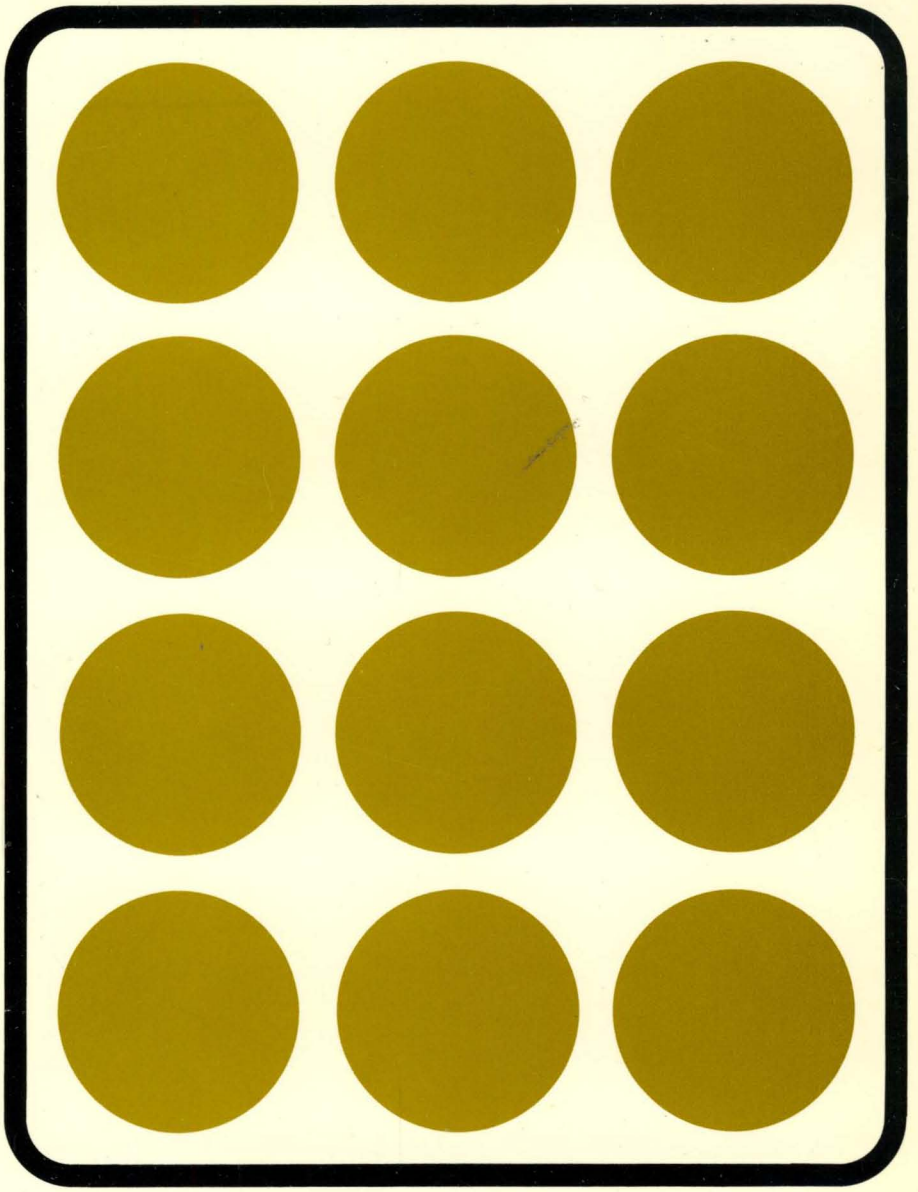
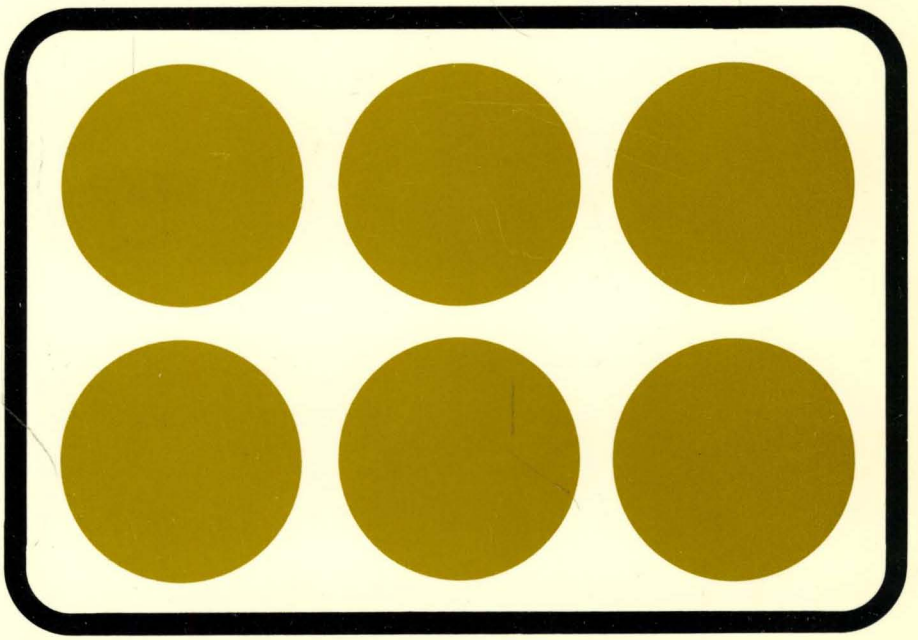


1992 DISK/TREND® REPORT



OPTICAL DISK DRIVES

1992 DISK/TREND® REPORT

OPTICAL DISK DRIVES

July, 1992

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

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

FOREWORD

After several years at a static technology plateau, optical drives are finally showing the promise of dramatic improvements in capacity, packaging, and performance. With 5.25" drives expected to double capacity next year and triple in 1994, there is hope that technology improvements may also drive sales improvements. The next wave of drive component improvements, with better lasers, media, heads and other elements is not yet available, but is not too far away. However, the much hyped multimedia market may take longer to spur sales than originally anticipated by many. Still, bit by bit, an industry is being built.

The industry is finally maturing to the point where some players are ready to throw in the towel, at least in selected product areas. We expect to see fewer drive and media producers, but more companies successfully competing in the subsystems and systems arena using optical disk drives as a basis for their products.

The four 'P' problems: Performance, package, price, and profitability still have not been conquered, and must be resolved before the optical storage industry can be fully competitive with magnetic recording technology.

The DISK/TREND Report has a new look this year, with new typography and new information. We think that you will find the report easier to read and use in this new format. Also new this year are tables breaking out write-once and erasable drives by disk diameter.

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 TABLES (Continued)

LIST OF FIGURES

INTRODUCTION

The DISK/TREND Report on optical disk drives is now in its seventh year. Coverage for optical disk libraries is being included for the third year. While the typography of the DISK/TREND reports has changed, the organization is consistent with reports of previous years. Here are a few useful reminders to 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 units with positioning mechanisms for libraries. All current optical disk drives have one spindle.
* Market share tables, usually included in DISK/TREND reports, are omitted for some product groups of this report, because the 1991 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 drives are write-once or erasable (rewritable)/multifunction types. Forecasts for drives and libraries using both types of technology are given in each optical disk drive product group section as appropriate.
* 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.
* Forecasts assume a 'normal' economy without economic cyclic effects.

SUMMARY: OPTICAL DISK DRIVES AND LIBRARIES

Industry size

Revenue grew strongly in 1991, primarily due to outstanding growth in the read-only drive product group, but growth was only moderate for read/write drives under 1 gigabyte and negative for drives over 1 gigabyte. For drives other than CD-ROMs, worldwide recession had a depressing effect on sales growth. Sales of 3.5" magneto-optic drives were particularly disappointing, although the reasons have more to do with design and marketing shortfalls than the recession.

1,659,400 optical disk drives were shipped in 1991, up 82.4% over 1990, but most of the gain was in CD-ROMs. Shipments of optical libraries reached 23,022 units, of which 73.5% were small read-only libraries. Drive revenues rose 27.7%, to almost $1.2 billion, while optical library revenues jumped 74.1% to $176.2 million. (The library revenues do not include the revenues of associated drives, to avoid double counting.)

U.S. manufacturers' revenue share rose to 6.0% of worldwide optical disk drive revenues, a slight improvement over their previous year's 5.2% share. U.S. companies held their share of library revenues, with 47.3% going to U.S. firms in 1991. The U.S. share of drive unit shipments rose weakly to 1.6%, but it is expected to improve somewhat, reaching 2.4% in 1995. The weak U.S. showing is the result of U.S. non-participation in the CD-ROM market. U.S. firm's share of library unit shipments declined to 14.9% in 1991, from 18.5% in 1990, because of a large increase in read-only library shipments by non-U.S. suppliers.

1991 sales in the United States accounted for 50.1% of worldwide revenue, an increase from 44.1% in 1990, while sales to U.S. firms accounted for 53.4% of library revenues, a slight decrease from 1990. In 1995, the U.S. market is expected to be a larger share, yielding 53.4% of a $2.9 billion drive market. The U.S. proportion of the library market is expected to reach the 58% level in 1995. Increasing usage of optical storage technology for records management is helping to drive the U.S. market.

IBM expanded its role as an optical storage manufacturer in 1992 with a 5.25" magneto-optic rewritable drive and announcement of support for the 3995 optical

library under System Managed Storage. IBM also remains a purchaser of 5.25" and 12" write-once drives and libraries to integrate into its systems. IBM, Hewlett-Packard, Sony and other firms are involved in a major initiative to expand the capacity of a standard 5.25" magneto-optic drive. IBM also introduced the first 3.5" optical library in 1992, with sales initially restricted to Japan.

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. Future improvements in drive capacity and performance will depend strongly upon improvements in laser technology.

The number of participants in the optical drive industry has declined by two to 36 with three companies entering and five firms exiting the industry. However, the number of firms making optical libraries increased from 23 to 26. Most of the changes in the drive manufacturer roster came from the Asian branch of the industry, while U.S. and European entrants were the primary cause of the change in the count of library producers.

TABLE 1

CONSOLIDATED WORLDWIDE REVENUES

OPTICAL DISK DRIVES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1991		Forecast							
	Revenues		1992		1993		1994		1995	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	6.4	7.7	17.9	27.0	31.6	51.6	54.6	96.5	84.1	154.8
Other U.S. Captive	12.9	16.8	14.2	22.1	25.3	40.7	32.6	51.8	41.4	66.2
TOTAL U.S. CAPTIVE	19.3	24.5	32.1	49.1	56.9	92.3	87.2	148.3	125.5	221.0
PCM/Reseller	20.2	28.3	23.8	34.6	26.4	38.7	37.3	54.3	41.9	59.6
OEM/Integrator	17.7	20.5	24.6	30.5	37.7	47.2	42.1	52.7	61.1	76.8
TOTAL U.S. NONCAPTIVE	37.9	48.8	48.4	65.1	64.1	85.9	79.4	107.0	103.0	136.4
TOTAL U.S. REVENUES	57.2	73.3	80.5	114.2	121.0	178.2	166.6	255.3	228.5	357.4
Non-U.S. Manufacturers										
Captive	78.9	397.8	129.8	541.4	191.8	666.2	247.0	799.7	286.3	889.2
PCM/Reseller	119.5	180.8	156.4	249.6	196.5	313.7	227.9	369.6	261.3	431.7
OEM/Integrator	335.2	528.0	467.3	701.0	593.4	914.7	714.0	1,113.4	778.6	1,231.0
TOTAL NON-U.S. REVENUES	533.6	1,106.6	753.5	1,492.0	981.7	1,894.6	1,188.9	2,282.7	1,326.2	2,551.9
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	590.8	1,179.9	834.0	1,606.2	1,102.7	2,072.8	1,355.5	2,538.0	1,554.7	2,909.3

TABLE 2

CONSOLIDATED WORLDWIDE REVENUES

OPTICAL LIBRARIES

REVENUE SUMMARY

	LIBRARY REVENUES, BY SHIPMENT DESTINATION (M)									
	1991		Forecast							
	Revenues		1992		1993		1994		1995	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	.3	.4	.9	.6	1.3	.8	1.7
Other U.S. Captive	30.3	42.6	34.9	64.2	45.9	83.5	57.6	107.4	71.9	133.3
TOTAL U.S. CAPTIVE	30.3	42.6	34.9	64.5	46.3	84.4	58.2	108.7	72.7	135.0
PCM/Reseller	1.8	2.3	4.5	5.9	5.4	7.0	4.7	6.0	4.4	5.7
OEM/Integrator	34.2	38.5	73.8	97.9	98.4	133.4	124.0	167.9	155.2	212.4
TOTAL U.S. NONCAPTIVE	36.0	40.8	78.3	103.8	103.8	140.4	128.7	173.9	159.6	218.1
TOTAL U.S. REVENUES	66.3	83.4	113.2	168.3	150.1	224.8	186.9	282.6	232.3	353.1
Non-U.S. Manufacturers										
Captive	--	42.4	--	46.4	.8	47.9	1.0	48.9	1.2	51.3
PCM/Reseller	6.1	11.5	13.9	23.4	15.3	25.6	15.7	26.6	15.5	26.5
OEM/Integrator	21.7	38.9	39.8	72.4	57.6	101.4	75.3	126.1	84.5	139.3
TOTAL NON-U.S. REVENUES	27.8	92.8	53.7	142.2	73.7	174.9	92.0	201.6	101.2	217.1
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	94.1	176.2	166.9	310.5	223.8	399.7	278.9	484.2	333.5	570.2

Figure 1

CHANGING PRODUCT MIX

Worldwide Optical Disk Drive Revenue

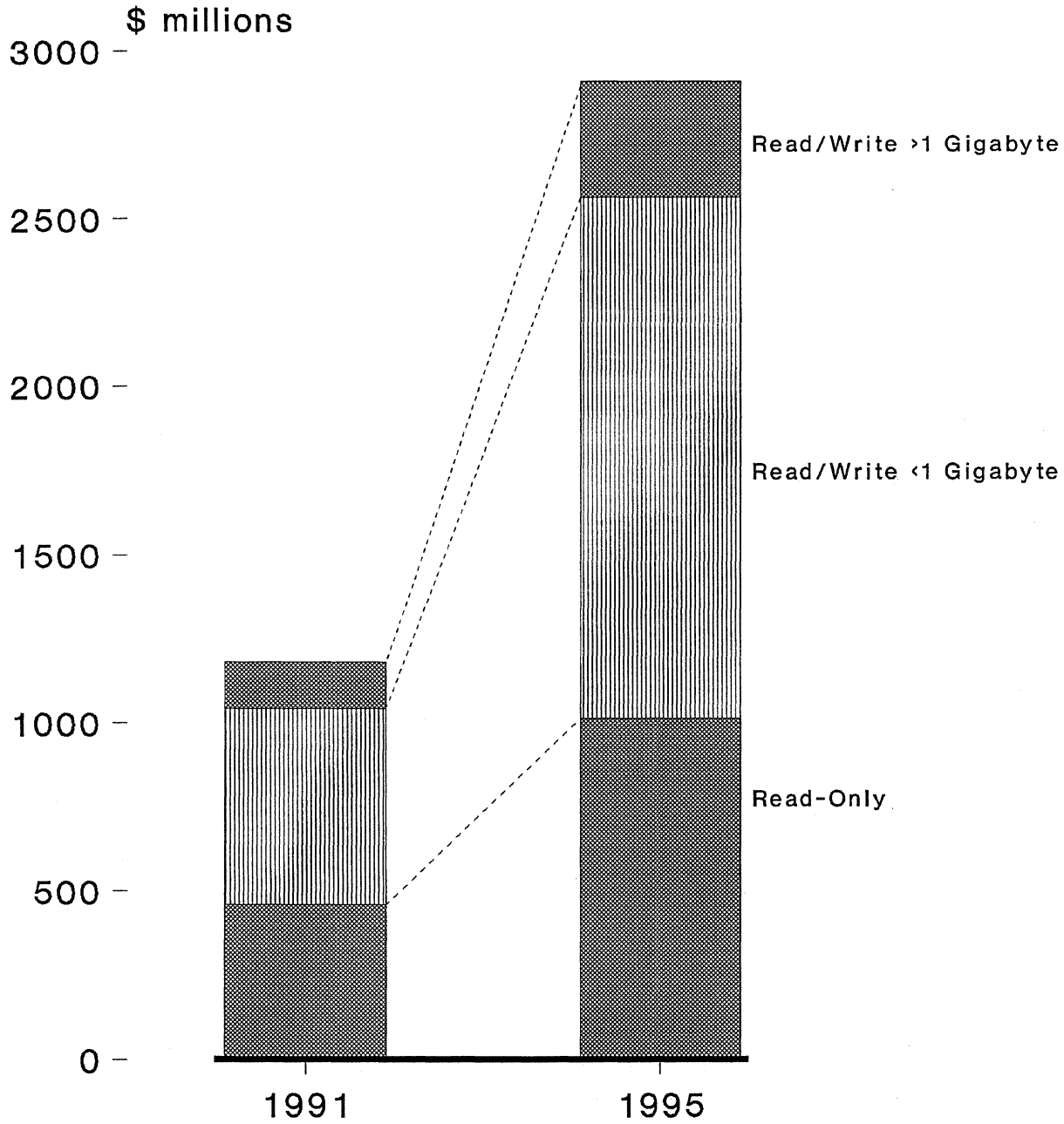
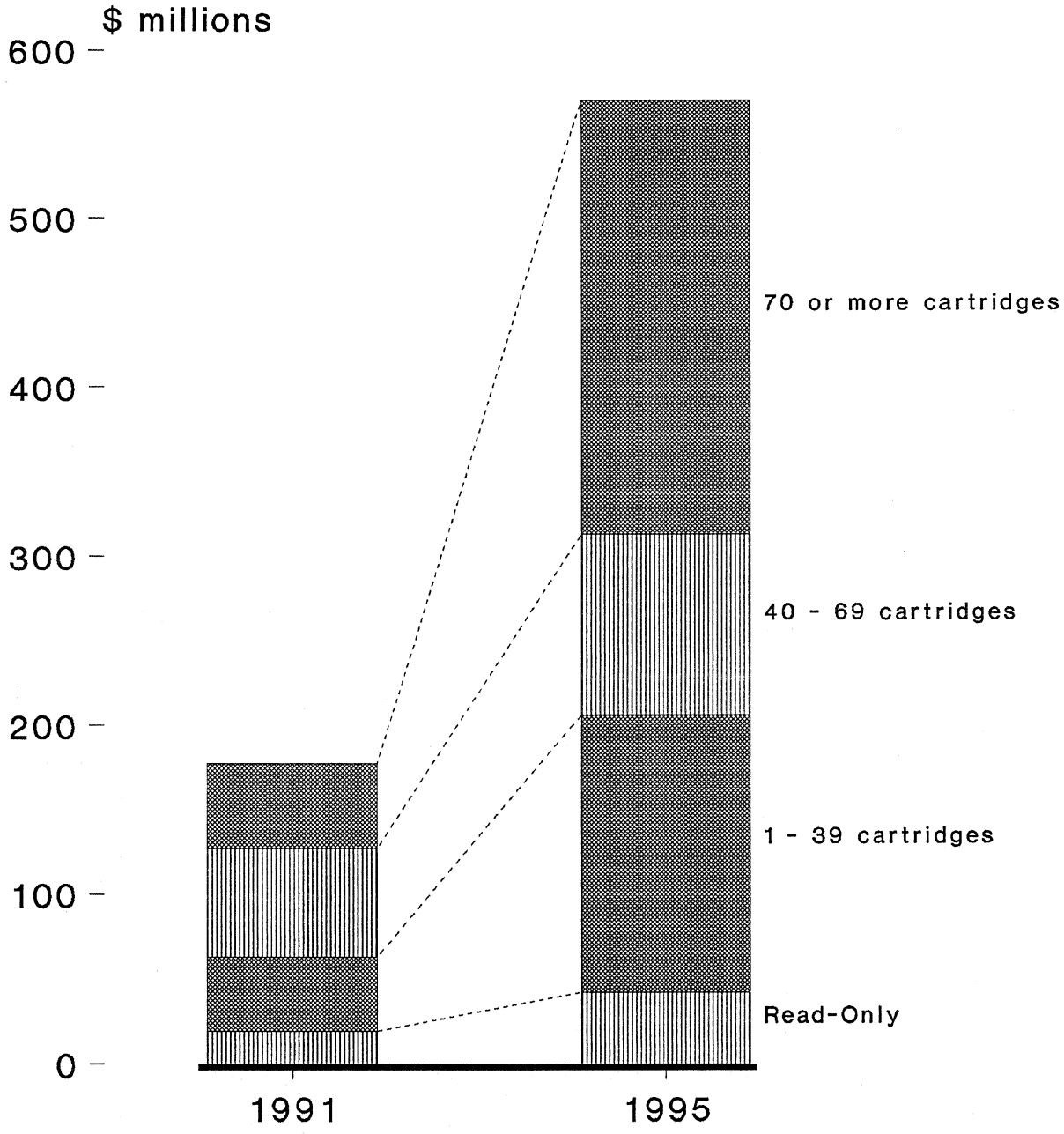


Figure 2

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 after-market 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.

OEM/Integrator optical disk drive revenues rose to 46.5% of the worldwide total of $1.18 billion in 1991, followed by captive revenues at 35.8%. PCM/Reseller revenues dropped to 17.7%. In 1995, of the $2.9 billion total revenues expected for optical disk drives, the OEM/Integrator share will rise slightly to 44.9%. PCM/Reseller revenue is projected to shrink to 16.9%, while the captive share is forecasted to grow slightly, to 38.2% of 1995 revenues.

1991 library revenues of $176.2 million were split 44.0% from OEM/Integrators, 48.2% from captive sales, and 7.8% from the PCM/Reseller channel. In 1995, library revenues of $570.2 million are expected to be divided 61.7% to OEM/Integrators, 32.7% to captive sales, and 5.6% 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, and some of the resellers handling libraries are beginning to acquire the characteristics of small OEMs as they increase their value-added content and perform increasing amounts of system integration.

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.

Industry participation

10 U.S. companies, 23 Asian firms and 3 European organizations compete in the optical disk drive market. The number of U.S. firms has increased by one (Pinnacle Micro), but Optimem stopped drive production, leaving no net gain. Four Asian producers have left the market, at least for the present, while 2 new entrants, Olympus and Teac, announced optical drives. Olympus had previously been active as a contract manufacturer of optical mechanisms. The list of European drive producers remained the same.

13 companies offer read-only drives, all of which are non-U.S. firms and 11 of which are Japanese organizations. 29 manufacturers are making read/write drives under 1 gigabyte: 21 of these have rewritable or multifunction drives, an increase from 16 last year.

11 U.S. firms, 10 Asian manufacturers and 5 European suppliers offer optical libraries. Of the 26 companies, 4 make read-only libraries, but 3 do not participate in other product groups. 11 firms make only 5.25" libraries, while 6 make only larger diameter libraries. 6 firms make libraries in two or more diameters.

The U.S. count of library manufacturers has risen by three (Borett, Docupoint, IBM), but the Asian manufacturer count for libraries has declined by one. The number of European library manufacturers has risen to 5 this year with the addition of K+S and ATG Gigadisc.

