. Use the arrow keys to find other manufacturers or specific product specifications. If you are not using Lotus 1-2-3, use the equivalent procedure for your spreadsheet.

Operating tips

Expanding the input or output ranges: The predefined output range is of a nominal size, and a search with broad parameters may result in overflowing the output range. In such a case, merely extend the output range (add more rows) using the Lotus 1-2-3 /DQEO command. Similarly, it is possible to extend the input range to add more products, but be sure you move the output range so that there is no overlap.

Memory overflow: If you should receive a memory overflow message while manipulating the specification data, it is usually because:

- o There are other 'pop-up' programs resident in the memory of your computer. These should be removed.

- o You have selected too large an output range. Use a smaller output range or delete some of the columns that contain data not relevant to your analysis. If you delete data, be sure that if you save your spreadsheet you use a different file name, otherwise you will overwrite the original file with the modified spreadsheet.

- o If you receive a memory overflow message while loading the data base, the data base is too large for your computer's available memory. You probably will have to remove other resident programs and reload Lotus 1-2-3 and the data base. If your computer doesn't have 640K memory, you will probably get this message.

Saving time

The specification data base is large and takes significant time to recompute or perform other operations. If you are interested in drives that belong to only a few product groups, it will probably save you time in the long run if you extract only those groups you are interested in into a new worksheet and use that for the analysis. Use spreadsheet FILE EXTRACT and FILE COMBINE commands for this purpose.

Another way to save time is to use the SORT capabilities of your spreadsheet to organize the data the way you find it most useful. The most commonly done sorts are by manufacturer name and by DISK/TREND product group, but it would also be possible to sort by average seek time, price, and so on.

Make sure that when you save a worksheet using the FILE SAVE command that you save it in a new file name. If you save it in the file name from which it was loaded, the original copy will be overwritten. If a file is overwritten unintentionally, it can take a long time to recreate.

If you are interested in only a subset of product groups, use the FILE EXTRACT and FILE COMBINE commands to move these records to another file and then use the second file for analysis. The smaller file will take less time to process.

Technical support

Just about all of your questions regarding the use of DISK/TREND ON DISK should be answered in this manual or in the Lotus 1-2-3 reference manual. However, if you need to contact us to resolve any points of confusion, report errors, or otherwise receive comfort:

Call us at: 415-961-6209

Ask for Technical Support

In order to make this process efficient, when you call--

1. Tell us what is on the diskette label.

2. Have your computer up and displaying the data or operation that is the subject of your call.

3. Have this manual and the Lotus 1-2-3 reference manual handy.

If you have questions about AutoImport as it is used with DISK/TREND ON DISK, contact DISK/TREND at the number above. Questions about other functions of AutoImport should be referred to White Crane Systems.