TABLE 3

CONSOLIDATED WORLDWIDE REVENUES
OPTICAL DISK DRIVES
MARKET CLASS REVIEW

REVENUE SUMMARY

WORLDWIDE REVENUES BY MANUFACTURER TYPE	1991 Revenues $M	1991 Revenues %	1992 Forecast $M	1992 Forecast %	1993 Forecast $M	1993 Forecast %	1994 Forecast $M	1994 Forecast %	1995 Forecast $M	1995 Forecast %
U.S. Manufacturers										
IBM Captive	7.7	.6%	27.0	1.6%	51.6	2.4%	96.5	3.8%	154.8	5.3%
	--		+250.6%		+91.1%		+87.0%		+60.4%	
Other U.S. Captive	16.8	1.4%	22.1	1.3%	40.7	1.9%	51.8	2.0%	66.2	2.2%
	--		+31.5%		+84.2%		+27.3%		+27.8%	
PCM/Reseller	28.3	2.3%	34.6	2.1%	38.7	1.8%	54.3	2.1%	59.6	2.0%
	+6.0%		+22.3%		+11.8%		+40.3%		+9.8%	
OEM/Integrator	20.5	1.7%	30.5	1.8%	47.2	2.2%	52.7	2.0%	76.8	2.6%
	-4.7%		+48.8%		+54.8%		+11.7%		+45.7%	
Total U.S. Manufacturers	73.3	6.0%	114.2	6.8%	178.2	8.3%	255.3	9.9%	357.4	12.1%
	+52.1%		+55.8%		+56.0%		+43.3%		+40.0%	
Non-U.S. Manufacturers										
Captive	397.8	33.7%	541.4	33.7%	666.2	32.1%	799.7	31.5%	889.2	30.5%
	+17.5%		+36.1%		+23.1%		+20.0%		+11.2%	
PCM/Reseller	180.8	15.3%	249.6	15.5%	313.7	15.1%	369.6	14.5%	431.7	14.8%
	-.8%		+38.1%		+25.7%		+17.8%		+16.8%	
OEM/Integrator	528.0	45.0%	701.0	44.0%	914.7	44.5%	1,113.4	44.1%	1,231.0	42.6%
	+48.9%		+32.8%		+30.5%		+21.7%		+10.6%	
Total Non-U.S. Manufacturers	1,106.6	94.0%	1,492.0	93.2%	1,894.6	91.7%	2,282.7	90.1%	2,551.9	87.9%
	+26.4%		+34.8%		+27.0%		+20.5%		+11.8%	
Worldwide Recap										
Captive	422.3	35.8%	590.5	36.8%	758.5	36.6%	948.0	37.4%	1,110.2	38.2%
	+24.8%		+39.8%		+28.5%		+25.0%		+17.1%	
PCM/Reseller	209.1	17.7%	284.2	17.7%	352.4	17.0%	423.9	16.7%	491.3	16.9%
	--		+35.9%		+24.0%		+20.3%		+15.9%	
OEM/Integrator	548.5	46.5%	731.5	45.5%	961.9	46.4%	1,166.1	45.9%	1,307.8	44.9%
	+45.8%		+33.4%		+31.5%		+21.2%		+12.2%	
Total All Manufacturers	1,179.9	100.0%	1,606.2	100.0%	2,072.8	100.0%	2,538.0	100.0%	2,909.3	100.0%
	+27.7%		+36.1%		+29.0%		+22.4%		+14.6%	

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	1991 Revenues $M	1991 Revenues %	1992 Forecast $M	1992 Forecast %	1993 Forecast $M	1993 Forecast %	1994 Forecast $M	1994 Forecast %	1995 Forecast $M	1995 Forecast %
U.S. Manufacturers										
IBM Captive	--	--	.3	--	.9	.2%	1.3	.2%	1.7	.2%
	--		--		+200.0%		+44.4%		+30.8%	
Other U.S. Captive	42.6	24.1%	64.2	20.6%	83.5	20.8%	107.4	22.1%	133.3	23.3%
	+73.9%		+50.7%		+30.1%		+28.6%		+24.1%	
PCM/Reseller	2.3	1.3%	5.9	1.9%	7.0	1.7%	6.0	1.2%	5.7	.9%
	-32.4%		+156.5%		+18.6%		-14.3%		-5.0%	
OEM/Integrator	38.5	21.8%	97.9	31.5%	133.4	33.3%	167.9	34.6%	212.4	37.2%
	+37.5%		+154.3%		+36.3%		+25.9%		+26.5%	
Total U.S. Manufacturers	83.4	47.2%	168.3	54.0%	224.8	56.0%	282.6	58.1%	353.1	61.6%
	+49.2%		+101.8%		+33.6%		+25.7%		+24.9%	
Non-U.S. Manufacturers										
Captive	42.4	24.0%	46.4	14.9%	47.9	11.9%	48.9	10.0%	51.3	8.9%
	+175.3%		+9.4%		+3.2%		+2.1%		+4.9%	
PCM/Reseller	11.5	6.5%	23.4	7.5%	25.6	6.4%	26.6	5.4%	26.5	4.6%
	+53.3%		+103.5%		+9.4%		+3.9%		-.4%	
OEM/Integrator	38.9	22.3%	72.4	23.6%	101.4	25.7%	126.1	26.5%	139.3	24.9%
	+73.7%		+86.1%		+40.1%		+24.4%		+10.5%	
Total Non-U.S. Manufacturers	92.8	52.8%	142.2	46.0%	174.9	44.0%	201.6	41.9%	217.1	38.4%
	+104.9%		+53.2%		+23.0%		+15.3%		+7.7%	
Worldwide Recap										
Captive	85.0	48.2%	110.9	35.7%	132.3	33.1%	157.6	32.5%	186.3	32.7%
	+113.0%		+30.5%		+19.3%		+19.1%		+18.2%	
PCM/Reseller	13.8	7.8%	29.3	9.4%	32.6	8.2%	32.6	6.7%	32.2	5.6%
	+26.6%		+112.3%		+11.3%		--		-1.2%	
OEM/Integrator	77.4	44.0%	170.3	54.9%	234.8	58.7%	294.0	60.8%	351.7	61.7%
	+53.6%		+120.0%		+37.9%		+25.2%		+19.6%	
Total All Manufacturers	176.2	100.0%	310.5	100.0%	399.7	100.0%	484.2	100.0%	570.2	100.0%
	+74.1%		+76.2%		+28.7%		+21.1%		+17.8%	

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

Product mix

Read-only drives increased their share to 86.6% of optical disk drives shipped in 1991, up from 78.4% in 1990 due to increasing acceptance of the CD-ROM as a desirable personal computer peripheral device and increasing consumer usage in games and personal data retrieval appliances such as the Sony Data Discman.

The share of read/write drives under 1 gigabyte declined to 12.9% in 1991, while read/write drives over 1 gigabyte declined to .5% of shipments due to declining captive sales in 1991 as well as the increasing prominence of the read-only drives.

Revenue leadership in the optical disk drive market is held by read/write drives less than 1 gigabyte, with 49.6%, followed by read-only drives with 38.9%. Read/write drives over 1 gigabyte had 11.5%. The share for the drives over 1 gigabyte is expected to decline until 1994, when sales of 5.25" drives with capacities over 1 gigabyte will help this product group start to increase both revenue and shipment share of market.

Over 91% of shipments of read/write drives less than 1 gigabyte will be erasable or multifunction drives in 1995. Read-only drive shipments are projected to pass the 6.0 million unit mark, holding 86.5% of total worldwide shipments. 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.

4.72" write-once drives that prepare disks in the CD-ROM format will become an increasingly important part of the product mix, and are expected to be the dominant type of write-once drive in 1995. This is partly due to demand for the 4.72" models and decline in shipments of 5.25" write-once drives as they are displaced by multifunction drives over the next several years.

While shipments of higher performance CD-ROM drives grew fastest in 1991 and 1992, from 1993 on the increasing use of CD-ROM drives in games and other consumer applications will cause faster growth for lower performance drives. Most CD-ROM drives are the 4.72" type, but 3.15" drives are produced by Sony for its Data Discman. Toshiba has announced an ISO compatible 3.15" drive which will be produced starting in late 1992.

The largest segment in 1991 for optical libraries remained the read-only library segment, with a 73.6% share of an 23,022 unit market. The next largest segment was the 1 to 39 disk cartridge library, which had a 14.0% share. The 40 to 69 cartridge libraries, which had the largest share in 1989, captured only a 10.2% share in 1991, down from 10.9% in 1990. Libraries with 70 or more cartridges held a 2.2% share. The major factors in the changes are the large numbers of read-only libraries and the popularity of 5 and 10 cartridge libraries in the 1 to 39 disk cartridge product group.

In 1995, the read-only libraries are expected to hold a 54.6% share of unit shipments, while the 1 to 39 disk group will follow with 30.2%. The 40 to 69 cartridge libraries will decrease their share slightly to 8.1%. Libraries with 70 or more cartridges will obtain a 7.1% 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 unit shipment statistics favor the bottom of the line, almost 64% of revenues will be generated from the two top of the line categories. 28.7% of the 1995 revenue will be generated by the 1 to 39 cartridge category, while 7.3% will be generated by read-only libraries.

TABLE 5

CONSOLIDATED WORLDWIDE REVENUES
OPTICAL DISK DRIVES
PRODUCT CATEGORY REVIEW

REVENUE SUMMARY

WORLDWIDE REVENUES	1991		Forecast							
ALL MANUFACTURERS	Revenues		1992		1993		1994		1995	
	$M	%	$M	%	$M	%	$M	%	$M	%
READ-ONLY	458.9	38.9%	626.2	39.0%	794.5	38.3%	928.2	36.6%	1,013.9	34.9%
ALL CAPACITIES	+58.1%		+36.5%		+26.9%		+16.8%		+9.2%	
READ/WRITE	585.4	49.6%	821.8	51.2%	1,078.0	52.0%	1,344.5	53.0%	1,550.5	53.3%
LESS THAN 1 GIGABYTE	+22.6%		+40.4%		+31.2%		+24.7%		+15.3%	
READ/WRITE	135.6	11.5%	158.2	9.8%	200.3	9.7%	265.3	10.4%	344.9	11.8%
MORE THAN 1 GIGABYTE	-13.0%		+16.7%		+26.6%		+32.5%		+30.0%	
Total Worldwide Revenue	1,179.9	100.0%	1,606.2	100.0%	2,072.8	100.0%	2,538.0	100.0%	2,909.3	100.0%
	+27.7%		+36.1%		+29.0%		+22.4%		+14.6%	
% U.S. Manufacturers	6.2%		7.1%		8.6%		10.0%		12.2%	

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	1991		Forecast							
ALL MANUFACTURERS	Revenues		1992		1993		1994		1995	
	$M	%	$M	%	$M	%	$M	%	$M	%
OPTICAL LIBRARIES	18.8	10.7%	26.9	8.7%	31.6	7.9%	38.1	7.9%	41.9	7.3%
READ-ONLY	+123.8%		+43.1%		+17.5%		+20.6%		+10.0%	
OPTICAL LIBRARIES	43.9	24.9%	89.4	28.8%	123.5	30.9%	146.0	30.2%	163.9	28.7%
1-39 DISKS	+54.6%		+103.6%		+38.1%		+18.2%		+12.3%	
OPTICAL LIBRARIES	64.0	36.3%	79.0	25.4%	89.4	22.4%	96.8	20.0%	107.4	18.8%
40-69 DISKS	+63.3%		+23.4%		+13.2%		+8.3%		+11.0%	
OPTICAL LIBRARIES	49.5	28.1%	115.2	37.1%	155.2	38.8%	203.3	41.9%	257.0	45.1%
70 OR MORE DISKS	+96.4%		+132.7%		+34.7%		+31.0%		+26.4%	
Total Worldwide Revenue	176.2	100.0%	310.5	100.0%	399.7	100.0%	484.2	100.0%	570.2	100.0%
	+74.1%		+76.2%		+28.7%		+21.1%		+17.8%	
% U.S. Manufacturers	47.3%		54.2%		56.2%		58.3%		61.9%	

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 IN THOUSANDS	1991 Shipments Units	1991 Shipments %	1992 Forecast Units	1992 Forecast %	1993 Forecast Units	1993 Forecast %	1994 Forecast Units	1994 Forecast %	1995 Forecast Units	1995 Forecast %
READ-ONLY	1,435.1	86.6%	2,305.0	87.1%	3,441.2	86.9%	4,759.3	86.6%	6,181.6	86.5%
ALL CAPACITIES	+101.3%		+60.6%		+49.3%		+38.3%		+29.9%	
READ/WRITE	214.5	12.9%	331.9	12.5%	510.3	12.9%	720.8	13.1%	930.0	13.0%
LESS THAN 1 GIGABYTE	+15.7%		+54.7%		+53.8%		+41.3%		+29.0%	
READ/WRITE	9.8	.5%	11.5	.4%	14.6	.2%	24.2	.3%	45.4	.5%
MORE THAN 1 GIGABYTE	-16.2%		+17.3%		+27.0%		+65.8%		+87.6%	
Total Worldwide Shipments	1,659.4	100.0%	2,648.4	100.0%	3,966.1	100.0%	5,504.3	100.0%	7,157.0	100.0%
	+82.4%		+59.6%		+49.8%		+38.8%		+30.0%	
% U.S. Manufacturers	1.6%		1.7%		2.0%		2.2%		2.4%	

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	1991 Shipments Units	1991 Shipments %	1992 Forecast Units	1992 Forecast %	1993 Forecast Units	1993 Forecast %	1994 Forecast Units	1994 Forecast %	1995 Forecast Units	1995 Forecast %
OPTICAL LIBRARIES	16,920.0	73.6%	22,205.0	64.8%	27,044.0	61.3%	31,163.0	58.6%	34,571.0	54.6%
READ-ONLY	+114.1%		+31.2%		+21.8%		+15.2%		+10.9%	
OPTICAL LIBRARIES	3,215.0	14.0%	7,181.0	21.0%	10,862.0	24.6%	14,338.0	26.9%	19,125.0	30.2%
1-39 DISKS	+55.9%		+123.4%		+51.3%		+32.0%		+33.4%	
OPTICAL LIBRARIES	2,341.0	10.2%	3,114.0	9.1%	3,731.0	8.5%	4,296.0	8.1%	5,128.0	8.1%
40-69 DISKS	+99.6%		+33.0%		+19.8%		+15.1%		+19.4%	
OPTICAL LIBRARIES	546.0	2.2%	1,749.0	5.1%	2,490.0	5.6%	3,412.0	6.4%	4,519.0	7.1%
70 OR MORE DISKS	+101.5%		+220.3%		+42.4%		+37.0%		+32.4%	
Total Worldwide Shipments	23,022.0	100.0%	34,249.0	100.0%	44,127.0	100.0%	53,209.0	100.0%	63,343.0	100.0%
	+101.8%		+48.8%		+28.8%		+20.6%		+19.0%	
% U.S. Manufacturers	14.9%		20.7%		21.9%		23.3%		26.3%	

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

Figure 3

WORLDWIDE SHIPMENT SUMMARY

Total Optical Disk Drives

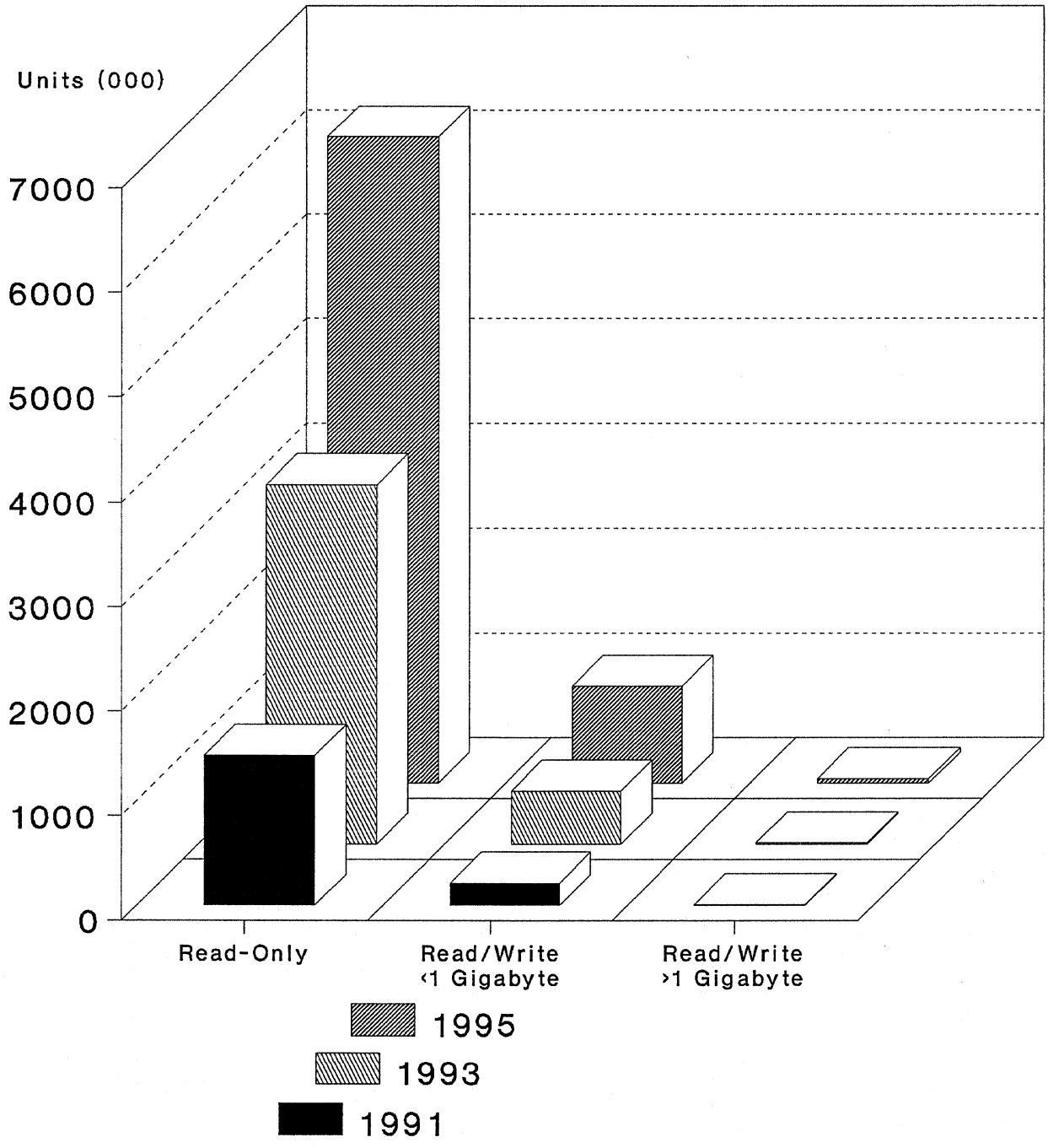
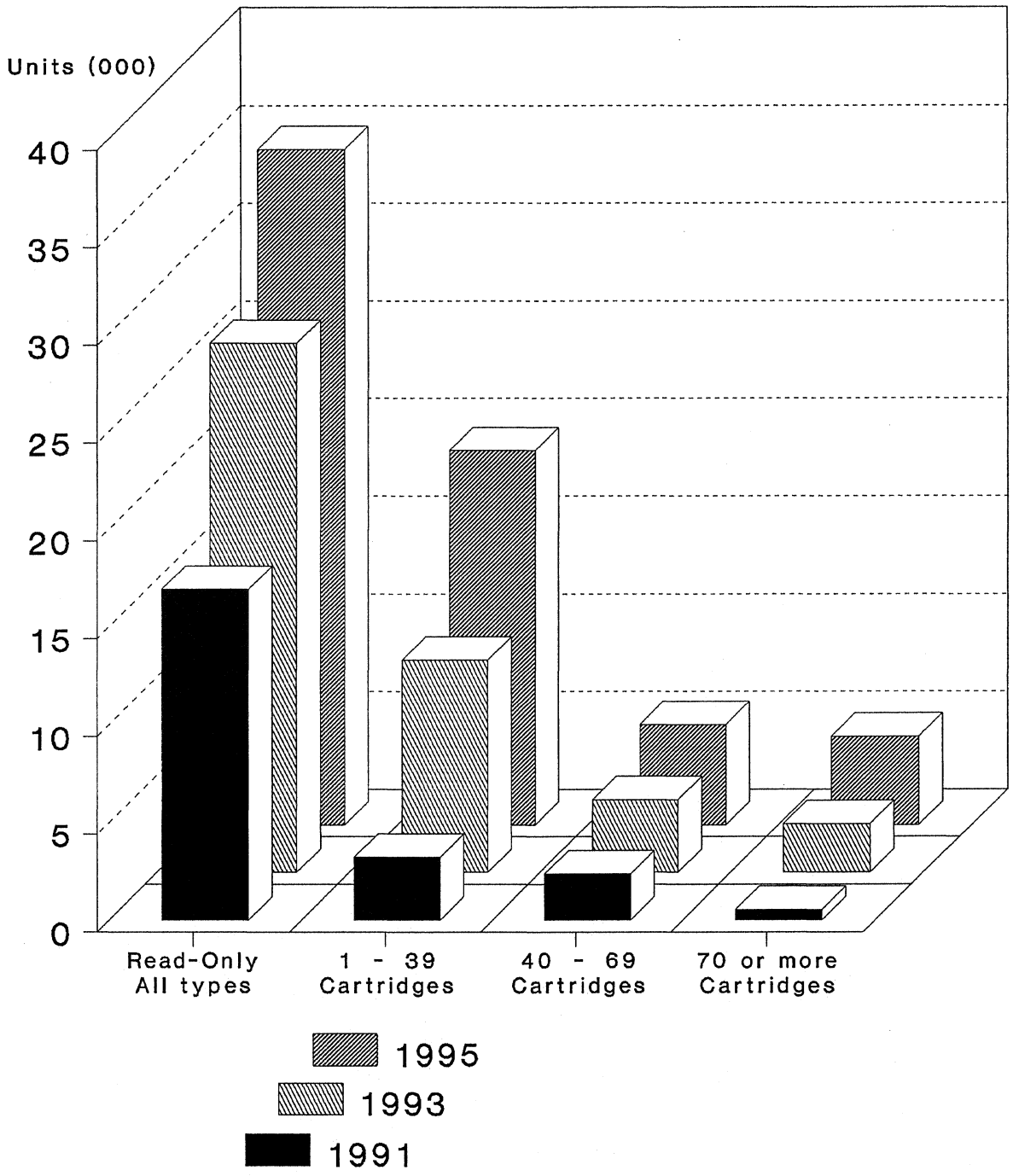


Figure 4

WORLDWIDE SHIPMENT SUMMARY

Total Optical Libraries



Noncaptive market

In the noncaptive distribution channels (OEM/Integrator and PCM/Reseller), read-only drives increased their share of unit shipments, capturing 86.8% of the worldwide market. Read/write drives less than 1 gigabyte were next with 12.7% and read/write drives over 1 gigabyte held .5%. The share percentages are expected to remain about the same over the period of the forecast, with strong CD-ROM sales resulting from the availability of multimedia software keeping the read-only category predominant.

1991 noncaptive drive revenues were also led by the read-only drives, with strong growth in unit shipments exceeding the effects of price declines. Read-only drives held 45.1% of noncaptive worldwide revenues, followed by the low capacity read/write product group with 42.8%, and high capacity read/write drives with 12.1%. A similar ranking is expected through 1995, although the high capacity read/write drives will increase their revenue share starting in 1994 as a result of the availability of 5.25" drives in this product group.

The major OEM/Integrator revenue producers in 1991 were Sony, Toshiba, Hitachi and Matsushita Electric, in that order. These four companies accounted for 69% of total OEM/Integrator market value, and Sony alone held 39.8% of the OEM/Integrator total. The share held by the top four is down about 4 points from 1990. NEC, Matsushita Electric, Sony and Maxoptix were the leading PCM/Reseller channel suppliers, together holding 61.6% share, about 8% less for the top four than in 1990. U.S. producers captured only 3.7% of OEM/Integrator revenues in 1991, but did improve their position in the PCM/Reseller channel with 13.5% share, compared to 12.8% in 1990.

The noncaptive share of optical disk drive revenues is expected to shrink somewhat in the 1991-1995 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.

80.4% of the optical libraries sold in the noncaptive market were generated by the read-only product group, followed by 11.8% in the 1 to 39 disk product group. Emphasis on the low-end segments will continue through 1995, with the read-only library product group holding 57.7% share in 1995 and the 1 to 39 cartridge libraries following with 29.9% share.

Library OEM/Integrator revenues are weighted more heavily to high-end libraries. In 1991, the 40 to 69 disk and more than 70 disk segments together captured 59.1% of 1991 noncaptive revenue. However, in 1992, the 1 to 39 disk product group will be the largest revenue producing segment because of the rapid growth of 12" libraries such as the LMSI Rapidchanger and Sony's recently announced 12 disk library.

In 1995, the 1 to 39 disk category is projected to have the lead with 37.0%, followed by the 70 or more disk product group with 35%. As with the shipment shares, revenue is shifting to lower-end segments with time, although the read-only segment 1995 share reaches only 10.9% because of the much lower pricing levels for most of the products in this segment.

U.S. library manufacturers captured 49.7% of the OEM/Integrator revenues and 16.7% of the PCM/Reseller revenues in 1991. Hewlett-Packard, Cygnet Systems and NKK were the leading OEM/Integrator channel suppliers with 51.1% of the revenues between them. The three top OEM/Integrator suppliers share was up about 5.8% from 1990. In the PCM/Reseller channel, Pioneer, NKK and Hewlett-Packard were the leaders. Noncaptive library revenues will rise from a 51.8% share of the worldwide total in 1991 to a 67.3% share in 1995, with the strongest growth coming in the OEM/Integrator channel from sales of low-end libraries.

TABLE 9

NONCAPTIVE WORLDWIDE REVENUES
OPTICAL DISK DRIVES
PRODUCT CATEGORY REVIEW

REVENUE SUMMARY

WORLDWIDE REVENUES	1991		Forecast							
ALL MANUFACTURERS	Revenues		1992		1993		1994		1995	
	$M	%	$M	%	$M	%	$M	%	$M	%
READ-ONLY	340.7	45.1%	467.2	46.1%	600.5	45.8%	716.5	45.2%	800.6	44.6%
ALL CAPACITIES	+77.8%		+37.1%		+28.5%		+19.3%		+11.7%	
READ/WRITE	324.4	42.8%	426.5	42.0%	546.3	41.6%	658.9	41.4%	739.0	41.1%
LESS THAN 1 GIGABYTE	+4.5%		+31.5%		+28.1%		+20.6%		+12.2%	
READ/WRITE	92.5	12.1%	122.0	11.9%	167.5	12.6%	214.6	13.4%	259.5	14.3%
MORE THAN 1 GIGABYTE	+11.2%		+31.9%		+37.3%		+28.1%		+20.9%	
Total Worldwide Revenues	757.6	100.0%	1,015.7	100.0%	1,314.3	100.0%	1,590.0	100.0%	1,799.1	100.0%
	+29.5%		+34.1%		+29.4%		+21.0%		+13.2%	
% U.S. Manufacturers	6.4%		6.4%		6.5%		6.7%		7.5%	

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

TABLE 10

NONCAPTIVE WORLDWIDE REVENUES
OPTICAL LIBRARIES
PRODUCT CATEGORY REVIEW

REVENUE SUMMARY

WORLDWIDE REVENUES	1991		Forecast							
ALL MANUFACTURERS	Revenues		1992		1993		1994		1995	
	$M	%	$M	%	$M	%	$M	%	$M	%
OPTICAL LIBRARIES	18.0	19.7%	25.9	13.0%	31.0	11.6%	37.7	11.5%	41.8	10.9%
READ-ONLY	+114.3%		+43.9%		+19.7%		+21.6%		+10.9%	
OPTICAL LIBRARIES	19.3	21.2%	67.2	33.7%	101.8	38.2%	124.5	38.3%	141.6	37.0%
1-39 DISKS	+39.9%		+248.2%		+51.5%		+22.3%		+13.7%	
OPTICAL LIBRARIES	32.5	35.7%	41.4	20.8%	50.7	18.9%	57.2	17.5%	65.9	17.1%
40-69 DISKS	+41.3%		+27.4%		+22.5%		+12.8%		+15.2%	
OPTICAL LIBRARIES	21.4	23.4%	65.1	32.5%	83.9	31.3%	107.2	32.7%	134.6	35.0%
70 OR MORE DISKS	+32.9%		+204.2%		+28.9%		+27.8%		+25.6%	
Total Worldwide Revenues	91.2	100.0%	199.6	100.0%	267.4	100.0%	326.6	100.0%	383.9	100.0%
	+48.8%		+118.9%		+34.0%		+22.1%		+17.5%	
% U.S. Manufacturers	44.7%		52.0%		52.5%		53.2%		56.8%	

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

TABLE 11

NONCAPTIVE WORLDWIDE SHIPMENTS
OPTICAL DISK DRIVES
PRODUCT CATEGORY REVIEW

UNIT SHIPMENT SUMMARY

UNIT SHIPMENTS IN THOUSANDS	1991 Shipments Units	1991 Shipments %	1992 Forecast Units	1992 Forecast %	1993 Forecast Units	1993 Forecast %	1994 Forecast Units	1994 Forecast %	1995 Forecast Units	1995 Forecast %
READ-ONLY	1,132.0	86.8%	1,811.1	87.5%	2,759.4	87.4%	3,942.1	87.7%	5,263.1	88.1%
ALL CAPACITIES	+128.0%		+60.0%		+52.4%		+42.9%		+33.5%	
READ/WRITE	165.8	12.7%	251.9	12.1%	389.3	12.3%	539.6	11.9%	682.9	11.4%
LESS THAN 1 GIGABYTE	+9.4%		+51.9%		+54.5%		+38.6%		+26.6%	
READ/WRITE	7.2	.5%	9.5	.4%	12.8	.3%	20.4	.4%	37.3	.5%
MORE THAN 1 GIGABYTE	--		+31.9%		+34.7%		+59.4%		+82.8%	
Total Worldwide Shipments	1,305.0	100.0%	2,072.5	100.0%	3,161.5	100.0%	4,502.1	100.0%	5,983.3	100.0%
	+99.1%		+58.8%		+52.5%		+42.4%		+32.9%	
% U.S. Manufacturers	1.5%		1.4%		1.5%		1.4%		1.4%	

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

TABLE 12

NONCAPTIVE WORLDWIDE SHIPMENTS
OPTICAL LIBRARIES
PRODUCT CATEGORY REVIEW

UNIT SHIPMENT SUMMARY

SHIPMENTS IN SINGLE UNITS	1991 Shipments Units	1991 Shipments %	1992 Forecast Units	1992 Forecast %	1993 Forecast Units	1993 Forecast %	1994 Forecast Units	1994 Forecast %	1995 Forecast Units	1995 Forecast %
OPTICAL LIBRARIES READ-ONLY	16,868.0	80.4%	22,140.0	69.5%	27,005.0	65.2%	31,140.0	62.0%	34,565.0	57.7%
	+113.5%		+31.3%		+22.0%		+15.3%		+11.0%	
OPTICAL LIBRARIES 1-39 DISKS	2,487.0	11.8%	6,397.0	20.0%	9,954.0	24.0%	13,330.0	26.5%	17,974.0	29.9%
	+47.2%		+157.2%		+55.6%		+33.9%		+34.8%	
OPTICAL LIBRARIES 40-69 DISKS	1,283.0	6.1%	1,933.0	6.1%	2,498.0	6.0%	3,016.0	6.0%	3,780.0	6.3%
	+37.4%		+50.7%		+29.2%		+20.7%		+25.3%	
OPTICAL LIBRARIES 70 OR MORE DISKS	376.0	1.7%	1,441.0	4.4%	2,042.0	4.8%	2,795.0	5.5%	3,718.0	6.1%
	+74.9%		+283.2%		+41.7%		+36.9%		+33.0%	
Total Worldwide Shipments	21,014.0	100.0%	31,911.0	100.0%	41,499.0	100.0%	50,281.0	100.0%	60,037.0	100.0%
	+95.6%		+51.9%		+30.0%		+21.2%		+19.4%	
% U.S. Manufacturers	12.9%		19.1%		20.4%		21.8%		24.8%	

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

Figure 5

WORLDWIDE SHIPMENT SUMMARY

Noncaptive Optical Disk Drives

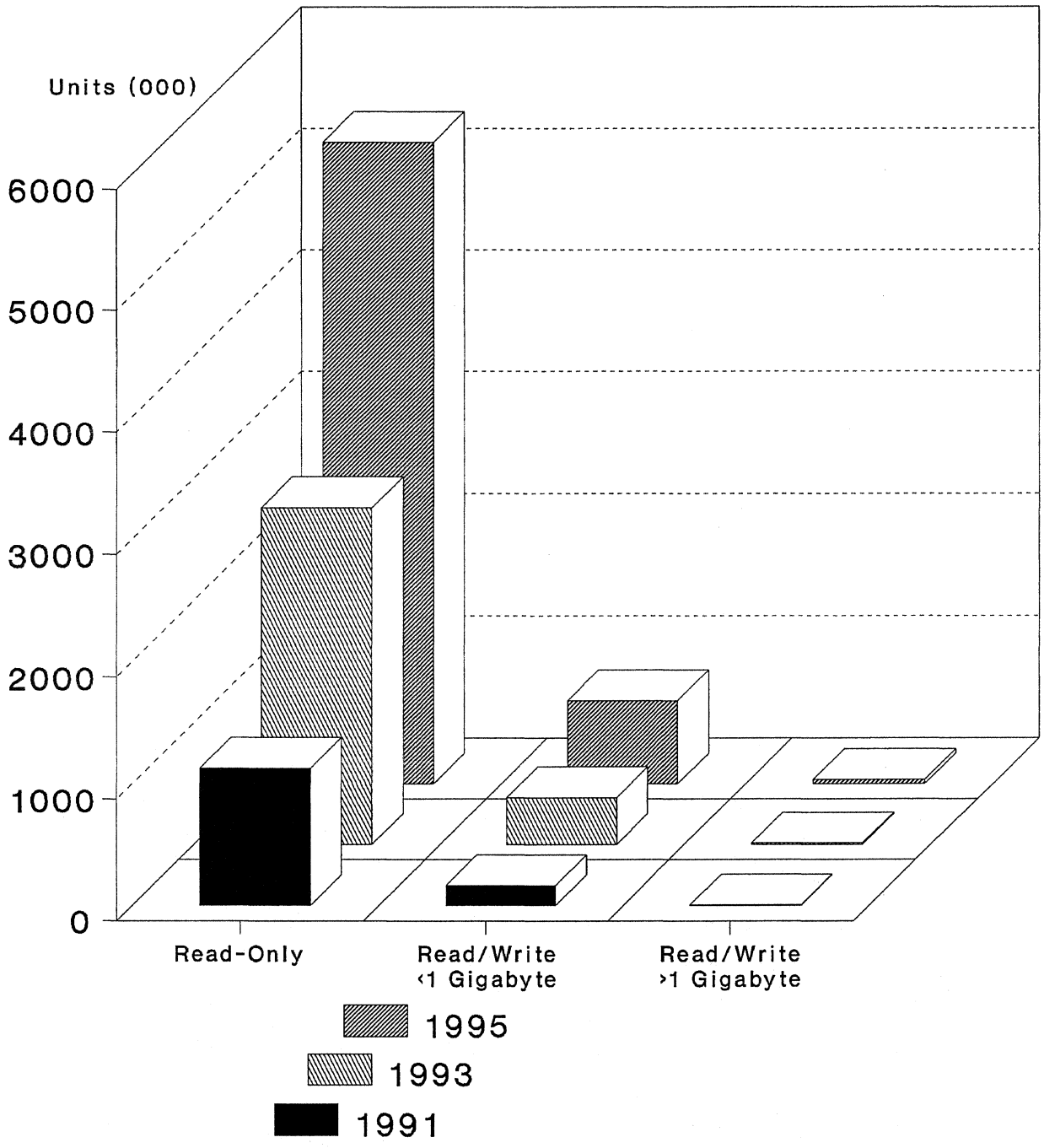


Figure 6

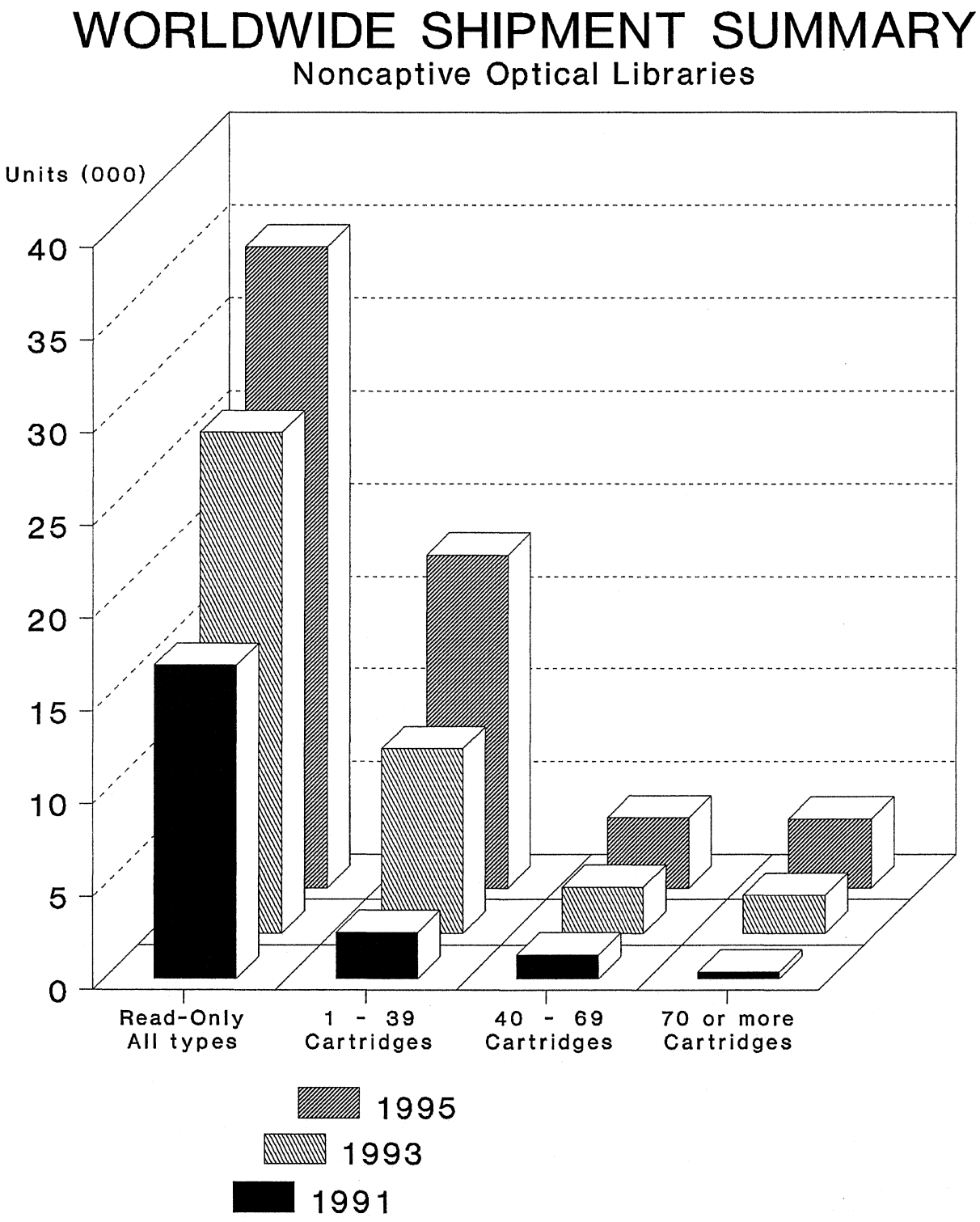

WORLDWIDE SHIPMENT SUMMARY
Noncaptive Optical Libraries
Units (000)
40
35
30
25
20
15
10
5
0
Read-Only
All types
1 - 39
Cartridges
40 - 69
Cartridges
70 or more
Cartridges
1995
1993
1991

TABLE 13

1991 ESTIMATED MARKET SHARES

WORLDWIDE REVENUES OF ALL OPTICAL DISK DRIVES
(Value of non-U.S. currencies estimated at average 1991 rates)

	CAPTIVE		PCM/RESELLER		OEM/INTEGRATOR		TOTAL INDUSTRY	
	$M	%	$M	%	$M	%	$M	%
U.S. MANUFACTURERS								
Hewlett-Packard	14.4	3.4	4.6	2.2	4.3	.8	23.3	2.0
Maxoptix	--	--	16.3	7.8	5.5	1.0	21.8	1.8
Other U.S.	10.1	2.4	7.4	3.5	10.7	2.0	28.2	2.4
U.S. Total	24.5	5.8	28.3	13.5	20.5	3.7	73.3	6.2
NON-U.S. MANUFACTURERS								
Canon	90.0	21.3	10.5	5.0	3.0	.5	103.5	8.8
Hitachi	18.3	4.3	10.3	4.9	51.7	9.4	80.3	6.8
Laser Magnetic Storage Int'l.	--	--	11.0	5.3	34.9	6.4	45.9	3.9
Matsushita Electric Industrial	45.1	10.7	26.3	12.6	49.7	9.1	121.1	10.3
NEC	113.2	26.8	61.8	29.6	4.8	.9	179.8	15.2
Ricoh	17.6	4.2	9.6	4.6	27.8	5.1	55.0	4.7
Sony	68.6	16.2	24.3	11.6	218.5	39.8	311.4	26.4
Toshiba	36.7	8.7	4.8	2.3	58.7	10.7	100.2	8.5
Other Non-U.S.	8.3	2.0	22.2	10.6	78.9	14.4	109.4	9.3
Non-U.S. Total	397.8	94.2	180.8	86.5	528.0	96.3	1,106.6	93.8
WORLDWIDE TOTAL	422.3	100.0	209.1	100.0	548.5	100.0	1,179.9	100.0

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

TABLE 14

1991 ESTIMATED MARKET SHARES

WORLDWIDE REVENUES OF ALL OPTICAL LIBRARIES
(Value of non-U.S. currencies estimated at average 1991 rates)

	CAPTIVE		PCM/RESELLER		OEM/INTEGRATOR		TOTAL INDUSTRY	
	$M	%	$M	%	$M	%	$M	%
U.S. MANUFACTURERS								
Cygnet Systems	--	--	.1	.7	12.5	16.1	12.6	7.2
Eastman Kodak	6.8	8.0	--	--	2.2	2.8	9.0	5.1
Filenet	19.3	22.7	--	--	3.2	4.1	22.5	12.8
Hewlett-Packard	15.6	18.4	.8	5.8	16.5	21.3	32.9	18.7
Other U.S.	.9	1.1	1.4	10.1	4.1	5.3	6.4	3.6
U.S. Total	42.6	50.1	2.3	16.7	38.5	49.7	83.4	47.3
NON-U.S. MANUFACTURERS								
Hitachi	38.9	45.8	.2	1.4	7.1	9.2	46.2	26.2
NKK	--	--	2.0	14.5	10.6	13.7	12.6	7.2
Pioneer	--	--	7.8	56.5	9.0	11.6	16.8	9.5
Sony	--	--	--	--	8.0	10.3	8.0	4.5
Other Non-U.S.	3.5	4.1	1.5	10.9	4.2	5.4	9.2	5.2
Non-U.S. Total	42.4	49.9	11.5	83.3	38.9	50.3	92.8	52.7
WORLDWIDE TOTAL	85.0	100.0	13.8	100.0	77.4	100.0	176.2	100.0

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

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,O,P		3.5 E, 5.25 E	
Literal	O,P		5.25, 5.25 E	
Maximum Storage	O		5.25	
Maxoptix	O,P		5.25 E	
Mountain Optech	O		3.5 E, 5.25, 5.25 E	
Pinnacle Micro	O,P		5.25 E	
Asian Manufacturers (23)				
Canon	C,O		5.25 E	
Chinon	O	4.72		
Fujitsu	C,O		3.5 E, 5.25 E	8 E
Hitachi	C,O,P	4.72	5.25, 5.25 E	12
JVC	O		4.72	
Kawasaki Steel	O		5.25	
Matsushita Electric Ind.	C,O	4.72	3.5 E, 5.25, 5.25 E	
Matsushita Electronic Comp.	O	4.72		
Mitsubishi Electric	O		3.5 E, 5.25, 5.25 E	
Mitsumi Electric	O	4.72		
MOST	O,P		3.5 E	
NEC	C,O	4.72	3.5 E, 5.25, 5.25 E	12
Nikon	O			12 E
Olympus	O		3.5 E	
Pioneer Electronic	O,P	4.72	5.25, 5.25 E	
Ricoh	C,O		3.5 E, 5.25, 5.25 E	
Sanyo	O,P	4.72		
Sharp	O,P		5.25 E	
Sony	C,O,P	3.15, 4.72	3.5 E, 4.72, 5.25 E	12
Teac	O		3.5 E	
Texel (Shinano Kenshi)	O	4.72		
Toshiba	O	3.15, 4.72	3.5 E	
Yamaha	C		4.72	
European Manufacturers (3)				
ATG Gigadisc	O		3.5 E	12
Laser Magnetic Storage	C,O,P	4.72	5.25	12
Philips Consumer Elect.	C,P	4.72	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 (11)	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		
Borett Automation Tech.	O	4.72			5.25, 12
Cygnet Systems	O		5.25, 12		12
Document Imaging Systems	O				5.25
Docupoint	C,O				5.25
Eastman Kodak	C,O,P			5.25	14
Filenet	C,O				12
Hewlett-Packard	C,O,P		5.25		5.25
IBM	C		3.5		
International Data Engin.	O,P		5.25		
Kubik Enterprises	O	4.72			
Asian Manufacturers (10)					
Aisin Seiki	O		5.25		
Fujitsu	C,O				5.25
Hitachi	C,O		5.25, 12	5.25, 12	
Matsushita Electric Indus.	C,O			5.25	
Mitsubishi Electric	C,O		5.25	5.25	5.25
NEC	C		5.25, 12	5.25	
NKK	O,P			5.25	5.25
Pioneer	O,P	4.72			
Ricoh	C		5.25	5.25	
Sony	C,O		12	12	
European Manufacturers (5)					
ATG Gigadisc	O		12		
DSM	O,C		5.25, 12	12	5.25, 12
K+S	O,P		5.25		
Laser Magnetic Storage	O,P		12		
NSM	O	4.72			

Numbers in table are diameters in inches.

TECHNICAL REVIEW

After several years of only slow improvements in optical disk drive technology, in 1991 and early 1992 there appeared a number of changes that should have a beneficial impact upon optical storage. These include improvements in form factor, packaging, capacity and performance. 128 megabyte 3.5" drives are available from several sources. IBM and Sony have jointly proposed a double capacity format for the 5.25" magneto-optic drives, and Sony has announced a 2.5" audio-oriented drive that has potential as a computer peripheral device. Fujitsu has announced the first 5.25" optical drive operating at 5,400 RPM, and also a 1 inch high 3.5" drive. CD-ROM drives with doubled spin rate and data transfer rate have been announced, and the first CD-write-once drives are beginning to ship.

Despite these gains, 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.
* Lack of high function integrated chips to do specialized coding, compression, or other signal processing functions.
* High drive and media prices.
* Incompatible physical and recording standards, preventing media interchange between systems.
* Low mass head design for improved performance and cost.
* Susceptibility to hostile environments, especially dust.
* Need for direct overwrite for magneto-optic drives and media.
* Incompatibilities between optical drives and optical libraries.
* Repackaging of drives into smaller industry standard form factors.

While year to year improvements in optical disk drive and library capabilities are being made, optical storage is still 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, better performance with 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.

Optical disk technology and applications

Three types of optical disk drives used as computer peripheral devices 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" proprietary 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 sold in the U.S. Toshiba has begun to market an ISO format 3.15" CD-ROM drive using media capable of storing 180 to 200 megabytes of data.

  In read-only recording, the disk is normally mass produced using a stamping process to impress the data upon the surface of the disk. The stamping master is produced using techniques analogous to those for making semiconductor masks. The sputtered aluminum surface onto which the master is impressed will vary its reflectivity in accordance with the data pattern. When scanned by a laser beam, the reflected rays carry a signal pattern which is processed within the drive to obtain the data content of the signal. Processing includes error correction and may include decompression if audio or video data is present.

  Because mass production of read-only optical disks is done by a mastering and mass replication process, rather than by recording directly on the disk, the cost per disk can be low, usually under a dollar per disk. However, 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. Additional standards proposals covering CD-WO are being prepared by the Frankfurt group, an ad hoc industry committee convened for that purpose.

  CD-ROM technology borrows heavily from the designs of 4.72" CD audio players now in volume production, so while drive costs are relatively low, performance is relatively slow. Inexpensive plastic lenses and low power lasers are commonly used. However, recently announced CD-ROM drives from NEC and Philips have doubled the RPM and the data transfer rate in order to support realtime full motion video output. Pioneer announced a quadrupling of RPM and data transfer rate in early 1992. Despite these improvements, average access time is still typically between 200 and 300 milliseconds, and is in the range of a second for the least expensive drives used for games.

Except for CD-ROM, the few other optical read-only (OROM) solutions offered have not met with success. Read-only memory formats include OROM capability on 3.5" and 5.25" and 12" media, but only the 3.5" format seems to be getting serious consideration. These are expected to be used as vehicles for software distribution and multimedia presentations as drive and media prices decline in the future. An alternate technology based upon the capacitive playback scheme developed by RCA for its videodisk system is also being developed, but is still in the startup stage.

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 as a result of the activities of the Rock Ridge group.

* Nonreversible optical disks: The first optical disk recording systems to enter the market were "nonreversible" 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 up to 10 gigabytes on a single removable disk. CD-WO drives, still costing over $5,000, have potential to eventually provide inexpensive write-once disks with 500 to 600 megabytes of storage.

  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 (known as Continuous Composite WORM, or CCW, or MO-WORM) achieved using magneto-optic media, which is normally rewritable, prestamped 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. However, high performance rewritable drives using CCW media can provide some improvement in write-once performance.

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 media suppliers specify a 30 year lifetime and claims of lifetimes exceeding 50 years are starting to appear. 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 offer capacities per disk in the range of 300 megabytes to over 10 gigabytes. The smaller capacity 5.25" products are being marketed as OEM drives for use in small systems and optical libraries; larger capacity drives are being used in captive systems and in optical libraries 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 or desire nonreversibility. These niches do exist and the low cost per byte of optical storage 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 that have entered 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: Magneto-optic (M-O) recording is the most commonly used rewritable technology, but rewritable phase change is also in use. Dye-polymer materials can also exhibit rewritability, but no such material has yet been developed to the point where it can compete with M-O or phase change recording.

  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 Electric 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 ceased operations, but licensed the technology to Teijin, where further development is occurring. Tandy has not given any indication of a completion date for its development project.

  Very high capacity rewritable drives require the availability of larger diameter rewritable media, which is difficult to fabricate with adequate yields within the current state of the art. The first 12" rewritable drive, with 2 gigabytes per side, was announced by Nikon in late 1991. However, improvements are being made in 5.25" drives and media as well. Sony has announced anticipated shipments of 5.25" drives with 650 megabyte per side capacity in late 1992, and other companies, including Hewlett-Packard and Hitachi have expressed interest in producing drives with over 1 gigabyte per side capacity. Maxoptix is currently shipping drives with 500 megabyte per side capability.

  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.

  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. Because the polarization shift is small, it is harder to get adequate signal to noise ratios with M-O media than it is with other types of media.

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 and Fujitsu has announced a 5,400 RPM model) 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 late 1993. 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 noncrystalline 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 is shipping phase change drives and media with over 100,000 cycles capability, so this segment of the market seems within the grasp of the technology. Phase change media also has the advantage of offering direct overwrite, a current limitation for M-O drives and media. Also, the drive does not require the bias magnet required in M-O drives.

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.

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.

* 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, 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. Drive design should also minimize the formation of dust during cartridge insertion and withdrawal and avoid dust ingestion from external sources.

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, although IBM's 1992 announcement of library subsystem use as a virtual 3390 model 2 may influence the industry to provide stronger mainframe support.

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.

* Backward compatibility: As new generations of drives and media are developed, the need to remain backward compatible with previous versions is becoming a critical issue for end users who have developed large libraries of media and do not want to have to invest in new media or conversion efforts as the result of moving to new drive technology. The need for backwards compatibility is also a problem for drive designers, who may have to sacrifice otherwise feasible performance and capacity gains in order to satisfy the compatibility criteria.

* 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 posi-

tion 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 and, therefore, the seek time.

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 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. Other head component integration 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. The faster 5.25" optical disk drives have reached the 10 megabit per second data transfer rates of small rigid magnetic disk drives.

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 at room temperature 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.

An anticipated near-term improvement is an AlGaInP laser with a wavelength of about 680 nanometers, compared to the commonly used AlGaAs 780 nanometer devices of today. Production volumes of the improved lasers are expected in late 1993, and this should result in an areal density improvement by a factor of about 1.4. These devices were available in sample quantities from Matsushita Electric in mid-1992 for about $700.

* Recording disks: Media has been an area of major challenge, especially for magneto-optic media, which requires many complex processing steps. Media suppliers were not prepared for the rapid ramp up in rewritable drive production that began in late 1988. There were 5.25" magneto-optic media shortages in 1989 due to yield problems, but these have abated as a result of additional production capacity and improved yields. Some media shortages of 3.5" magneto-optic disks were observed in 1991 but abated in 1992. 12" write-once and 14" write-once media are now obtainable in adequate quantities, although there is little standardization. 12" rewritable media is available from Nikon, but 14" media is still experimental. 3M has supplied some 14" rewritable media in small quantities. Yields for 12" or 14" magneto-optic media are low because of the large surface area that must be sputtered for each layer.

  Most read/write optical disks made to date use complex multilayer 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. Small amounts of niobium added to the usual rare earth-transition metal alloys used for magneto-optical media give some promise of reducing the corrosion sensitivity of magneto-optic disks.

At present, there is overcapacity 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 preformatting 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 interchange 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, although not all are media problems.

There is considerable potential for 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 stability 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 uses.

Most of the substrates used so far have been plastic. However, the ability of glass to provide smoothness, freedom from distortion 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 high performance 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, although there are doubts it will function properly at high RPM. It remains to be seen if high performance computer peripherals can use this design technique effectively.

Media life is a declining 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 favored 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. The Sony/IBM high capacity proposal specified a 1.4 micron track pitch, or about 18,000 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.

* Semiconductor Logic: Because the shipments of optical drives are small, integration of the electronics for read/write drives into single chips or chip sets has been slow to occur. However, some chips, such as the AMD

optical disk controller announced in 1992, are starting to appear. The net effect will be to reduce cost, power requirements and packaging size. Optical drives have yet to take advantage of the new 3.3 volt logic now becoming available. The relatively high masses that must be moved and the rapid spin-up and spin-down times desired may make it impractical to use 3.3 volt power in high performance drives.

* 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, and one firm, Fujitsu, announced a one inch high 3.5" drive in 1992. 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 have also shown CD format write-once systems. At the 1992 Microsoft CD-ROM conference, Philips and JVC made preliminary announcements of write-once drives.

  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 and desk top 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 tabletop 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. Many drives now have the SCSI controller embedded within the standard drive package, eliminating the need for a separate controller card.

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. Some drives, such as the Maxoptix RXT-HD, incorporate internal data compression and decompression as well as error correction.

  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 data base 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 seamlessly integrate optical libraries to mainframe computers.

* 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. The new drives that spin the disks at higher RPM do not impact standards for the media. However, proposals for double density CD-ROM media are not likely to be well received because they would create incompatibility problems with the installed base of drives and with present disk replication equipment.

The UNIX community is 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 coexistence 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. The Rock Ridge group, an ad hoc working group formed by companies with UNIX interests, completed specific recommendations for ISO 9660 extensions in 1991. The Frankfurt group, a similar body, has prepared standards proposals for CD-WO. ISO 9660 is incorporated within this proposal, as is capability for incremental writes.

Multimedia formats are an area of standards conflict. Three primary approaches now contend in the marketplace: CD-I, DVI, and CDTV, as well as proprietary proposals from various companies.

In early 1986, Sony and Philips released the CD-I (Compact Disc-Interactive) specification 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 few commercial 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, but such a standard probably won't 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. 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 complete. The 3.5" standard (ISO draft standard 10090) based on CCS is all but finally approved as of mid-1992, 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. The rewritable standards effort has focussed heavily upon magneto-optic recording and has not yet taken on a standard for rewritable phase change. ISO draft standard 11560, covering MO-WORM, is currently being considered by various standards bodies. It may be approved by late 1992.

While IBM products frequently set de facto standards, IBM's early interest and activity in the optical storage area was too weak to override the formal standards activities. Currently IBM is very active within X3B11 in the formulation of the 3.5" standards and the next generation 5.25" standards. IBM pressed strongly for inclusion of read-only capability on 3.5" media, suggesting strong interest in software or document distribution. With the announcement of IBM's own 5.25" rewritable drives, and particularly with the joint IBM/Sony high capacity proposal, IBM is influencing standards on both a de facto and formal level.

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 firms haven't shown much interest in a 12" optical disk standard.

As a result of criticism of the slow pace of standards generation, the various national standards committees are using a fast-track approach to standards making that was created by ECMA. While not providing the intensive peer review of the full formal process, it helps speed up standards generation where fundamental technical issues are not involved.

* 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 can produce 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 using 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

The other technologies which compete with optical storage are in a continuous state of evolution, constantly improving capacity, performance, quality, form factor, lower power, greater functionality and other key parameters. Even if optical drives were today able to compete strongly against alternate technologies, 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. Some optical disk drives are achieving 3,600 RPM rotation rates and one has reached 5,400 RPM, while magnetic drives are routinely moving to 5,400 RPM at the high end of the performance range. Furthermore, magnetic drives do not require a separate erase pass. 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 in volume production from Brier Technology and Insite Peripherals. Iomega will begin in mid-1992. Several Japanese firms are also expected to produce floppy drives with capacities of 20 megabytes or more 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

* Optical cards: Three companies have announced optical cards: Drexler Technology Corporation, Optical Recording Corporation, and NTT. 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. Capacity is 2.86 megabytes when formatted and with error correction. 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. No product has yet gone into production.

  In addition, Toppan Printing Company, Sony, Canon and Dai Nippon Printing announced alternate formats, but these did not have the momentum of the Drexler-led effort, and of these, Canon's effort has been the only alternate effort to proceed. Canon announced a 4 megabyte reader in 1992. NTT announced development of a 1 megabyte card in late 1991, but no product announcement has yet been made.

  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, and Olympus Optical are sources for Drexler-compatible optical card readers. Lasercard Systems Corporation, a Drexler subsidiary, offers complete optical card based systems using the Conlux drives. As of mid-1992, all producers together had delivered only a few hundred card readers.

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 has prepared a similar standard for use in the United States, with approval expected in 1992. A similar 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 floppy disks 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 portable personal records, 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. 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 start-up company, attempted to develop an optical tape drive using a 50 gigabyte tape cartridge similar in dimensions to the IBM 3480 tape cartridge. The firm ran out of money in 1992 and has ceased operations.

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, but the total number of drives shipped is small.

* Electron Trapping: An approach 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. In its current form, the design requires multiple lasers operating at different wavelengths.

* 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 U.C. approach involves photochromic materials mixed with a polymer material. It must be operated at very cold temperatures for good performance.

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 is being challenged by optical drive based systems, as IBM has introduced rewritable disk based library storage systems supported as virtual 3390 magnetic drives.

  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 effects 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.

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.

Noncaptive: 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 noncaptive sales channel.

Example:

* Shipments by Toshiba are noncaptive, 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. The term includes drives and libraries to be connected to systems of all types, including personal computers, minicomputers 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.

Example

* Maxoptix is considered a U.S. manufacturer, even though it 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 1992 constant dollars.

Forecasts: Expected unit 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 in the forecasts.

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

Application classification

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

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 for a single user. Examples: IBM PS/2, Apple Macintosh, Compaq Deskpro.

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.

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

Consumer and hobby systems: Systems sold primarily to consumers for nonbusiness applications. Examples: Sony Data Discman, NEC PC engine, most Atari models. 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

1992 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
Hitachi	CDR 1700S, CDR-3600, CDR 3700
Laser Magnetic Storage	CM 205, CM 214
Matsushita Electric	CR-501, CR-521, LK-MC501, LK-MC521
Matsushita Electronic Components	EBP-103, EBP-302, EBP-201
Mitsumi Electric	CMRC-LU0, CRS-UF, CRS-XP
NEC	PC-CD10, PC-CD103, N5267-38
NEC Home Electronics	CDR-37, CDR-83, CDR-84
Philips (Magnavox)	CDD461, CDD401, CDI-601, CDM50
Pioneer	DRM-600/610, DRM-604X
Sanyo	ROM-3000U, ROM-4015, ROM-4026U
Sony	CDU-541, CDU-561, CDU-6100, CDU-7101
Texel (Shinano Kenshi)	DM-3120, DM-3024, DM-5011, DM-5120
Toshiba	XM-3301B, TXM3301

3.15" disk diameter (CD-ROM)

Sony	Data Discman
Toshiba	XM-8100B

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 use 4.72" (12 cm.) or 3.15" (8 cm.) media.

Read-only drives and media are a form of electronic publishing. Data is placed on the disks during a mass replication process analogous to the printing of a book or the stamping of a phonograph record. 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 3,000 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.

In this report, CD audio players equipped with electronics to read CD-ROM formatted disks are counted as CD-ROM drives. Drives of this type are most often used with electronic games or other consumer applications.

Market status

For the first time, shipments of CD-ROM drives substantially exceeded forecast, driven by an increasing number of useful titles, acceptance by personal computer manufacturers and falling prices. Interest in applications employing multimedia is also contributing to strong growth, although there are still few multimedia applications being published. Higher performance is also a reality, with drives operating at double or quadruple spin rates and data transfer rates now becoming available. The market has also clearly fragmented into a high performance, higher price segment and a low performance, economy segment. In 1991, the strongest gains in shipments were in the high performance segment.

Unit shipments more than doubled to over 1.4 million units in 1991, up from 712,800 units in 1990. Revenue leapt 61.4%, from $284.3 million to $458.9 million, but declining prices and product mix kept revenue growth from matching shipment growth. Despite the booming sales, the read-only drive industry is entering a concentration phase, with weaker manufacturers starting to drop out. All read-only drives are made by non-U.S. companies: With the exception of the Philips companies, all of the currently active suppliers are Japanese companies.

Sony introduced a 3.15" CD-ROM in the Data Discman in 1990, and until Toshiba announced a 3.15" drive in 1992, it was the only one in production. As of mid-1992, Data Discman is still the only product to incorporate a 3.15" (8 centimeter) drive. The Sony drive uses a proprietary format, while the Toshiba drive will play disks in the standard CD-ROM format. Other firms are considering introducing a 3.15" drive but have delayed because of an insufficient number of supporting titles and because Data Discman uses a proprietary format.

IBM, Hewlett-Packard, DEC, Sun Microsystems and other firms are using the 4.72" CD-ROM as a means of distributing system documentation or software. An

increasing number of firms, including Sony, Fujitsu and Tandy include CD-ROM as an integral part of some system models, but the majority of drives are still sold in external or add-on configurations. IBM offers a CD-ROM add-on kit for internal installation.

Sony and Matsushita and Toshiba were the leading noncaptive producers in 1991, followed by Hitachi and LMSI. NEC remained the leading captive producer on the strength of sales for its game products.

CD-ROM drives capable of operating with multimedia titles are now entering the marketplace, with such features as embedded XA support, double spin rate and transfer rate to support full screen, full motion video, and improved seek times. CD-I, DVI and CDTV equipment and titles and authoring equipment have become more readily available, but the real explosion in multimedia titles isn't expected until 1993.

Marketing trends

The strong shipment growth in 1991 portends a period of several years in which growth will remain strong. 6.1 million CD-ROM drives are forecasted for shipment in 1995, with revenues expected to jump to $1.01 billion. Shipments of 3.15" drives, about 7.1% of 1991 shipments, are expected to make up 6.6% of unit shipments in 1995. This share would probably be higher except that there will probably be competition after 1993 from the 2.5" Sony Minidisc format that will limit growth of the 3.15" CD-ROM. Lack of titles published in the 3.15" format also hampers shipment growth.

Overall OEM prices are expected to decrease from an average $257 in 1990 to $123 in 1995, 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 eventually obtain a share of the market.

Pricing of titles impacts sales of drives. In some cases, such as the Government Printing Office release of the U.S. legal code on CD-ROM, the cost of subscribing to the disc is so low that users find the subscription plus the cost of a CD-ROM is less than the subscription cost of the paper-based product. This is

an encouraging trend for government publications, where charges are based on production cost, but it seems unlikely to spread to the commercial world, where prices are set more upon the basis of the perceived value of the information, rather than production costs. Nevertheless, the low pricing is one of the reasons that the government sector is moving and will continue to move relatively quickly to embrace CD-ROM.

About 70% of 1995 shipments are projected to be through OEM channels, up from 62% in 1991. Reseller shipments, 16.1% of the 1991 total, will remain nearly flat at 14.3% in 1995. The share of captive shipments is expected to decline 21.1% in 1991 to 14.8% in 1995. 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. Large numbers of games using CD-ROMs are expected to be sold by companies such as Nintendo and Sega beginning in late 1992. NEC has been selling a CD-ROM drive as an option for its PC Engine home computer system for several years. 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. Older CD-ROMs have been advertised by mail order firms at the $200 retail level. OEM prices for low performance CD-ROMs are well under $200. 25.2% of 4.72" drive shipments in 1991 were low-end, increasing to 29.3% of such shipments in 1994. If low-end 3.15" drives are included, the low-end drives were 32.7% of 1991 shipments and will account for 33.4% in 1995. 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, including games and players for the Kodak Photo CD system.

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. Low volume shipments began in 1991 and will reach substantial volume in 1993.

The use of CD-ROM as a vehicle for multimedia data storage is expected to grow rapidly over the next several years. 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, with the Eastman Kodak Photo CD program, introduced in 1992, being the most conspicuous example. Kodak has also demonstrated Photo CD on the DVI system. CDTV, Commodore's consumer oriented CD-ROM multimedia player using still a third format, was introduced formally in the spring of 1991. CDTV is not compatible with the other major multimedia formats.

While CD-ROM sales are expected to benefit from multimedia activities, the multimedia area has been over-marketed to the point where the expectations of many may be equally over-inflated. Until users and suppliers learn what capabilities are really useful in various applications, a process that may take several years, multimedia related growth is expected to be steady but moderate. Game applications will probably be the fastest growing multimedia application area for the next two years.

Applications

Read-only drives are used almost exclusively with micro-based systems, including personal computers, multiple user microcomputers, games and consumer appliances based upon microcomputers. The consumer applications now appear to be the fastest growing area of CD-ROM use. A significant new application is in the Eastman Kodak Photo CD program, which converts photographic images to video files on a CD-WORM, creating a write-once recording in the CD-ROM format that can be played back on CD-ROM drives equipped to handle the multi-session recording format used.

Individual personal computers, accounted for 40.0% of drive unit shipments in 1991. Consumer computer and other applications, notably games such as the NEC PC Engine, accounted for 21.4%. In 1995, consumer applications, led by entertainment, education and automotive uses, are expected to be the largest application area, with 38.9% of the units sold. Single user business computers will follow, with 24.9% of the shipments in 1995. While it is still unusual for computer manufacturers to deliver systems with CD-ROMs built in, Apple will be

delivering MacIntosh computers with built in multimedia-capable drives in 1992, as will some PC clone makers.

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 storage 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 began in 1991, volume is expected to build only gradually in 1992, with 1993 being the first year of significant shipments.

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. A negative factor impacting the 3.15" format is that all of the CD-ROM firms mastering the 3.15" format are in Japan, so there is less incentive for U.S. publishers to use the 3.15" CD-ROM format.

The published content of a CD-ROM can be of broad general interest, such as an encyclopedia, dictionary or 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, construction or automotive 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, computer manuals, company procedure manuals and all types of reference works. Video and audio data bases containing static images (clip art), video sequences and sound sequences are also available.

Government use of CD-ROM has expanded rapidly because CD-ROM use permits major savings in printing, inventory and distribution costs. Information retrieval is also vastly more efficient by electronic means. In some cases, it has been possible to make government statistics and documentary information available to the general public that was not previously available due to the cost of dissemination. Where CD-ROM is used to distribute libraries of forms, the process of updating the forms is simpler because only a new disk needs to be sent and the number of obsolete forms discarded can be reduced.

The CD-ROM most widely distributed within the U.S. government concerns the management of hazardous materials. This disk is currently distributed to over 7,000 sites.

A few companies, including Sun Microsystems and Hewlett-Packard have begun distributing software and documentation on CD-ROM as part of a major effort to reduce costs and improve service to customers. A few CD-ROM disks containing software are also available from independent publishers.

Other than consumer oriented applications, applications for CD-ROM titles tend to be vertical market oriented. So far, there has been no broadly based application (such as spreadsheets or word processing) that has successfully spanned a broad range of industries or markets. A wildly successful application with a universal market seems unlikely, and the most probable outlook is for CD-ROM to succeed through moderate sales of large numbers of niche-oriented applications. Use within companies with internally generated applications will continue to produce significant demand for CD-ROM drives.

Education and industrial training are current areas of applications strength for CD-ROM, and these segments will be early and significant users of CD-ROM multimedia capabilities in the future. In the consumer area, games and the Kodak Photo CD effort seem most likely to develop as large scale applications of CD-ROM and multimedia technology.

Photo CD applications will probably develop in the industrial photography area at a faster rate than in the consumer area, but the consumer market is potentially larger in the long run. Another effect of the Photo CD effort will be to create a de facto standard for communicating images between personal computers and television monitors. Whether Photo CD achieves success or not, it will influence the direction of writable CD recording standards.

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 1995, larger systems, including file servers, are expected to absorb 10.1% of the units sold. This is a decline from 19.5% in 1991 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.

CD-ROM is finding a market in on-board mapping systems for vehicle navigation and dispatching 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 being 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, but significant product differentiation in terms of performance and embedded features is starting to appear. The areas receiving the most attention are:

Multimedia support: 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. Newer drives have embedded XA capability. Older CD-ROM drives are not able to operate with the XA format and will need modification or special adapters. An interesting trend is the inclusion of CD-ROM drive interfaces on sound

synthesizer cards for IBM PC compatible computers. However, these interfaces often support only the CD-ROM drives of a particular supplier.

Capacity: A few companies have been investigating expansion of CD-ROM recording capacity to two or three times the current level. Because of the perceived need to retain reading compatibility with the existing disk format, these efforts have been slow to bear fruit and higher capacity drives and disks, though desirable, are not anticipated in the next three year period except, possibly, as technology announcements. A major obstacle is the investment and time that will be required to upgrade mastering facilities to be able to produce any new high capacity format.

New Vision Technologies, a start-up firm, is developing CE-ROM, a high capacity format based upon the capacitive effect playback technology used originally by RCA in its video recorders. Development objectives include a threefold capacity improvement and a tenfold improvement in data transfer rate compared to the standard CD-ROM drive. If successful, the drives enhanced capabilities might attract support from multimedia publishers and games producers.

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 caddy issue is unlikely to impact the low performance drives . Because of cost pressures, game machines and other consumer oriented CD-ROM designs will do away with the caddy and use top loading or drawer loading designs. However, the reliability and avoidance of handling damage provided by caddies is expected to make them a necessity in high end drives used with file servers. Jukebox designers may find the caddy easier for the picker mechanism to handle than unprotected disks.

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 extended the 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 has prepared proposals to that end. The standards for CD-ROM are currently being extended to accommodate disks written using the new multisession recording standard.

Standards for motion video compression being worked out by MPEG (Motion Picture Experts Group) are expected to be formally adopted in 1992 for CD-I, with the first MPEG decoder chips available in 1992. The more complex encoder chip sets are expected to make their appearance by mid-1993. 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. These standards, while important for multimedia software generally, will apply regardless of the storage device used.

Related standards issues may 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 required.

Performance: Average access times, which decreased below the .5 second range in 1986 have dipped well under 400 milliseconds since 1989 and are now breaching the 300 millisecond barrier. Further gains in seek time without raising cost significantly are difficult. Users will get faster data transfer rates, especially when multimedia is used, but as the data format is fixed, by means of faster rotation rates. Several firms have announced drives with at least double the current data transfer rate, with the improvement in performance achieved by doubling the rotation rate. Pioneer has made a preliminary announcement of a quadrupled rate drive.

Software: Development of software to support use with major operating systems and application programs, such as text search and the spectrum of multimedia applications, continues. While drivers are available for support of CD-ROM on most computing platforms, specific combinations of drives, operating systems and drivers still exhibit incompatibilities.

Cost reduction: Cost reduction programs are continuing. Plastic molded lenses, for instance, have replaced polished glass lenses. In some low performance drives, stepping motors are used rather than more expensive positioning methods.

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 frequently mounted externally to the desktop computers and internally in tower configurations.

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 nonexperts prepare

multimedia titles. The advent of write-once CD drives will lead to the product offerings including all software and hardware tools needed to produce the playable disk.

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. A few firms (Kubik and Pioneer) 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 began appearing in 1990 and 1991 from Toshiba, Mitsumi and others.

There is also concern about the long term stability of the disks. Accelerated environmental testing shows a wide variety of resistance to temperature and humidity, with the major variation the result of imperfect sealing of the protective layer of the disk, especially at the edges.

Writable CD: Writable CD-format media and systems are expensive but are becoming more readily available. Philips, Sony, Yamaha and JVC currently are shipping drives, usually as part of a complete mastering system. Some companies are exploring rewritable CD-ROM format 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 with CD-ROM drives unlikely.

Forecasting assumptions

1. CD-ROM drive production capability will be able to meet demand throughout the forecast period. The form factor will fit within the 5.25" half high standard. Production of the 3.15" form factor drive by firms other than Sony will not occur before late 1992.

2. The ISO formatted disk interchange standard for CD-ROM will continue to be accepted by drive manufacturers and publishers. Multisession capability will be incorporated in most new CD-ROM models by late 1993.

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 consumer segment, including games, home systems, and automotive will resume strong growth in late 1992.

5. There will be no significant shipments of expanded capacity CD-ROM drives during the forecast period.

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 1995.

7. The CD-I format will impact primarily the home and education markets. Production hardware will appear in the latter part of 1992 but 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 late 1992, and the first year of 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 for CD-ROMs to be used with mainframe and minicomputer systems. Small libraries attachable to individual personal computers or freestanding workstations will continue to be available.

10. There will be only minor impact on CD-ROM shipments from the Sony 2.5" minidisk or other unannounced low-end optical drives until 1995.

1992 DISK/TREND REPORT

TABLE 17

READ-ONLY OPTICAL DISK DRIVES, ALL CAPACITIES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1991 Revenues		Forecast 1992		1993		1994		1995	
	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. NONCAPTIVE	--	--	--	--	--	--	--	--	--	--
TOTAL U.S. REVENUES	--	--	--	--	--	--	--	--	--	--
Non-U.S. Manufacturers										
Captive	8.3	118.2	12.2	159.0	22.2	194.0	28.5	211.7	34.0	213.3
PCM/Reseller	78.4	109.0	98.6	144.4	123.6	188.0	144.0	228.3	159.6	261.9
OEM/Integrator	162.9	231.7	241.2	322.8	295.5	412.5	340.5	488.2	367.7	538.7
TOTAL NON-U.S. REVENUES	249.6	458.9	352.0	626.2	441.3	794.5	513.0	928.2	561.3	1,013.9
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	249.6	458.9	352.0	626.2	441.3	794.5	513.0	928.2	561.3	1,013.9
OEM Average Price ($000)		.257		.219		.182		.150		.123

TABLE 18

READ-ONLY OPTICAL DISK DRIVES, ALL CAPACITIES

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1991		Forecast							
	Shipments		1992		1993		1994		1995	
	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. NONCAPTIVE	--	--	--	--	--	--	--	--	--	--
TOTAL U.S. SHIPMENTS	--	--	--	--	--	--	--	--	--	--
Non-U.S. Manufacturers										
Captive	23.9	303.1	40.1	493.9	76.0	681.8	107.9	817.2	151.4	918.5
PCM/Reseller	168.9	231.5	231.7	339.6	325.7	495.8	426.5	678.5	537.9	885.7
OEM/Integrator	565.7	900.5	1,052.5	1,471.5	1,524.7	2,263.6	2,098.2	3,263.6	2,749.4	4,377.4
TOTAL NON-U.S. SHIPMENTS	758.5	1,435.1	1,324.3	2,305.0	1,926.4	3,441.2	2,632.6	4,759.3	3,438.7	6,181.6
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	758.5	1,435.1	1,324.3	2,305.0	1,926.4	3,441.2	2,632.6	4,759.3	3,438.7	6,181.6
Cumulative Shipments (Units in thousands)										
IBM	--	--	--	--	--	--	--	--	--	--
Non-IBM	1,533.6	3,085.0	2,857.9	5,390.0	4,784.3	8,831.2	7,416.9	13,590.5	10,855.6	19,772.1
WORLDWIDE TOTAL	1,533.6	3,085.0	2,857.9	5,390.0	4,784.3	8,831.2	7,416.9	13,590.5	10,855.6	19,772.1

TABLE 19

READ-ONLY OPTICAL DISK DRIVES, ALL CAPACITIES

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1991 Revenues			Forecast											
				1992			1993			1994			1995		
	4.72" H	4.72" L	3.15"	4.72" H	4.72" L	3.15"	4.72" H	4.72" L	3.15"	4.72" H	4.72" L	3.15"	4.72" H	4.72" L	3.15"
U.S. MANUFACTURERS															
TOTAL U.S. REVENUES	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
NON-U.S. MANUFACTURERS															
Captive	10.1	75.0	33.1	11.2	100.8	47.0	13.4	119.8	60.8	16.5	129.7	65.5	20.7	139.0	53.6
PCM/Reseller	95.1	13.9	--	129.7	14.7	--	175.1	12.9	--	216.9	11.4	--	251.4	10.5	--
OEM/Integrator	215.1	16.6	--	301.3	21.2	.3	377.1	33.7	1.7	421.4	59.2	7.6	433.3	90.3	15.1
TOTAL NON-U.S. REVENUES	320.3	105.5	33.1	442.2	136.7	47.3	565.6	166.4	62.5	654.8	200.3	73.1	705.4	239.8	68.7
WORLDWIDE RECAP															
Captive	10.1	75.0	33.1	11.2	100.8	47.0	13.4	119.8	60.8	16.5	129.7	65.5	20.7	139.0	53.6
	-34.0%	+16.5%	+75.1%	+10.9%	+34.4%	+42.0%	+19.6%	+18.8%	+29.4%	+23.1%	+8.3%	+7.7%	+25.5%	+7.2%	-18.2%
PCM/Reseller	95.1	13.9	--	129.7	14.7	--	175.1	12.9	--	216.9	11.4	--	251.4	10.5	--
	+1.7%	-3.5%	--	+36.4%	+5.8%	--	+35.0%	-12.2%	--	+23.9%	-11.6%	--	+15.9%	-7.9%	--
OEM/Integrator	215.1	16.6	--	301.3	21.2	.3	377.1	33.7	1.7	421.4	59.2	7.6	433.3	90.3	15.1
	+157.0%	--	--	+40.1%	+27.7%	--	+25.2%	+59.0%	+466.7%	+11.7%	+75.7%	+347.1%	+2.8%	+52.5%	+98.7%
Total Revenues	320.3	105.5	33.1	442.2	136.7	47.3	565.6	166.4	62.5	654.8	200.3	73.1	705.4	239.8	68.7
	+66.4%	+33.9%	+75.1%	+38.1%	+29.6%	+42.9%	+27.9%	+21.7%	+32.1%	+15.8%	+20.4%	+17.0%	+7.7%	+19.7%	-6.0%
ANNUAL SHARE, BY DIAMETER	69.9%	23.0%	7.1%	70.7%	21.8%	7.5%	71.3%	20.9%	7.8%	70.6%	21.6%	7.8%	69.7%	23.7%	6.6%

Note: 4.72" H are high performance drives with average seek time of 500 ms. or less.
4.72" L are low performance drives with average seek time of more than 500 ms.

TABLE 20

READ-ONLY OPTICAL DISK DRIVES, ALL CAPACITIES

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DISK DIAMETER

	1991 Shipments			Forecast 1992			1993			1994			1995		
	4.72" H	4.72" L	3.15"	4.72" H	4.72" L	3.15"	4.72" H	4.72" L	3.15"	4.72" H	4.72" L	3.15"	4.72" H	4.72" L	3.15"
U.S. MANUFACTURERS															
TOTAL U.S. SHIPMENTS	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
NON-U.S. MANUFACTURERS															
Captive	10.0	183.0	110.1	12.0	325.0	156.9	15.0	460.8	206.0	19.4	563.8	234.0	25.6	637.9	255.0
PCM/Reseller	204.5	27.0	--	309.5	30.1	--	460.9	34.9	--	637.9	40.6	--	838.2	47.5	--
OEM/Integrator	749.5	151.0	--	1,297.5	173.0	1.0	1,933.7	323.9	6.0	2,569.2	665.4	29.0	3,186.1	1,128.3	63.0
TOTAL NON-U.S. SHIPMENTS	964.0	361.0	110.1	1,619.0	528.1	157.9	2,409.6	819.6	212.0	3,226.5	1,269.8	263.0	4,049.9	1,813.7	318.0
WORLDWIDE RECAP															
Captive	10.0	183.0	110.1	12.0	325.0	156.9	15.0	460.8	206.0	19.4	563.8	234.0	25.6	637.9	255.0
	-10.7%	+56.4%	+25.1%	+20.0%	+77.6%	+42.5%	+25.0%	+41.8%	+31.3%	+29.3%	+22.4%	+13.6%	+32.0%	+13.1%	+9.0%
PCM/Reseller	204.5	27.0	--	309.5	30.1	--	460.9	34.9	--	637.9	40.6	--	838.2	47.5	--
	+9.0%	-22.9%	--	+51.3%	+11.5%	--	+48.9%	+15.9%	--	+38.4%	+16.3%	--	+31.4%	+17.0%	--
OEM/Integrator	749.5	151.0	--	1,297.5	173.0	1.0	1,933.7	323.9	6.0	2,569.2	665.4	29.0	3,186.1	1,128.3	63.0
	+173.6%	--	--	+73.1%	+14.6%	--	+49.0%	+87.2%	+500.0%	+32.9%	+105.4%	+383.3%	+24.0%	+69.6%	+117.2%
Total Shipments	964.0	361.0	110.1	1,619.0	528.1	157.9	2,409.6	819.6	212.0	3,226.5	1,269.8	263.0	4,049.9	1,813.7	318.0
	+103.9%	+137.5%	+25.1%	+67.9%	+46.3%	+43.4%	+48.8%	+55.2%	+34.3%	+33.9%	+54.9%	+24.1%	+25.5%	+42.8%	+20.9%
ANNUAL SHARE, BY DIAMETER	67.3%	25.2%	7.5%	70.3%	22.9%	6.8%	70.1%	23.8%	6.1%	67.9%	26.7%	5.4%	65.6%	29.3%	5.1%

Note: 4.72" H are high performance drives with average seek time of 500 ms. or less.
4.72" L are low performance drives with average seek time of more than 500 ms.

TABLE 21

READ-ONLY OPTICAL DISK DRIVES, ALL CAPACITIES

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1991 Estimate Units (000)	1991 Estimate %	1995 Projection Units (000)	1995 Projection %
MAINFRAME/SUPERMINI General purpose	21.0	1.5	6.2	.1
MINICOMPUTERS AND MULTIUSER MICROS Business and professional, including networks	280.8	19.5	624.3	10.1
PERSONAL COMPUTERS Business and professional, single user	574.0	40.0	1,539.3	24.9
OFFICE SYSTEMS AND WORKSTATIONS Dedicated application	54.0	3.8	136.0	2.2
NON-OFFICE SYSTEMS AND WORKSTATIONS Technical, distribution, medical, other specialized	147.5	10.3	1,193.0	19.3
CONSUMER AND HOBBY COMPUTERS	307.1	21.4	2,404.6	38.9
OTHER APPLICATIONS	50.7	3.5	278.2	4.5
Total	1,435.1	100.0	6,181.6	100.0

TABLE 22

READ-ONLY OPTICAL DISK DRIVES, ALL CAPACITIES

MARKET SHARE SUMMARY
Worldwide Shipments of Noncaptive Disk Drives

	1991 Net Shipments					
	To United States Destinations			Worldwide		
	Units (000)		%	Units (000)		%
Drive Manufacturers	4.72"	Total		4.72"	Total	
Sony	252.7	252.7	34.4	304.8	304.8	26.9
Matsushita Elec. Ind.	79.0	79.0	10.8	266.2	266.2	23.5
Toshiba	131.8	131.8	17.9	147.2	147.2	13.0
NEC	90.0	90.0	12.3	126.0	126.0	11.1
Hitachi	71.8	71.8	9.8	101.5	101.5	9.0
Other U.S.	--	--	--	--	--	--
Other Non-U.S.	109.3	109.3	14.8	186.3	186.3	16.5
TOTAL	734.6	734.6	100.0	1132.0	1132.0	100.0

Note: Matsushita Electric Industrial shipments include shipments from Matsushita Electronic Components.

READ/WRITE OPTICAL DRIVES LESS THAN 1 GIGABYTE

1992 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

ATG Gigadisc	GD 90-MO (E)
IBM	MD 3125B (E)
Matsushita Electric Industrial	LF-3100 (E), LF-3104 (E)
Mitsubishi Electric	ME-3E1 (E)
MOST	RMD 5100-S (E),RMD 5200-S (E)
NEC	PC-OD301 (E)
Olympus	MOS300E (E)
Sony	SMO-D301 (E)
Teac	OD-3000 (E)
Toshiba	OD-D300 (E)

4.72" disk diameter

JVC	XR-W1001
Philips Consumer Electronics	CDD521
Sony	CDW-W1, CDW-900E
Yamaha	YPR-1

5.25" disk diameter

Canon	MO-5001S (E), OM-500D (E)
Cherokee Data Systems	CR6000, CR6800
Fujitsu	M2507B (E), M2511A (E)
Hewlett-Packard	C1716C (E), C1716A (E)
Hitachi	OD 101-1, OD-112-1 (E)
Honeywell	AN/MU-928
IBM	0632 (E)
Kawasaki Steel	KL1200S
Laser Magnetic Storage	510
Literal	525 GB, 525 GBX2, I-525MF (E)
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, CS-1000 (E)
NEC	PC-OD102, N7915 (E)
Pioneer	DD-M5101, DE-U7001 (E)
Ricoh	RO-5043, RO-5042 (E), RO-5031E (E)
Sharp	JY 700 (E), JY-750 (E)
Sony	SMO-E501 (E), SMO-E511 (E)

(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, CD-WORM) also fits into this category. Multi-function drives capable of using either rewritable or write-once media are considered rewritable drives for purposes of this report. Multifunction drives (MO-WORM) 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.

Note that this year's report has separate disk diameter shipment and revenue tables for write-once and rewritable drives.

Market status

1991 was not a particularly good year for this segment of the optical drive industry. 5.25" write-once drive shipments actually declined for the first time, although growth for 5.25" rewritable drives continued. Unfavorable economic conditions depressed overall sales growth, and while 1992 is expected to be better, 1990 was probably the peak year for 5.25" write-once shipments, which will be increasingly impacted by 5.25" multifunction drives.

Shipments of 3.5" drives were especially disappointing. While several firms joined the ranks of 3.5" drive manufacturers, they had little impact on sales. The reasons for the poor showing include: Later than anticipated introductions and deliveries, excessive price coupled with lackluster performance, some reliability problems, media interchange problems, lack of published titles for the 3.5" OROM format and IBM's lukewarm support of the product. Moderate success has been achieved in the Apple MacIntosh add-on market, where there is less price sensitivity.

Unit shipments reached 214,500 units, up only 15.7% from 1991. Write-once drive shipments declined 18.2% to 43,800 units, but this decline was offset by a

29.5% increase in shipments of rewritable drives. To some extent, write-once shipments were hurt by sales of multifunction drives, but the major impact of the multifunction drive will come in 1993 and later as sales of MO-WORM drives begin to accelerate.

Sony, Ricoh, and Matsushita Electric again were the leading producers. Matsushita remains the leading manufacturer of write-once drives, while Sony continues as the leader in rewritable drives. Rewritable drive shipments again outnumbered write-once drive shipments with rewritable drives claiming 79.6% of unit shipments, up about 8% from 1991. 90.1% of the rewritable drives shipped in this product group were 5.25" drives, although 3.5" drives are expected to account for nearly 47% of sales in 1995. This gain is the result of anticipated lower prices, higher capacity, and improved performance.

1991 worldwide revenues increased 22.5% to $585.4 million, with all of the gain coming from sales of rewritable drives. U.S. firms accounted for 11.7% of 1991 revenues, up from 8.4% in 1990. The U.S. market accounted for 48.3% of worldwide revenues in 1991, up slightly from 47.1% in 1990.

Marketing trends

Strong growth for 5.25" rewritable drive shipments is anticipated through 1995. Shipments of 5.25" write-once drives are projected to recover a bit this year due to an improved economy, but are expected to weaken after 1992 as multifunction drives become more accepted.

Demand for 128 megabyte 3.5" rewritable drives will grow, though many system producers will find their benefits marginal until prices come down or packaging, performance (especially data transfer rate) and capacity improve. Demand for the 256 megabyte products now entering the market will be modest until there is some level of industry consensus on media and drive standards for second generation 3.5" drives.

The forecasted growth in 3.5" erasable drive shipments results from price competition due to an increasing number of sources, the positive influence anticipated from IBM's endorsement of the technology, expected capacity and performance improvements. Growth could be even larger if OEM prices, initially

exceeding the $800 level, drop to the $400 level to allow optical drives to compete more effectively with small tape drives and other removable products such as SyQuest's 3.5" 105 megabyte removable cartridge magnetic drive.

Sales of MO-WORM have grown slowly because most customers interested in write-once technology are already committed to previous technologies and have little incentive to change. However, new customers for write-once applications are more likely to choose MO-WORM, because it will share cost decreases and capability increases with rewritable M-O media. The impact of shipments to new customers should become more apparent as economic conditions improve.

For the total product group, 331,900 units are expected to ship in 1992, growing to 930,000 units in 1994. Rewritable drives are expected to account for 91.3% of shipments in 1995, of which 46.9% will be 3.5" and 53.1% will be 5.25" units. Only 8.7% of the forecasted 1995 total will be write-once units, and the majority of these, 52.3%, are expected to be 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.

The 4.72" write-once drive is a 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. JVC has announced 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. Sony and Philips have announced 4.72" write-once drives that will be used in the Eastman Kodak Photo CD program and other multi-session recording applications. 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.

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 1994. 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 average capacity of drives in this product group is expected to substantially expand over the next several years. Optical library users, in particular, desire expansion of 5.25" media capacity to 3 or 4 times the current 327 megabytes per side offered by most drives today. Even a doubling would be attractive, and this is likely within a year. A tripling of capacity, probably to over a gigabyte per side, is likely before the end of 1994, assuming development of red diode lasers stays on schedule, and such drives will begin to slow sales of the lower capacity 5.25" drives in this product group.

Applications

Write-once and rewritable optical drives under 1 gigabyte are finding applications as save/restore devices in microcomputer and minicomputer systems where extensive 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.

Specific applications for drives in this product group include:

Save/restore operations

* 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.

The faster erasable drives such as the Maxoptix "Tahiti" are finding 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.

3.5" drives are used to provide project oriented storage on a single volume, and are frequently used in desktop publishing environments. They 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.

Personal computers were the largest application for optical drives in this product group in 1991. They accounted for 36.8% of the units shipped, down from 43.3% in 1990. The shares of office workstations and non-office workstations declined to 20.2% and 14.3% respectively, while multiuser systems increased share to 26.1%. The shift is believed to be associated with increased shipments of rewritable drives used for backup on file servers and use in departmental systems supporting image storage applications.

3.5" drives are largely associated with personal computers and will be responsible for a slight increase in the share of drives used with personal computers in 1995. The share of usage by networks will decline lightly, and the share held by dedicated office workstations will also decrease somewhat as personal computers take over some of the functions currently performed by dedicated systems. Technical workstations will slightly increase their share of total optical drive usage, a trend that will be encouraged by the higher capacity drives entering the market in 1993.

About 5% of the production of 5.25" drives in this product group is expected to be used in optical library subsystems, such as those sold by Hewlett-Packard, IDE, Hitachi, NKK and others. Jukebox applications are expected to account for 7% of 5.25" drive shipments in 1995.

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 over 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.

Technical trends

Drive technology continues to improve and the rate of product development for the next few years is expected to accelerate. The key areas of change are reviewed below.

Capacity: Capacity of 5.25" rewritable drives is expected to increase to at least the 650 megabytes per side range in 1993, with some firms propos-

ing 1 gigabyte per side as a possibility in 2 years. Similar improvements in write-once technology are possible. The increases will be due to a combination of factors, including improved optics and shorter laser wavelength permitting smaller spots and higher BPI and TPI, reduction of track pitch from 1.6 microns to 1.4 microns (about a 40% improvement), the adoption of pulse width modulation, zone bit recording, (about a 33% improvement) and variable track pitch (about 40-50% improvement). Changes in encoding methods might also modestly improve capacity. For drives that will be dedicated to image storage, embedded data compression implemented in a single chip or small chip set should be feasible. It is unlikely that all of these possibilities will be implemented on any one drive in the near term, but they are expected to be standard features by 1995. Some of these techniques, such as ZBR, are used on certain optical drives currently in production.

Three different approaches to next generation drives with removable media have been proposed. Sony and IBM have proposed a double capacity version of the standard ISO rewritable format which will have approximately 650 megabytes per media side. Hitachi and Hewlett-Packard are offering a triple capacity version, while Maxoptix is promoting its current 500 megabyte per side as a next generation standard. It is likely that all of these will co-exist: Maxoptix is currently shipping its product, the Sony/IBM product may ship in late 1992, and the Hitachi/H-P approach, which requires pulse width modulation and recording format changes, may be realized in 1994 after technical uncertainties have been resolved. The Sony/IBM approach is derivative from the present standard and should be implemented relatively easily. It is also downward compatible with existing ISO standard magneto-optic media. Some consideration has been given to a quadrupling of current capacity, but this would probably require 680 nanometer semiconductor diode lasers, which are unlikely to be available at reasonable cost until 1994.

The second generation approaches have some things in common, including zone bit recording, use of M-O media, continuous composite servo format, multi-functional design, 1.4 micron track pitch or less, and probably will use 780 nanometer lasers, at least initially. It also seems likely that 3,000 RPM or higher spin rates will be standard.

In addition to removable drives, some companies are developing magneto-optical drives with non-removable media. Fujitsu has produced a few 8 inch diameter products, and 5.25" products offering very high capacity may make an appearance before 1995.

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. A few companies have looked at the possibility of 325 megabytes per side using pulse width modulation. Others are considering the use of double sided 3.5" media. MOST has begun shipments of a 256 megabyte drive, although it uses a unique recording format, and ATG Gigadisc has made a preliminary announcement of a 3.5" 250 megabyte sampled servo drive with 32 millisecond average access time.

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 MO-WORM, 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. It is anticipated that this will gradually become the dominant form of write once recording, but that it will take many years for MO-WORM to displace ablative writing in the installed base of systems.

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. The most challenging problem at present is the elimination of the need for a separate erase pass before writing. Technical problems and uncertainty about adequate yields for the complex media structures required suggest that direct overwrite may not be available on a production basis until mid-1994.

Multifunctionality can 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. This has been embodied in ISO draft standard 11560.

Magneto-optical techniques are not the only 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 to over one million cycles.

Phase change media permits the interchange of write-once and erasable media on a single drive. It also provides direct overwrite capability and may permit simpler drive designs than for M-O drives. Phase change media as yet does not have specific standards in place, and efforts to create standards have been initiates, although no formal project existed as of mid-1992.

Dye-based media may eventually become commercially significant for erasable optical disks. Still in R&D status, this type of media is potentially 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 for several years. 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 30 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 remain the plastic material of choice because of its relative stability and moisture resistance.

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 holding tight tolerances over a larger area.

Glass is used as a substrate for some media. The material is free of birefringence effects that distort the optical path, is non-permeable to moisture, is flat, and distortion free. 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 laten-

cy in the drive due to the reduced need to perform error correction during data reads. Glass also is less likely to deform at high spin rates, reducing runout and servo tracking difficulties.

Most drive makers are now convinced that glass substrates are safe to use in small diameter drives, although more costly than plastic. Glass is also denser than plastic, resulting in longer spin-up and spin-down times, a disadvantage when used in optical libraries. Sharp, Maxoptix and Matsushita produce 5.25" erasable drives that can use glass substrate media. Other manufacturers are expected to do the same.

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, but are less likely to have a long archival life.

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 incorporating 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. RPM is expected to increase to 3,000-3,600 RPM for newer drive designs, and one, Fujitsu's 5.25" drive, operates at 5,400 RPM.

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. Fujitsu is the first company to announce a 25.4 mm high 3.5" drive.

Military interest has spurred the design of ruggedized optical drives. At least 2 firms are actively engaged in pursuing this product area, including Cherokee and Mountain Optech.

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 international standards 10089 and 10090 cover rewritable 5.25" and 3.5" media respectively. DIS 11560 covers MO-WORM. 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 the 3.5" drives formally announced to date. A 3.5" sampled servo format known as DBF (Discrete Block Format) has been proposed as an alternative to the CCS format, but has less capacity (117 megabytes) and thus may not be well accepted.

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 1992. 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. This will be an important standard, because at the present time media written on the same drive but on different systems using different controllers and driver software could well be incompatible.

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. Unfortunately, different versions of SCSI and some differences between internal controller design have caused interchangeability problems.

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 applications.

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

* More storage capacity is available than many 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.

Competing Products: Strong competition for the 3.5" 128 megabyte optical drive will be provided by the SyQuest 3.5" 105 megabyte cartridge drive. The OEM price, in the $300 range, is substantially under the price expected for 3.5" M-O drives for the next 2 years. Performance of the SyQuest drive is also superior to that of current M-O drives.

Forecasting assumptions

1. 5.25" drives with over 1 gigabyte of capacity per side will start to divert shipments of 5.25" drives from this product group beginning in 1995.
2. Rewritable and write-once media will be available in adequate production quantities throughout the forecast period.
3. 4.72" write-once drives will be available from multiple sources throughout the forecast period. No 4.72" rewritable storage is anticipated within the forecast period.
4. No 2.5" drives will be offered in this product group until after 1994.
5. Strong growth from the document storage systems industry and the conservatism of information resource managers will extend the life of 5.25" write-once drives through 1995, although they will be displaced by multifunction drives in most new installations.
6. 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)									
	1991		Forecast							
	Revenues		1992		1993		1994		1995	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	6.4	7.7	17.9	27.0	31.6	51.6	50.3	90.8	67.1	129.3
Other U.S. Captive	10.5	14.4	11.9	19.8	23.0	38.4	30.4	49.6	37.0	61.8
TOTAL U.S. CAPTIVE	16.9	22.1	29.8	46.8	54.6	90.0	80.7	140.4	104.1	191.1
PCM/Reseller	20.2	28.3	23.8	34.6	26.4	38.7	36.9	53.9	40.1	57.8
OEM/Integrator	15.3	18.1	22.3	28.2	35.2	44.7	34.1	43.7	42.1	53.0
TOTAL U.S. NONCAPTIVE	35.5	46.4	46.1	62.8	61.6	83.4	71.0	97.6	82.2	110.8
TOTAL U.S. REVENUES	52.4	68.5	75.9	109.6	116.2	173.4	151.7	238.0	186.3	301.9
Non-U.S. Manufacturers										
Captive	67.0	238.9	112.3	348.5	162.4	441.7	209.5	545.2	240.8	620.4
PCM/Reseller	40.0	67.7	48.3	90.6	59.6	106.8	65.9	116.0	76.6	132.9
OEM/Integrator	123.1	210.3	164.0	273.1	207.5	356.1	263.6	445.3	286.1	495.3
TOTAL NON-U.S. REVENUES	230.1	516.9	324.6	712.2	429.5	904.6	539.0	1,106.5	603.5	1,248.6
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	282.5	585.4	400.5	821.8	545.7	1,078.0	690.7	1,344.5	789.8	1,550.5
OEM Average Price ($000)		1.866		1.605		1.323		1.130		.992

TABLE 24

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 1 GIGABYTE

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1991		Forecast							
	Shipments		1992		1993		1994		1995	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	3.0	3.6	7.1	10.3	13.4	21.6	22.8	41.5	32.6	64.0
Other U.S. Captive	2.7	3.7	3.6	6.0	7.2	12.0	9.8	16.0	12.2	20.4
TOTAL U.S. CAPTIVE	5.7	7.3	10.7	16.3	20.6	33.6	32.6	57.5	44.8	84.4
PCM/Reseller	8.3	11.8	10.7	15.7	14.0	20.6	21.2	31.2	24.7	35.8
OEM/Integrator	6.5	7.9	10.6	13.8	20.5	26.8	22.5	29.7	31.9	41.1
TOTAL U.S. NONCAPTIVE	14.8	19.7	21.3	29.5	34.5	47.4	43.7	60.9	56.6	76.9
TOTAL U.S. SHIPMENTS	20.5	27.0	32.0	45.8	55.1	81.0	76.3	118.4	101.4	161.3
Non-U.S. Manufacturers										
Captive	12.6	41.4	23.5	63.7	32.5	87.4	48.6	123.7	63.5	162.7
PCM/Reseller	19.6	31.6	27.3	48.5	37.8	65.8	44.8	75.5	56.8	94.2
OEM/Integrator	66.8	114.5	96.8	173.9	148.3	276.1	219.7	403.2	275.0	511.8
TOTAL NON-U.S. SHIPMENTS	99.0	187.5	147.6	286.1	218.6	429.3	313.1	602.4	395.3	768.7
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	119.5	214.5	179.6	331.9	273.7	510.3	389.4	720.8	496.7	930.0
Cumulative Shipments (Units in thousands)										
IBM	5.0	6.3	12.1	16.6	25.5	38.2	48.3	79.7	80.9	143.7
Non-IBM	309.4	550.8	481.9	872.4	742.2	1,361.1	1,108.8	2,040.4	1,572.9	2,906.4
WORLDWIDE TOTAL	314.4	557.1	494.0	889.0	767.7	1,399.3	1,157.1	2,120.1	1,653.8	3,050.1

TABLE 25

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 1 GIGABYTE

WORLDWIDE REVENUES ($M)

WRITE-ONCE DRIVES: BREAKDOWN BY DISK DIAMETER

	1991 Revenues		Forecast 1992		1993		1994		1995	
	5.25"	4.72"	5.25"	4.72"	5.25"	4.72"	5.25"	4.72"	5.25"	4.72"
U.S. MANUFACTURERS										
PCM/Reseller	7.5	--	7.7	--	6.5	--	6.0	--	5.0	--
OEM/Integrator	8.0	--	7.2	--	7.3	--	6.7	--	6.3	--
TOTAL U.S. REVENUES	15.5	--	14.9	--	13.8	--	12.7	--	11.3	--
NON-U.S. MANUFACTURERS										
Captive	40.5	15.0	41.0	41.4	39.5	88.1	37.3	115.9	33.2	124.1
PCM/Reseller	17.6	--	20.4	--	18.3	--	15.7	.3	13.9	5.1
OEM/Integrator	32.6	8.0	48.9	16.6	48.6	24.4	48.3	32.4	43.9	38.3
TOTAL NON-U.S. REVENUES	90.7	23.0	110.3	58.0	106.4	112.5	101.3	148.6	91.0	167.5
WORLDWIDE RECAP										
Captive	40.5 -14.7%	15.0 +172.7%	41.0 +1.2%	41.4 +176.0%	39.5 -3.7%	88.1 +112.8%	37.3 -5.6%	115.9 +31.6%	33.2 -11.0%	124.1 +7.1%
PCM/Reseller	25.1 -13.4%	-- --	28.1 +12.0%	-- --	24.8 -11.7%	-- --	21.7 -12.5%	.3 --	18.9 -12.9%	5.1 --
OEM/Integrator	40.6 -27.2%	8.0 +95.1%	56.1 +38.2%	16.6 +107.5%	55.9 -.4%	24.4 +47.0%	55.0 -1.6%	32.4 +32.8%	50.2 -8.7%	38.3 +18.2%
Total Revenues	106.2 -19.7%	23.0 +139.6%	125.2 +17.9%	58.0 +152.2%	120.2 -4.0%	112.5 +94.0%	114.0 -5.2%	148.6 +32.1%	102.3 -10.3%	167.5 +12.7%
ANNUAL SHARE, BY DIAMETER	82.3%	17.7%	68.4%	31.6%	51.8%	48.2%	43.5%	56.5%	38.0%	62.0%

Note: 5.25" drives include 8" drives.

TABLE 26

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 1 GIGABYTE

WORLDWIDE SHIPMENTS (000)

WRITE-ONCE DRIVES: BREAKDOWN BY DISK DIAMETER

	1991 Shipments		Forecast 1992		1993		1994		1995	
	5.25"	4.72"	5.25"	4.72"	5.25"	4.72"	5.25"	4.72"	5.25"	4.72"
U.S. MANUFACTURERS										
PCM/Reseller	2.5	--	2.7	--	2.5	--	2.4	--	2.1	--
OEM/Integrator	2.9	--	2.9	--	3.0	--	2.9	--	2.8	--
TOTAL U.S. SHIPMENTS	5.4	--	5.6	--	5.5	--	5.3	--	4.9	--
NON-U.S. MANUFACTURERS										
Captive	11.1	.9	11.4	3.6	10.9	8.9	10.2	14.3	8.8	18.8
PCM/Reseller	8.6	--	10.9	--	10.7	--	9.8	.1	8.5	2.3
OEM/Integrator	17.2	.6	18.7	2.8	18.7	6.7	17.7	12.4	16.5	21.5
TOTAL NON-U.S. SHIPMENTS	36.9	1.5	41.0	6.4	40.3	15.6	37.7	26.8	33.8	42.6
WORLDWIDE RECAP										
Captive	11.1 -14.6%	.9 +350.0%	11.4 +2.7%	3.6 +300.0%	10.9 -4.4%	8.9 +147.2%	10.2 -6.4%	14.3 +60.7%	8.8 -13.7%	18.8 +31.5%
PCM/Reseller	11.1 -9.0%	-- --	13.6 +22.5%	-- --	13.2 -2.9%	-- --	12.2 -7.6%	.1 --	10.6 -13.1%	2.3 --
OEM/Integrator	20.1 -28.2%	.6 +200.0%	21.6 +7.5%	2.8 +366.7%	21.7 +.5%	6.7 +139.3%	20.6 -5.1%	12.4 +85.1%	19.3 -6.3%	21.5 +73.4%
Total Shipments	42.3 -20.5%	1.5 +275.0%	46.6 +10.2%	6.4 +326.7%	45.8 -1.7%	15.6 +143.8%	43.0 -6.1%	26.8 +71.8%	38.7 -10.0%	42.6 +59.0%
ANNUAL SHARE, BY DIAMETER	96.7%	3.3%	88.0%	12.0%	74.7%	25.3%	61.7%	38.3%	47.7%	52.3%

Note: 5.25" drives include 8" drives.

TABLE 27

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 1 GIGABYTE

WORLDWIDE REVENUES ($M)

REWRITABLE DRIVES: BREAKDOWN BY DISK DIAMETER

	1991 Revenues		Forecast 1992		1993		1994		1995	
	5.25"	3.5"	5.25"	3.5"	5.25"	3.5"	5.25"	3.5"	5.25"	3.5"
U.S. MANUFACTURERS										
IBM Captive	--	7.7	13.7	13.3	19.8	31.8	28.1	62.7	32.9	96.4
Other U.S. Captive	14.4	--	19.8	--	38.4	--	49.6	--	61.8	--
PCM/Reseller	20.8	--	26.9	--	31.4	.8	44.1	3.8	48.8	4.0
OEM/Integrator	9.8	.3	20.1	.9	32.8	4.6	31.4	5.6	40.1	6.6
TOTAL U.S. REVENUES	45.0	8.0	80.5	14.2	122.4	37.2	153.2	72.1	183.6	107.0
NON-U.S. MANUFACTURERS										
Captive	175.9	7.5	230.0	36.1	242.8	71.3	264.0	128.0	281.8	181.3
PCM/Reseller	49.1	1.0	65.5	4.7	76.6	11.9	84.2	15.8	91.0	22.9
OEM/Integrator	158.2	11.5	155.6	52.0	180.0	103.1	230.4	134.2	269.4	143.7
TOTAL NON-U.S. REVENUES	383.2	20.0	451.1	92.8	499.4	186.3	578.6	278.0	642.2	347.9
WORLDWIDE RECAP										
Captive	190.3 +66.6%	15.2 --	263.5 +38.5%	49.4 +225.0%	301.0 +14.2%	103.1 +108.7%	341.7 +13.5%	190.7 +85.0%	376.5 +10.2%	277.7 +45.6%
PCM/Reseller	69.9 +10.8%	1.0 +400.0%	92.4 +32.2%	4.7 +370.0%	108.0 +16.9%	12.7 +170.2%	128.3 +18.8%	19.6 +54.3%	139.8 +9.0%	26.9 +37.2%
OEM/Integrator	168.0 +6.2%	11.8 --	175.7 +4.6%	52.9 +348.3%	212.8 +21.1%	107.7 +103.6%	261.8 +23.0%	139.8 +29.8%	309.5 +18.2%	150.3 +7.5%
Total Revenues	428.2 +27.6%	28.0 --	531.6 +24.1%	107.0 +282.1%	621.8 +17.0%	223.5 +108.9%	731.8 +17.7%	350.1 +56.6%	825.8 +12.8%	454.9 +29.9%
ANNUAL SHARE, BY DIAMETER	94.0%	6.0%	83.3%	16.7%	73.7%	26.3%	67.7%	32.3%	64.6%	35.4%

Note: 5.25" drives include 8" drives.

TABLE 28

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 1 GIGABYTE

WORLDWIDE SHIPMENTS (000)

REWRITABLE DRIVES: BREAKDOWN BY DISK DIAMETER

	1991 Shipments		Forecast							
			1992		1993		1994		1995	
	5.25"	3.5"	5.25"	3.5"	5.25"	3.5"	5.25"	3.5"	5.25"	3.5"
U.S. MANUFACTURERS										
IBM Captive	--	3.6	3.8	6.5	5.2	16.4	7.4	34.1	8.9	55.1
Other U.S. Captive	3.7	--	6.0	--	12.0	--	16.0	--	20.4	--
PCM/Reseller	9.3	--	13.0	--	17.5	.6	25.8	3.0	30.3	3.4
OEM/Integrator	4.7	.3	9.7	1.2	18.2	5.6	19.5	7.3	29.0	9.3
TOTAL U.S. SHIPMENTS	17.7	3.9	32.5	7.7	52.9	22.6	68.7	44.4	88.6	67.8
NON-U.S. MANUFACTURERS										
Captive	27.9	1.5	36.8	11.9	43.2	24.4	54.1	45.1	69.4	65.7
PCM/Reseller	22.1	.9	32.5	5.1	41.9	13.2	46.8	18.8	55.1	28.3
OEM/Integrator	85.9	10.8	94.5	57.9	125.0	125.7	178.6	194.5	236.3	237.5
TOTAL NON-U.S. SHIPMENTS	135.9	13.2	163.8	74.9	210.1	163.3	279.5	258.4	360.8	331.5
WORLDWIDE RECAP										
Captive	31.6 +53.4%	5.1 --	46.6 +47.5%	18.4 +260.8%	60.4 +29.6%	40.8 +121.7%	77.5 +28.3%	79.2 +94.1%	98.7 +27.4%	120.8 +52.5%
PCM/Reseller	31.4 +16.3%	.9 +800.0%	45.5 +44.9%	5.1 +466.7%	59.4 +30.5%	13.8 +170.6%	72.6 +22.2%	21.8 +58.0%	85.4 +17.6%	31.7 +45.4%
OEM/Integrator	90.6 +7.7%	11.1 --	104.2 +15.0%	59.1 +432.4%	143.2 +37.4%	131.3 +122.2%	198.1 +38.3%	201.8 +53.7%	265.3 +33.9%	246.8 +22.3%
Total Shipments	153.6 +16.6%	17.1 --	196.3 +27.8%	82.6 +383.0%	263.0 +34.0%	185.9 +125.1%	348.2 +32.4%	302.8 +62.9%	449.4 +29.1%	399.3 +31.9%
ANNUAL SHARE, BY DIAMETER	90.1%	9.9%	70.5%	29.5%	58.7%	41.3%	53.6%	46.4%	53.1%	46.9%

Note: 5.25" drives include 8" drives.

TABLE 29

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 1 GIGABYTE

WORLDWIDE SHIPMENTS (000)

ERASABLE/WRITE-ONCE DRIVE ANALYSIS

	1991 --Shipments--		Forecast							
			1992		1993		1994		1995	
	Units	%	Units	%	Units	%	Units	%	Units	%
U.S. MANUFACTURERS										
Captive Total	7.3		16.3		33.6		57.5		84.4	
Erasable	7.3	100.0%	16.3	100.0%	33.6	100.0%	57.5	100.0%	84.4	100.0%
OEM/PCM Total	19.7		29.5		47.4		60.9		76.9	
Write-Once	5.4	27.4%	5.6	19.0%	5.5	11.6%	5.3	8.7%	4.9	6.4%
Erasable	14.3	72.6%	23.9	81.0%	41.9	88.4%	55.6	91.3%	72.0	93.6%
Total U.S.	27.0		45.8		81.0		118.4		161.3	
Write-Once	5.4	20.0%	5.6	12.2%	5.5	6.8%	5.3	4.5%	4.9	3.0%
Erasable	21.6	80.0%	40.2	87.8%	75.5	93.2%	113.1	95.5%	156.4	97.0%
NON-U.S. MANUFACTURERS										
Captive Total	41.4		63.7		87.4		123.7		162.7	
Write-Once	12.0	29.0%	15.0	23.5%	19.8	22.7%	24.5	19.8%	27.6	17.0%
Erasable	29.4	71.0%	48.7	76.5%	67.6	77.3%	99.2	80.2%	135.1	83.0%
OEM/PCM Total	146.1		222.4		341.9		478.7		606.0	
Write-Once	26.4	18.1%	32.4	14.6%	36.1	10.6%	40.0	8.4%	48.8	8.1%
Erasable	119.7	81.9%	190.0	85.4%	305.8	89.4%	438.7	91.6%	557.2	91.9%
Total Non-U.S.	187.5		286.1		429.3		602.4		768.7	
Write-Once	38.4	20.5%	47.4	16.6%	55.9	13.0%	64.5	10.7%	76.4	9.9%
Erasable	149.1	79.5%	238.7	83.4%	373.4	87.0%	537.9	89.3%	692.3	90.1%
WORLDWIDE RECAP										
Total Worldwide Shipments	214.5		331.9		510.3		720.8		930.0	
	+15.7%		+54.7%		+53.7%		+41.2%		+29.0%	
Write-Once	43.8	20.4%	53.0	16.0%	61.4	12.0%	69.8	9.7%	81.3	8.7%
	-18.2%		+21.0%		+15.8%		+13.6%		+16.4%	
Erasable	170.7	79.6%	278.9	84.0%	448.9	88.0%	651.0	90.3%	848.7	91.3%
	+29.5%		+63.3%		+60.9%		+45.0%		+30.3%	

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

TABLE 30

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 1 GIGABYTE

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1991 Estimate Units (000)	1991 Estimate %	1995 Projection Units (000)	1995 Projection %
MAINFRAME/SUPERMINI General purpose	4.8	2.2	20.5	2.2
MINICOMPUTERS AND MULTIUSER MICROS Business and professional, including networks	56.1	26.1	173.9	18.7
PERSONAL COMPUTERS Business and professional, single user	78.9	36.8	377.6	40.6
OFFICE SYSTEMS AND WORKSTATIONS Dedicated application	43.3	20.2	174.8	18.8
NON-OFFICE SYSTEMS AND WORKSTATIONS Technical, distribution, medical, other specialized	30.6	14.3	156.2	16.8
CONSUMER AND HOBBY COMPUTERS	.2	.1	11.2	1.2
OTHER APPLICATIONS	.6	.3	15.8	1.7
Total	214.5	100.0	930.0	100.0

TABLE 31

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 1 GIGABYTE

MARKET SHARE SUMMARY
Worldwide Shipments of Noncaptive Disk Drives

	1991 Net Shipments									
	To United States Destinations					Worldwide				
	Units (000)				%	Units (000)				%
Drive Manufacturers	5.25"	4.72"	3.5"	Total		5.25"	4.72"	3.5"	Total	
Sony	38.2	.2	3.6	42.0	41.5	62.5	.3	8.9	71.7	43.2
Ricoh	16.0	--	--	16.0	15.8	23.9	--	--	23.9	14.4
Matsushita Elec. Ind.	14.0	--	.3	14.3	14.1	21.1	--	.7	21.8	13.1
Other U.S.	14.6	--	.2	14.8	14.7	19.4	--	.3	19.7	11.9
Other Non-U.S.	11.7	.3	2.2	14.1	13.9	26.3	.3	2.1	28.7	17.4
TOTAL	94.5	.5	6.2	101.2	100.0	153.2	.6	12.0	165.8	100.0

READ/WRITE OPTICAL DRIVES MORE THAN 1 GIGABYTE

1992 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, GD9001
Hitachi	OD 301A-1, OD 321-1
Laser Magnetic Storage	1200E, 1250E, LD 4100
NEC	N7913/N6513-23, N6513-20
Nikon	MO-DD120C (Erasable)
Sony	WDD 600, WDD 3000

8" diameter

Fujitsu	F6443 (Erasable)

High capacity optical disk drives are read/write drives, either write-once or erasable. Most drives in this capacity range are 12" write-once types, although Nikon has formally announced of a 12" erasable drive for 1992 shipment and Fujitsu has shipped small numbers of a non-removable 8" erasable drive. Eastman Kodak produces high capacity 14" drives as well. 5.25" drives are expected to enter this product group near the end of the forecast period.

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. With the arrival of 12" optical libraries holding a single drive and fewer than 15 disks, the 12" drives will also be used in departmental systems and small work groups.

Market status

1991 drive shipments declined 17% to 9,800 units as a result of lower captive shipments. This decline was probably the result of weak economic conditions that caused postponement of capital equipment purchases. 1991 revenues declined 13% to $135.6 million. U.S. firms generated only 3.5% of total worldwide revenues, but 43.3% of worldwide revenue was generated in the U.S. market.

Almost 98% of units shipped were produced by non-U.S. firms, a slightly higher share than in 1990. 45.9% of unit shipments went to the U.S. market, while 54.1% were sold elsewhere. 1991's leading noncaptive producers were Sony, LMSI, and ATG Gigadisc. Toshiba and Hitachi were strong captive producers.

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 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

With the worldwide economic situation slowly improving, shipments are expected to increase in 1992 and throughout the forecast period. In 1994 and 1995, shipments are expected to increase dramatically as a new generation of higher capacity 12" drives appears and 5.25" drives with capacity over 1 gigabyte per side enter the market. While the 5.25" drives won't have the same capacity per media unit as the 12" drives, their higher performance, lower price, rewritability, and probable multifunctionality is expected to make them immediately popular. The competition from 5.25" drives will probably halt or reverse the tendency of 12" drive prices to climb each year. It is anticipated that most of the 5.25" drives in this product group will be rewritable or multifunction, but a few write-

once drive models may appear as early as 1993. However, they are not expected to have a major impact because customers will be anticipating the arrival of rewritable drives and media. If rewritable drives are delayed beyond 1994, 5.25" write-once drives have an opportunity for modest success.

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 9,800 units in 1991 to 45,500 units in 1995, with 61% of these being sold in the U.S. market. About half of the 1995 units are expected to be 5.25" units. The introduction of 5.25" drives in this product group is also expected to drive the OEM sales revenues from 47.4% in 1991 to over 64% in 1995.

Total revenues in the forecast period are expected to grow from $135.6 million (11.5% of the worldwide optical disk drive market) to $344.9 million (11.8% of the worldwide optical disk drive market). Drive sales should be helped by expanding sales of small optical libraries with a single 12" drive. The U.S. market is expected to generate about 59% of 1995 worldwide revenues for this product group, with U.S. firms' share of worldwide revenues growing to 16.1%. Most of the U.S. share will come from sales of 5.25" drives.

Average OEM drive prices are expected to climb through 1993 as product mix shifts to higher capacity drives and the more expensive rewritable drives begin to capture market share, but this trend will be reversed in 1994 as 5.25" drives with capacity over 1 gigabyte per side enter the market.

While IBM has an active optical disk drive development program, 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. IBM may eventually produce a 5.25"

drive in this product group.

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 1991 for high capacity optical drives were again office systems and non-office workstations. Together, these categories accounted for 67.9% of unit shipments, up slightly from 67.5 in 1990. In 1995, 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 because they need to service account inquiries in real time.

Approximately 21% of the drives in this group were shipped in automated library subsystems in 1991, and this percentage will leap dramatically in 1992 and later years as shipments of small optical libraries with a single 12" drive begin to increase. By 1995, over 50% of the drives 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 large library is expected to increase with time, so that by 1995 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. Where low cost per stored record is more important than rapid on-line retrieval of a record, microfilm still competes effectively against optical storage.

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. Ample evidence of this trend is available at conferences appealing to managers concerned with records storage: Previously dominated by micrographics oriented speakers and exhibitors, meetings such as the AIIM conference now have such a strong bias towards optical storage that micrographics exhibitors are frustrated with their current low profile.

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, and Sony's 1992 introduction of a somewhat similar product, attempts 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 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 12" high capacity media are finally starting to materialize. Although the initial product designs are already established and incompatible, the ANSI X3B11 technical subcommittee, which has the U.S. charter to develop such a standard, obtained agreement on a 17 mm height for 12" media cartridges. However, other issues impacting a standard for 12" media may not be resolved for some time to come. In any event, the continuous servo/sampled servo conflict yet remains. 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 IBM announcement of a 12" drive is unlikely.

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 4.5 gigabytes per side, much 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 1994.

Rewritability: Nikon has announced 1992 availability 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 media is likely to 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.

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, and at least one U.S. firm has a 5.25" development effort aimed at producing a very high capacity, high performance multiple platter drive.

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.

Not all drives in this product group have the drive controller integrated into the drive package yet, but this is expected to become more common in the future as the degree of electronics integration improves. Smaller drives expand disk storage space when drives are used in optical libraries, so embedding the controller in the drive is advantageous.

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" write-once and rewritable 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 servo 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. GE, 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 considerations for 5.25" media are much the same as in the low capacity drive group.

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 12" IBM-produced optical drives are anticipated in this product group through 1995.
2. There will continue to be an adequate supply of write-once media for products in this group.

3. There will be no generally accepted standard for 12" drives and media through 1995.
4. There will be no significant shipments of 5.25" rewritable drives in this product group until late 1994.
5. Rewritable 12" drives and media will have only marginal impact through 1993, but will have significant impact on shipments after that.
6. LMSI's dual head drive will be a major factor in market growth in this category.

TABLE 32

READ/WRITE OPTICAL DISK DRIVES, MORE THAN 1 GIGABYTE

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1991		Forecast							
	Revenues		1992		1993		1994		1995	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	4.3	5.7	17.0	25.5
Other U.S. Captive	2.4	2.4	2.3	2.3	2.3	2.3	2.2	2.2	4.4	4.4
TOTAL U.S. CAPTIVE	2.4	2.4	2.3	2.3	2.3	2.3	6.5	7.9	21.4	29.9
PCM/Reseller	--	--	--	--	--	--	.4	.4	1.8	1.8
OEM/Integrator	2.4	2.4	2.3	2.3	2.5	2.5	8.0	9.0	19.0	23.8
TOTAL U.S. NONCAPTIVE	2.4	2.4	2.3	2.3	2.5	2.5	8.4	9.4	20.8	25.6
TOTAL U.S. REVENUES	4.8	4.8	4.6	4.6	4.8	4.8	14.9	17.3	42.2	55.5
Non-U.S. Manufacturers										
Captive	3.6	40.7	5.3	33.9	7.2	30.5	9.0	42.8	11.5	55.5
PCM/Reseller	1.1	4.1	9.5	14.6	13.3	18.9	18.0	25.3	25.1	36.9
OEM/Integrator	49.2	86.0	62.1	105.1	90.4	146.1	109.9	179.9	124.8	197.0
TOTAL NON-U.S. REVENUES	53.9	130.8	76.9	153.6	110.9	195.5	136.9	248.0	161.4	289.4
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	58.7	135.6	81.5	158.2	115.7	200.3	151.8	265.3	203.6	344.9
OEM Average Price ($000)		12.8		13.1		13.3		10.7		7.2

TABLE 33

READ/WRITE OPTICAL DISK DRIVES, MORE THAN 1 GIGABYTE

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1991		Forecast							
	Shipments		1992		1993		1994		1995	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	.6	.8	2.4	3.6
Other U.S. Captive	.1	.1	.1	.1	.1	.1	.1	.1	.2	.2
TOTAL U.S. CAPTIVE	.1	.1	.1	.1	.1	.1	.7	.9	2.6	3.8
PCM/Reseller	--	--	--	--	--	--	.1	.1	.5	.5
OEM/Integrator	.1	.1	.1	.1	.3	.3	2.3	2.8	6.2	8.4
TOTAL U.S. NONCAPTIVE	.1	.1	.1	.1	.3	.3	2.4	2.9	6.7	8.9
TOTAL U.S. SHIPMENTS	.2	.2	.2	.2	.4	.4	3.1	3.8	9.3	12.7
Non-U.S. Manufacturers										
Captive	.2	2.5	.3	1.9	.4	1.7	.5	2.9	.7	4.3
PCM/Reseller	.1	.3	.9	1.3	1.2	1.7	2.0	2.8	4.4	6.3
OEM/Integrator	4.0	6.8	4.9	8.1	6.6	10.8	8.4	14.7	13.4	22.1
TOTAL NON-U.S. SHIPMENTS	4.3	9.6	6.1	11.3	8.2	14.2	10.9	20.4	18.5	32.7
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	4.5	9.8	6.3	11.5	8.6	14.6	14.0	24.2	27.8	45.4
Cumulative Shipments (Units in thousands)										
IBM	--	--	--	--	--	--	.6	.8	3.0	4.4
Non-IBM	28.4	66.5	34.7	78.0	43.3	92.6	56.7	116.0	82.1	157.8
WORLDWIDE TOTAL	28.4	66.5	34.7	78.0	43.3	92.6	57.3	116.8	85.1	162.2

TABLE 34

READ/WRITE OPTICAL DISK DRIVES, MORE THAN 1 GIGABYTE

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1991 Estimate Units (000)	1991 Estimate %	1995 Projection Units (000)	1995 Projection %
MAINFRAME/SUPERMINI General purpose	.6	6.6	1.5	3.3
MINICOMPUTERS AND MULTIUSER MICROS Business and professional, including networks	2.1	21.7	11.0	24.2
PERSONAL COMPUTERS Business and professional, single user	.4	3.8	.5	1.2
OFFICE SYSTEMS AND WORKSTATIONS Dedicated application	3.6	35.8	18.4	40.5
NON-OFFICE SYSTEMS AND WORKSTATIONS Technical, distribution, medical, other specialized	3.1	32.1	13.8	30.4
CONSUMER AND HOBBY COMPUTERS	--	--	--	--
OTHER APPLICATIONS	--	--	.2	.4
Total	9.8	100.0	45.4	100.0

READ-ONLY OPTICAL LIBRARIES

1992 DISK/TREND REPORT

READ-ONLY OPTICAL LIBRARIES

Coverage

Examples of optical disk libraries in this group include:

4.72" disk diameter (CD-ROM)

Borett Automation Technologies	VLC
Kubik Enterprises	DDC-240, CDR240M
NSM	CDR-100
Pioneer	DRM-600, DRM 604, 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

Only a few firms are shipping read-only library devices, and of these, only Pioneer has significant shipment volume. Read-only libraries range from the carousel style 240 disk version of Kubik 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 entering production status. NSM, a German organization, has shipped a few libraries based upon a previous audio player version. The most elaborate library in this class is produced by Borett Automation Technologies and uses an industrial robot. It is a variant of a design developed to handle other forms of media, and requires the disk to be in a caddy.

Marketing trends

1991 read-only library revenues more than doubled to $18.8 million, largely as a result of Pioneer's success with its six disk library, and is expected to reach $18.6 million in 1994. The number of competitors and the complexity of the solutions offered are 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 1991 were 16,920 units. In 1995, shipments of 34,571 units are projected, but the majority of these shipments are expected to be low-end libraries holding no more than ten disks. About 60% of the total unit shipments will be to U.S. companies, and of this amount, 53% will be sold to OEMs. 58% of all reseller shipments will also be to U.S. companies, as will 63% 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. Pioneer's high performance version, which rotates at four times the normal speed, is expected to sell strongly to server installations and to multimedia intensive applications because of its quadrupled data transfer rate.

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, but has been shown in a high performance version offering up to four times the standard CD-ROM data transfer rate and rotation rate. Kubik's rotary carousel design is innovative and provides a relatively high storage density. Interfaces

are standard RS-232 or SCSI variants. Next Technology, a U.K. firm that had developed a CD-ROM library, sold its design to another firm, which has yet to put it into production

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.

There is some competition for read-only libraries from configurations of multiple CD-ROM drives usually attached to file servers, that can provide multiple disk availability or offer multiple user access to the same disk with minimal delay. Where only one or a few disks need to be used by a work group, this may be a favored approach.

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. IBM will not be a producer.

3. There will be no significant changes in library technology impacting read-only libraries over the period of the forecast.

4. Additional competitors will eventually appear in the low-end library market, resulting in price competition that will spur unit shipments.

TABLE 35

OPTICAL LIBRARIES, READ-ONLY

REVENUE SUMMARY

	LIBRARY REVENUES, BY SHIPMENT DESTINATION ($M)									
	1991 Revenues		Forecast 1992		1993		1994		1995	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	.8	.8	.8	1.0	.4	.6	.3	.4	.1	.1
TOTAL U.S. CAPTIVE	.8	.8	.8	1.0	.4	.6	.3	.4	.1	.1
PCM/Reseller	--	--	--	--	--	--	--	--	--	--
OEM/Integrator	.2	.2	2.1	2.8	3.6	4.3	6.1	7.2	6.8	8.0
TOTAL U.S. NONCAPTIVE	.2	.2	2.1	2.8	3.6	4.3	6.1	7.2	6.8	8.0
TOTAL U.S. REVENUES	1.0	1.0	2.9	3.8	4.0	4.9	6.4	7.6	6.9	8.1
Non-U.S. Manufacturers										
Captive	--	--	--	--	--	--	--	--	--	--
PCM/Reseller	5.0	8.7	6.0	10.8	7.1	12.3	7.9	13.9	8.8	15.4
OEM/Integrator	5.9	9.1	8.0	12.3	9.6	14.4	11.0	16.6	12.3	18.4
TOTAL NON-U.S. REVENUES	10.9	17.8	14.0	23.1	16.7	26.7	18.9	30.5	21.1	33.8
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	11.9	18.8	16.9	26.9	20.7	31.6	25.3	38.1	28.0	41.9
OEM Average Price ($000)		1.0		1.2		1.3		1.4		1.4

TABLE 36

OPTICAL LIBRARIES, READ-ONLY

UNIT SHIPMENT SUMMARY (SINGLE UNITS)

	LIBRARY UNIT SHIPMENTS, BY SHIPMENT DESTINATION									
	1991		Forecast							
	Shipments		1992		1993		1994		1995	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	52.0	52.0	50.0	65.0	28.0	39.0	19.0	23.0	6.0	6.0
TOTAL U.S. CAPTIVE	52.0	52.0	50.0	65.0	28.0	39.0	19.0	23.0	6.0	6.0
PCM/Reseller	--	--	--	--	--	--	--	--	--	--
OEM/Integrator	13.0	13.0	150.0	200.0	280.0	335.0	510.0	600.0	615.0	725.0
TOTAL U.S. NONCAPTIVE	13.0	13.0	150.0	200.0	280.0	335.0	510.0	600.0	615.0	725.0
TOTAL U.S. SHIPMENTS	65.0	65.0	200.0	265.0	308.0	374.0	529.0	623.0	621.0	731.0
Non-U.S. Manufacturers										
Captive	--	--	--	--	--	--	--	--	--	--
PCM/Reseller	5,030.0	7,855.0	6,010.0	10,040.0	7,110.0	12,270.0	7,920.0	13,910.0	8,800.0	15,380.0
OEM/Integrator	5,850.0	9,000.0	7,960.0	11,900.0	9,600.0	14,400.0	11,040.0	16,630.0	12,320.0	18,460.0
TOTAL NON-U.S. SHIPMENTS	10,880.0	16,855.0	13,970.0	21,940.0	16,710.0	26,670.0	18,960.0	30,540.0	21,120.0	33,840.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	10,945.0	16,920.0	14,170.0	22,205.0	17,018.0	27,044.0	19,489.0	31,163.0	21,741.0	34,571.0
Cumulative Shipments (Units in thousands)										
IBM	--	--	--	--	--	--	--	--	--	--
Non-IBM	17.9	27.3	32.1	49.5	49.1	76.5	68.6	107.7	90.3	142.3
WORLDWIDE TOTAL	17.9	27.3	32.1	49.5	49.1	76.5	68.6	107.7	90.3	142.3

READ/WRITE OPTICAL LIBRARIES 1-39 CARTRIDGES

1992 DISK/TREND REPORT

READ/WRITE OPTICAL LIBRARIES
1 - 39 CARTRIDGES

Coverage

Examples of optical disk libraries in this group include:

3.5" disk diameter

IBM	5558-B01

5.25" disk diameter

Aisin Seiki	JC2000
Cygnet Systems	5250/W
DSM	4000
Hewlett-Packard	C1710M-105, C1713M, 10LC
Hitachi	OL101-11, OL112-21
International Data Engineering	7000, 7100, 9000, LG5
K&S	Megastore 1000
Mitsubishi Electric	ME-5G2-Z
NEC	N1137-06
Ricoh	RJ5160
Toshiba	WM-A012

12" disk diameter

Access	ODSR
ATG Gigadisc	GF 6910
Cygnet Systems	1602
DSM	20, 27, 28, 30, 38
Hitachi	OL301
Laser Magnetic Storage	LF 4500
NEC	N7923
Sony	WDA-E330

5.25" optical libraries remain the predominant type in this product group, and the first 3.5" optical library in the group has been announced by IBM. The libraries represented in the list above are quite diverse, ranging from the tabletop, single drive, 5 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. Al-

though the first 12" rewritable drive (from Nikon) has gone into production, it requires adaptation before it can appear in an optical library. The IBM 3.5" library uses IBM's rewritable 3.5" drive.

Market status

3,215 libraries were shipped in 1991 for this group, an increase of 55.9% from 1991. Revenues grew to $43.9 million from $28.4 million, 54.5% gain. About 53.5% of 1991 revenues and 85.4% of 1991 shipments were generated by U.S. manufacturers, notably IDE and Hewlett-Packard. 65.2% of unit 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 and Hewlett-Packard, which together shipped approximately 80% 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, buy, and install drives.

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 are expected to reach 19,125 units worldwide in 1995, with about 62.5% 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 12" single-drive libraries will cause a temporary increase in the average price within this group during the early portion of the forecast period. However, viewed separately, high-end and low-end price declines will occur gradually throughout the period.

About 87.5% of the 1995 shipments are projected to be made to OEMs and system integrators. 6.4% will be through PCM/Resellers, and 2.8% will be captive shipments. 5.25" shipments, which were 87.9% of the 1991 total shipments, is expected to decline to 60.8% in 1995, as a result of the anticipated success of the 12" autochangers in this product group and the gradual growth of the 3.5" library, which is projected to capture a 9% share in 1995.

1994 revenues are expected to reach $163.9 million, with 43.3% from U.S. firms. This is about a 17% decline from 1991, and reflects anticipated small library introductions from non-U.S. manufacturers in the next two years. 60.1% of the worldwide library revenues from this product group are expected to be generated in the U.S. market in 1995.

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 have been imitated by other producers, at least in terms of entries in the product segment, and more of the increased competition will be felt in the single drive library category as new designs for small networks and workstation support become available. A new generation of tabletop libraries with disk capacities appeared in 1991 with the introduction of IDE's five disk unit.

An increasing number of firms are introducing 12" libraries in this group with fewer than 15 disks. LMSI has been joined by Sony and ATG Gigadisc, and it appears likely that other firms will also introduce small 12" libraries.

As noted previously, the majority of shipments will be on an OEM basis, with about 87.5% of 1995 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, Sony and ATG Gigadisc libraries occupy a middle ground: While relatively low in price, and having only one drive, they provide on-line capacity so large (especially the dual head LMSI design) that throughput may frequently be better than that of multidrive 5.25" units. In cases where rewritable media is not required, the small 12" library may displace some 5.25" libraries in both single user and multiuser systems. The small 12" libraries, the only write-once libraries in this product group, are expected to sustain growth through 1995.

Technical trends

For the time being, libraries in this product group will continue to use 5.25" or 12" drives and media. 3.5" libraries, introduced by IBM, and under active consideration at several other firms, will get some market share. However, 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 relatively unattractive. They may have some appeal as automated disk writers for software duplication where the production requirement is nominal, but specialized equipment for this purpose is already in the market.

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 func-

tions is improving reliability. Some libraries will perform several hundred thousand cartridge exchanges between failures. It is not unusual for library manufacturers to require drive suppliers to make drives specified to withstand over 300,000 cartridge insertions, in order to achieve adequate system reliability.

Forecasting assumptions

1. There will be several 3.5" library units in the market by the end of 1993.

2. The 5.25" format will remain the most commonly used, but it will receive competition from 12" libraries.

3. Erasable drives will be used in more libraries than will write-once drives, which 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 37

OPTICAL LIBRARIES, 1-39 DISKS

REVENUE SUMMARY

	LIBRARY REVENUES, BY SHIPMENT DESTINATION ($M)									
	1991 Revenues		Forecast 1992		1993		1994		1995	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	.3	.4	.9	.6	1.3	.8	1.7
Other U.S. Captive	8.6	14.1	7.7	12.5	6.9	11.0	6.4	10.1	6.3	9.8
TOTAL U.S. CAPTIVE	8.6	14.1	7.7	12.8	7.3	11.9	7.0	11.4	7.1	11.5
PCM/Reseller	1.7	2.2	3.5	5.0	3.7	5.1	2.8	3.9	2.2	3.1
OEM/Integrator	10.6	12.9	15.0	21.6	22.5	34.2	28.1	42.4	37.5	56.5
TOTAL U.S. NONCAPTIVE	12.3	15.1	18.5	26.6	26.2	39.3	30.9	46.3	39.7	59.6
TOTAL U.S. REVENUES	20.9	29.2	26.2	39.4	33.5	51.2	37.9	57.7	46.8	71.1
Non-U.S. Manufacturers										
Captive	--	10.5	--	9.4	.3	9.8	.5	10.1	.7	10.8
PCM/Reseller	.1	.2	6.8	10.1	7.0	10.8	6.3	9.9	5.0	8.2
OEM/Integrator	2.5	4.0	16.7	30.7	28.6	51.7	41.4	68.3	46.1	73.8
TOTAL NON-U.S. REVENUES	2.6	14.7	23.5	50.2	35.9	72.3	48.2	88.3	51.8	92.8
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	23.5	43.9	49.7	89.6	69.4	123.5	86.1	146.0	98.6	163.9
OEM Average Price ($000)		8.5		10.4		10.1		9.3		7.8

TABLE 38

OPTICAL LIBRARIES, 1-39 DISKS

UNIT SHIPMENT SUMMARY (SINGLE UNITS)

	LIBRARY UNIT SHIPMENTS, BY SHIPMENT DESTINATION									
	1991 Shipments		Forecast 1992		1993		1994		1995	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	56.0	62.0	146.0	97.0	213.0	133.0	284.0
Other U.S. Captive	307.0	503.0	321.0	521.0	342.0	547.0	354.0	561.0	387.0	605.0
TOTAL U.S. CAPTIVE	307.0	503.0	321.0	577.0	404.0	693.0	451.0	774.0	520.0	889.0
PCM/Reseller	354.0	494.0	550.0	790.0	589.0	816.0	515.0	726.0	454.0	634.0
OEM/Integrator	1,307.0	1,749.0	2,153.0	3,143.0	2,889.0	4,516.0	3,913.0	5,934.0	5,770.0	8,699.0
TOTAL U.S. NON-CAPTIVE	1,661.0	2,243.0	2,703.0	3,933.0	3,478.0	5,332.0	4,428.0	6,660.0	6,224.0	9,333.0
TOTAL U.S. SHIPMENTS	1,968.0	2,746.0	3,024.0	4,510.0	3,882.0	6,025.0	4,879.0	7,434.0	6,744.0	10,222.0
Non-U.S. Manufacturers										
Captive	--	225.0	--	207.0	6.0	215.0	12.0	234.0	18.0	262.0
PCM/Reseller	3.0	10.0	402.0	595.0	421.0	653.0	408.0	644.0	357.0	596.0
OEM/Integrator	124.0	234.0	906.0	1,862.0	2,117.0	3,969.0	3,530.0	6,026.0	4,831.0	8,045.0
TOTAL NON-U.S. SHIPMENTS	127.0	469.0	1,308.0	2,664.0	2,544.0	4,837.0	3,950.0	6,904.0	5,206.0	8,903.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	2,095.0	3,215.0	4,332.0	7,174.0	6,426.0	10,862.0	8,829.0	14,338.0	11,950.0	19,125.0
Cumulative Shipments (Single units)										
IBM	--	--	--	56.0	62.0	202.0	159.0	415.0	292.0	699.0
Non-IBM	3,601.0	5,864.0	7,933.0	12,982.0	14,297.0	23,698.0	23,029.0	37,823.0	34,846.0	56,664.0
WORLDWIDE TOTAL	3,601.0	5,864.0	7,933.0	13,038.0	14,359.0	23,900.0	23,188.0	38,238.0	35,138.0	57,363.0

TABLE 39

OPTICAL LIBRARIES, 1-39 DISKS

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1991 Revenues		Forecast											
	1992			1993			1994			1995		
	12"	5.25"	12"	5.25"	3.5"	12"	5.25"	3.5"	12"	5.25"	3.5"	12"	5.25"	3.5"
U.S. MANUFACTURERS														
IBM Captive	--	--	--	--	.3	--	--	.9	--	--	1.3	--	--	1.7
Other U.S. Captive	.1	14.0	--	12.5	--	.1	10.9	--	.1	10.0	--	.2	9.6	--
PCM/Reseller	--	2.2	--	5.0	--	--	5.0	.1	--	3.5	.4	--	2.3	.8
OEM/Integrator	.5	12.4	1.0	20.4	.2	1.5	31.5	1.2	1.7	39.3	1.4	2.1	52.4	2.0
TOTAL U.S. REVENUES	.6	28.6	1.0	37.9	.5	1.6	47.4	2.2	1.8	52.8	3.1	2.3	64.3	4.5
NON-U.S. MANUFACTURERS														
Captive	10.2	.3	9.0	.4	--	9.4	.4	--	9.5	.6	--	9.9	.9	--
PCM/Reseller	.1	.1	10.1	--	--	10.2	.5	.1	9.1	.7	.1	7.3	.8	.1
OEM/Integrator	3.4	.6	29.0	1.7	--	44.8	6.6	.3	58.1	8.5	1.7	59.9	10.8	3.1
TOTAL NON-U.S. REVENUES	13.7	1.0	48.1	2.1	--	64.4	7.5	.4	76.7	9.8	1.8	77.1	12.5	3.2
WORLDWIDE RECAP														
Captive	10.3	14.3	9.0	12.9	.3	9.5	11.3	.9	9.6	10.6	1.3	10.1	10.5	1.7
	+41.1%	+95.9%	-12.6%	-9.8%	--	+5.6%	-12.4%	+200.0%	+1.1%	-6.2%	+44.4%	+5.2%	-.9%	+30.8%
PCM/Reseller	.1	2.3	10.1	5.0	--	10.2	5.5	.2	9.1	4.2	.5	7.3	3.1	.9
	--	-41.0%	--	+117.4%	--	+1.0%	+10.0%	--	-10.8%	-23.6%	+150.0%	-19.8%	-26.2%	+80.0%
OEM/Integrator	3.9	13.0	30.0	22.1	.2	46.3	38.1	1.5	59.8	47.8	3.1	62.0	63.2	5.1
	+143.8%	+58.5%	+669.2%	+70.0%	--	+54.3%	+72.4%	+650.0%	+29.2%	+25.5%	+106.7%	+3.7%	+32.2%	+64.5%
Total Revenues	14.3	29.6	49.1	40.0	.5	66.0	54.9	2.6	78.5	62.6	4.9	79.4	76.8	7.7
	+58.9%	+52.6%	+243.4%	+35.1%	--	+34.4%	+37.3%	+420.0%	+18.9%	+14.0%	+88.5%	+1.1%	+22.7%	+57.1%
ANNUAL SHARE, BY DIAMETER	32.6%	67.4%	54.9%	44.6%	.5%	53.5%	44.5%	2.0%	53.9%	42.9%	3.2%	48.5%	46.9%	4.6%

TABLE 40

OPTICAL LIBRARIES, 1-39 DISKS

WORLDWIDE SHIPMENTS (UNITS)

BREAKDOWN BY DISK DIAMETER

	1991 Shipments		Forecast											
	1992			1993			1994			1995		
	12"	5.25"	12"	5.25"	3.5"	12"	5.25"	3.5"	12"	5.25"	3.5"	12"	5.25"	3.5"
U.S. MANUFACTURERS														
IBM Captive	--	--	--	--	56.0	--	--	146.0	--	--	213.0	--	--	284.0
Other U.S. Captive	2.0	501.0	1.0	520.0	--	2.0	545.0	--	3.0	558.0	--	4.0	601.0	--
PCM/Reseller	--	494.0	--	790.0	--	--	796.0	20.0	--	646.0	80.0	--	478.0	156.0
OEM/Integrator	15.0	1,734.0	25.0	3,070.0	48.0	38.0	4,244.0	234.0	44.0	5,605.0	285.0	56.0	8,142.0	501.0
TOTAL U.S. SHIPMENTS	17.0	2,729.0	26.0	4,380.0	104.0	40.0	5,585.0	400.0	47.0	6,809.0	578.0	60.0	9,221.0	941.0
NON-U.S. MANUFACTURERS														
Captive	215.0	10.0	194.0	13.0	--	200.0	15.0	--	210.0	24.0	--	230.0	32.0	--
PCM/Reseller	3.0	7.0	595.0	--	--	601.0	40.0	12.0	566.0	61.0	17.0	487.0	85.0	24.0
OEM/Integrator	154.0	80.0	1,587.0	275.0	--	2,801.0	1,108.0	60.0	4,149.0	1,466.0	411.0	4,997.0	2,269.0	779.0
TOTAL NON-U.S. SHIPMENTS	372.0	97.0	2,376.0	288.0	--	3,602.0	1,163.0	72.0	4,925.0	1,551.0	428.0	5,714.0	2,386.0	803.0
WORLDWIDE RECAP														
Captive	217.0	511.0	195.0	533.0	56.0	202.0	560.0	146.0	213.0	582.0	213.0	234.0	633.0	284.0
	+44.7%	+130.2%	-10.1%	+4.3%	--	+3.6%	+5.1%	+160.7%	+5.4%	+3.9%	+45.9%	+9.9%	+8.8%	+33.3%
PCM/Reseller	3.0	501.0	595.0	790.0	--	601.0	836.0	32.0	566.0	707.0	97.0	487.0	563.0	180.0
	--	-44.7%	--	+57.7%	--	+1.0%	+5.8%	--	-5.8%	-15.4%	+203.1%	-14.0%	-20.4%	+85.6%
OEM/Integrator	169.0	1,814.0	1,612.0	3,345.0	48.0	2,839.0	5,352.0	294.0	4,193.0	7,071.0	696.0	5,053.0	10,411.0	1,280.0
	+213.0%	+149.5%	+853.8%	+84.4%	--	+76.1%	+60.0%	+512.5%	+47.7%	+32.1%	+136.7%	+20.5%	+47.2%	+83.9%
Total Shipments	389.0	2,826.0	2,402.0	4,668.0	104.0	3,642.0	6,748.0	472.0	4,972.0	8,360.0	1,006.0	5,774.0	11,607.0	1,744.0
	+87.9%	+52.3%	+517.5%	+65.2%	--	+51.6%	+44.6%	+353.8%	+36.5%	+23.9%	+113.1%	+16.1%	+38.8%	+73.4%
ANNUAL SHARE, BY DIAMETER	12.1%	87.9%	33.6%	65.1%	1.3%	33.6%	62.1%	4.3%	34.8%	58.3%	6.9%	30.2%	60.8%	9.0%

TABLE 41

OPTICAL LIBRARIES, 1-39 DISKS

WORLDWIDE SHIPMENTS (SINGLE UNITS)

ERASABLE/WRITE-ONCE DRIVE ANALYSIS

	1991 --Shipments--		Forecast							
			1992		1993		1994		1995	
	Units	%	Units	%	Units	%	Units	%	Units	%
U.S. MANUFACTURERS										
Captive Total	503.0		577.0		693.0		774.0		889.0	
Write-Once	2.0	.4%	1.0	.2%	2.0	.3%	3.0	.4%	4.0	.4%
Erasable	501.0	99.6%	576.0	99.8%	691.0	99.7%	771.0	99.6%	885.0	99.6%
OEM/PCM Total	2,243.0		3,933.0		5,332.0		6,660.0		9,333.0	
Write-Once	950.0	42.4%	1,235.0	31.4%	1,420.0	26.6%	1,650.0	24.8%	1,906.0	20.4%
Erasable	1,293.0	57.6%	2,698.0	68.6%	3,912.0	73.4%	5,010.0	75.2%	7,427.0	79.6%
Total U.S.	2,746.0		4,510.0		6,025.0		7,434.0		10,222.0	
Write-Once	952.0	34.7%	1,236.0	27.4%	1,422.0	23.6%	1,653.0	22.2%	1,910.0	18.7%
Erasable	1,794.0	65.3%	3,274.0	72.6%	4,603.0	76.4%	5,781.0	77.8%	8,312.0	81.3%
NON-U.S. MANUFACTURERS										
Captive Total	225.0		207.0		215.0		234.0		262.0	
Write-Once	218.0	97.0%	197.0	95.3%	203.0	94.5%	214.0	91.6%	234.0	89.4%
Erasable	7.0	3.0%	10.0	4.7%	12.0	5.5%	20.0	8.4%	28.0	10.6%
OEM/PCM Total	244.0		2,457.0		4,622.0		6,670.0		8,641.0	
Write-Once	222.0	91.1%	2,315.0	94.3%	3,651.0	79.1%	4,878.0	73.2%	5,583.0	64.7%
Erasable	22.0	8.9%	142.0	5.7%	971.0	20.9%	1,792.0	26.8%	3,058.0	35.3%
Total Non-U.S.	469.0		2,664.0		4,837.0		6,904.0		8,903.0	
Write-Once	440.0	93.9%	2,512.0	94.4%	3,854.0	79.8%	5,092.0	73.9%	5,817.0	65.4%
Erasable	29.0	6.1%	152.0	5.6%	983.0	20.2%	1,812.0	26.1%	3,086.0	34.6%
WORLDWIDE RECAP										
Total Worldwide Shipments	3,215.0		7,174.0		10,862.0		14,338.0		19,125.0	
	+55.9%		+123.1%		+51.4%		+32.0%		+33.3%	
Write-Once	1,392.0	43.3%	3,748.0	52.3%	5,276.0	48.6%	6,745.0	47.0%	7,727.0	40.4%
	+82.2%		+169.2%		+40.7%		+27.8%		+14.5%	
Erasable	1,823.0	56.7%	3,426.0	47.7%	5,586.0	51.4%	7,593.0	53.0%	11,398.0	59.6%
	+40.4%		+87.9%		+63.0%		+35.9%		+50.1%	

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

READ/WRITE OPTICAL LIBRARIES 40-69 CARTRIDGES

1992 DISK/TREND REPORT

READ/WRITE OPTICAL LIBRARIES
40 - 69 CARTRIDGES

Coverage

Examples of optical disk libraries in this group include:

5.25" disk diameter

Eastman Kodak	560, 560E
Hitachi	OL101-12, OL112-12, OL114-12
Matsushita Electric Industry	LF-J5000A, LF-J7000A
Mitsubishi Electric	MW-5G2-A, ME-5G2-A
NEC	N7925-81, ND3605-19, N5817-31
NKK	N-556E, N-556ET, N-556W, N-556MP
Ricoh	RJ5330E

12" disk diameter

Cygnet Systems	1802
DSM	48
Filenet	OSAR 64
Hitachi	OL321-22/32
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

1991 shipments of optical libraries in this product group rose sharply to 2,341 units, up 86% from 1,253 units in 1990. Shipments of 5.25" units again exceeded shipments of 12" units, capturing 87.1% of worldwide shipments, as compared to 71.8% in 1990. The last 8" optical libraries in this product group were delivered in 1991 and are now out of production.

1991 revenues climbed 58.4 % to $64 million. 21.7% of worldwide revenues were generated by 12" libraries as a result of higher average prices compared to 5.25" libraries. This is markedly lower than the 56.8% share held by 12" drives in

1990, and reflects the rapid growth of 5.25" unit shipments and a moderate decline of 12" library shipments, which was probably due to adverse economic conditions. Growth in 12" library shipments is expected to resume in 1992.

Marketing trends

Forecasted unit shipments will grow to over 5,100 optical disk libraries in 1995 for this product group. The 1995 balance between 12" and 5.25" drive usage will remain heavily in favor of 5.25", and is likely to become more so in 1995 as high capacity 5.25" drives begin to be extensively used.

The number of manufacturers of 12" libraries in this group will probably decline with time, but the number of 5.25" participants is expected to increase somewhat. It is also possible that there may be some 3.5" libraries in this product group within a few years, but the timing is too uncertain to forecast.

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 multifunction drives.

Only 40.9% of the 1991 shipments of libraries in this group involved write-once drives, and in 1995, only a third of the units will have only write-once drives anticipated. The balance could shift more quickly if a true de facto standard for multifunction 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. A considerable percentage of the 5.25" libraries in this category are used in technical design environments where they serve an engineering design team. Few libraries in this category will be used with personal computers because they are too expensive for most installations and the amount of data stored is more than a single user could reasonably use.

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. Some libraries will appear that can mix media types within one library, with the picker mechanism adaptable enough to route media to and from the appropriate drives. The Borett library, which appears in the DISK/TREND product group for libraries with over 70 disks, may be a precursor of similar capabilities in this product group.

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, costs are low, and excellent software tools are available.

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 market 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, although pickers capable of handling several types of media within one library are anticipated.

TABLE 42

OPTICAL LIBRARIES, 40-69 DISKS

REVENUE SUMMARY

	LIBRARY REVENUES, BY SHIPMENT DESTINATION ($M)									
	1991 Revenues		Forecast 1992		1993		1994		1995	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	--	--	.9	1.0	.9	1.0	1.0	1.1	1.1	1.3
TOTAL U.S. CAPTIVE	--	--	.9	1.0	.9	1.0	1.0	1.1	1.1	1.3
PCM/Reseller	--	--	.8	.8	1.3	1.3	1.4	1.4	1.6	1.8
OEM/Integrator	5.2	6.0	9.6	12.4	13.2	16.3	16.7	20.4	19.3	23.8
TOTAL U.S. NONCAPTIVE	5.2	6.0	10.4	13.2	14.5	17.6	18.1	21.8	20.9	25.6
TOTAL U.S. REVENUES	5.2	6.0	11.3	14.2	15.4	18.6	19.1	22.9	22.0	26.9
Non-U.S. Manufacturers										
Captive	--	31.5	--	36.6	.5	37.7	.5	38.5	.5	40.2
PCM/Reseller	1.0	2.2	1.0	1.9	1.1	1.8	1.2	1.9	1.2	1.8
OEM/Integrator	13.1	24.3	13.9	26.3	17.5	31.3	18.7	33.5	21.5	38.5
TOTAL NON-U.S. REVENUES	14.1	58.0	14.9	64.8	19.1	70.8	20.4	73.9	23.2	80.5
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	19.3	64.0	26.2	79.0	34.5	89.4	39.5	96.8	45.2	107.4
OEM Average Price ($000)		26.2		21.7		20.4		19.0		17.3

TABLE 43

OPTICAL LIBRARIES, 40-69 DISKS

UNIT SHIPMENT SUMMARY (SINGLE UNITS)

	LIBRARY UNIT SHIPMENTS, BY SHIPMENT DESTINATION									
	1991		Forecast							
	Shipments		1992		1993		1994		1995	
	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	36.0	35.0	39.0	39.0	44.0	43.0	49.0
TOTAL U.S. CAPTIVE	--	--	32.0	36.0	35.0	39.0	39.0	44.0	43.0	49.0
PCM/Reseller	--	--	59.0	62.0	93.0	96.0	104.0	109.0	114.0	123.0
OEM/Integrator	106.0	122.0	493.0	560.0	707.0	790.0	958.0	1,083.0	1,223.0	1,404.0
TOTAL U.S. NONCAPTIVE	106.0	122.0	552.0	622.0	800.0	886.0	1,062.0	1,192.0	1,337.0	1,527.0
TOTAL U.S. SHIPMENTS	106.0	122.0	584.0	658.0	835.0	925.0	1,101.0	1,236.0	1,380.0	1,576.0
Non-U.S. Manufacturers										
Captive	--	1,058.0	--	1,145.0	15.0	1,194.0	16.0	1,236.0	18.0	1,299.0
PCM/Reseller	58.0	125.0	44.0	86.0	40.0	69.0	40.0	67.0	39.0	65.0
OEM/Integrator	553.0	1,036.0	640.0	1,225.0	820.0	1,543.0	933.0	1,757.0	1,167.0	2,188.0
TOTAL NON-U.S. SHIPMENTS	611.0	2,219.0	684.0	2,456.0	875.0	2,806.0	989.0	3,060.0	1,224.0	3,552.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	717.0	2,341.0	1,268.0	3,114.0	1,710.0	3,731.0	2,090.0	4,296.0	2,604.0	5,128.0
Cumulative Shipments (Single units)										
IBM	--	--	--	--	--	--	--	--	--	--
Non-IBM	1,557.0	4,184.0	2,825.0	7,298.0	4,535.0	11,029.0	6,625.0	15,325.0	9,229.0	20,453.0
WORLDWIDE TOTAL	1,557.0	4,184.0	2,825.0	7,298.0	4,535.0	11,029.0	6,625.0	15,325.0	9,229.0	20,453.0

TABLE 44

OPTICAL LIBRARIES, 40-69 DISKS

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1991 Revenues		Forecast							
	1992		1993		1994		1995			
	12"	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"	5.25"
U.S. MANUFACTURERS										
Other U.S. Captive	--	--	--	1.0	--	1.0	--	1.1	--	1.3
PCM/Reseller	--	--	--	.8	--	1.3	--	1.4	--	1.8
OEM/Integrator	5.7	.3	6.2	6.2	7.2	9.1	7.4	13.0	7.7	16.1
TOTAL U.S. REVENUES	5.7	.3	6.2	8.0	7.2	11.4	7.4	15.5	7.7	19.2
NON-U.S. MANUFACTURERS										
Captive	.1	31.4	5.2	31.4	5.7	32.0	6.1	32.4	6.5	33.7
PCM/Reseller	.1	2.1	.9	1.0	1.2	.6	1.3	.6	1.4	.4
OEM/Integrator	8.0	16.3	8.9	17.4	10.8	20.5	11.6	21.9	12.4	26.1
TOTAL NON-U.S. REVENUES	8.2	49.8	15.0	49.8	17.7	53.1	19.0	54.9	20.3	60.2
WORLDWIDE RECAP										
Captive	.1 -99.0%	31.4 +912.9%	5.2 --	32.4 +3.2%	5.7 +9.6%	33.0 +1.9%	6.1 +7.0%	33.5 +1.5%	6.5 +6.6%	35.0 +4.5%
PCM/Reseller	.1 --	2.1 -27.6%	.9 +800.0%	1.8 -14.3%	1.2 +33.3%	1.9 +5.6%	1.3 +8.3%	2.0 +5.3%	1.4 +7.7%	2.2 +10.0%
OEM/Integrator	13.7 +10.5%	16.6 +118.4%	15.1 +10.2%	23.6 +42.2%	18.0 +19.2%	29.6 +25.4%	19.0 +5.6%	34.9 +17.9%	20.1 +5.8%	42.2 +20.9%
Total Revenues	13.9 -39.6%	50.1 +268.4%	21.2 +52.5%	57.8 +15.4%	24.9 +17.5%	64.5 +11.6%	26.4 +6.0%	70.4 +9.1%	28.0 +6.1%	79.4 +12.8%
ANNUAL SHARE, BY DIAMETER	21.7%	78.3%	26.8%	73.2%	27.9%	72.1%	27.3%	72.7%	26.1%	73.9%

Note: 12" libraries includes 14" libraries.

TABLE 45

OPTICAL LIBRARIES, 40-69 DISKS

WORLDWIDE SHIPMENTS (UNITS)

BREAKDOWN BY DISK DIAMETER

	1991 Shipments		Forecast							
			1992		1993		1994		1995	
	12"	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"	5.25"
U.S. MANUFACTURERS										
Other U.S. Captive	--	--	--	36.0	--	39.0	--	44.0	--	49.0
PCM/Reseller	--	--	--	62.0	--	96.0	--	109.0	--	123.0
OEM/Integrator	98.0	24.0	105.0	455.0	117.0	673.0	121.0	962.0	123.0	1,281.0
TOTAL U.S. SHIPMENTS	98.0	24.0	105.0	553.0	117.0	808.0	121.0	1,115.0	123.0	1,453.0
NON-U.S. MANUFACTURERS										
Captive	2.0	1,056.0	80.0	1,065.0	86.0	1,108.0	91.0	1,145.0	96.0	1,203.0
PCM/Reseller	3.0	122.0	21.0	65.0	28.0	41.0	33.0	34.0	36.0	29.0
OEM/Integrator	200.0	836.0	240.0	985.0	301.0	1,242.0	341.0	1,416.0	374.0	1,814.0
TOTAL NON-U.S. SHIPMENTS	205.0	2,014.0	341.0	2,115.0	415.0	2,391.0	465.0	2,595.0	506.0	3,046.0
WORLDWIDE RECAP										
Captive	2.0 -97.6%	1,056.0 +826.3%	80.0 --	1,101.0 +4.3%	86.0 +7.5%	1,147.0 +4.2%	91.0 +5.8%	1,189.0 +3.7%	96.0 +5.5%	1,252.0 +5.3%
PCM/Reseller	3.0 +200.0%	122.0 -33.7%	21.0 +600.0%	127.0 +4.1%	28.0 +33.3%	137.0 +7.9%	33.0 +17.9%	143.0 +4.4%	36.0 +9.1%	152.0 +6.3%
OEM/Integrator	298.0 +11.2%	860.0 +78.8%	345.0 +15.8%	1,440.0 +67.4%	418.0 +21.2%	1,915.0 +33.0%	462.0 +10.5%	2,378.0 +24.2%	497.0 +7.6%	3,095.0 +30.2%
Total Shipments	303.0 -14.4%	2,038.0 +161.6%	446.0 +47.2%	2,668.0 +30.9%	532.0 +19.3%	3,199.0 +19.9%	586.0 +10.2%	3,710.0 +16.0%	629.0 +7.3%	4,499.0 +21.3%
ANNUAL SHARE, BY DIAMETER	12.9%	87.1%	14.3%	85.7%	14.3%	85.7%	13.6%	86.4%	12.3%	87.7%

Note: 12" libraries includes 14" libraries.

TABLE 46

OPTICAL LIBRARIES, 40-69 DISKS

WORLDWIDE SHIPMENTS (SINGLE UNITS)

ERASABLE/WRITE-ONCE DRIVE ANALYSIS

	1991 --Shipments--		Forecast 1992		1993		1994		1995	
	Units	%	Units	%	Units	%	Units	%	Units	%
U.S. MANUFACTURERS										
Captive Total	--		36.0		39.0		44.0		49.0	
Write-Once	--	--	36.0	100.0%	39.0	100.0%	44.0	100.0%	49.0	100.0%
OEM/PCM Total	122.0		622.0		886.0		1,192.0		1,527.0	
Write-Once	100.0	82.1%	477.0	76.8%	608.0	68.7%	683.0	57.4%	736.0	48.2%
Erasable	22.0	17.9%	145.0	23.2%	278.0	31.3%	509.0	42.6%	791.0	51.8%
Total U.S.	122.0		658.0		925.0		1,236.0		1,576.0	
Write-Once	100.0	82.1%	513.0	78.1%	647.0	70.0%	727.0	58.9%	785.0	49.8%
Erasable	22.0	17.9%	145.0	21.9%	278.0	30.0%	509.0	41.1%	791.0	50.2%
NON-U.S. MANUFACTURERS										
Captive Total	1,058.0		1,145.0		1,194.0		1,236.0		1,299.0	
Write-Once	473.0	44.7%	453.0	39.6%	508.0	42.5%	511.0	41.3%	506.0	39.0%
Erasable	585.0	55.3%	692.0	60.4%	686.0	57.5%	725.0	58.7%	793.0	61.0%
OEM/PCM Total	1,161.0		1,311.0		1,612.0		1,824.0		2,253.0	
Write-Once	384.0	33.1%	385.0	29.4%	444.0	27.5%	435.0	23.8%	417.0	18.5%
Erasable	777.0	66.9%	926.0	70.6%	1,168.0	72.5%	1,389.0	76.2%	1,836.0	81.5%
Total Non-U.S.	2,219.0		2,456.0		2,806.0		3,060.0		3,552.0	
Write-Once	857.0	38.6%	838.0	34.1%	952.0	33.9%	946.0	30.9%	923.0	26.0%
Erasable	1,362.0	61.4%	1,618.0	65.9%	1,854.0	66.1%	2,114.0	69.1%	2,629.0	74.0%
WORLDWIDE RECAP										
Total Worldwide Shipments	2,341.0		3,114.0		3,731.0		4,296.0		5,128.0	
	+99.5%		+33.0%		+19.8%		+15.1%		+19.3%	
Write-Once	957.0	40.9%	1,351.0	43.4%	1,599.0	42.9%	1,673.0	38.9%	1,708.0	33.3%
	+14.0%		+41.1%		+18.3%		+4.6%		+2.0%	
Erasable	1,384.0	59.1%	1,763.0	56.6%	2,132.0	57.1%	2,623.0	61.1%	3,420.0	66.7%
	+314.3%		+27.3%		+20.9%		+23.0%		+30.3%	

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

READ/WRITE OPTICAL LIBRARIES 70 OR MORE CARTRIDGES

1992 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

Borett Automation Technology	VLC
Document Imaging Systems	D75-1, D255-1, D510-2, D1050-2
Docupoint	DP 500
DSM	100, 2000, 5100, 5200, 5500, 6300
Fujitsu	F6445/10, F6445/20, F6445/30
Hewlett-Packard	C1714M, C1715M
Mitsubishi Electric	ME-5G2-B, MW-5G2-B, ME-5G2-C
NKK	N-5160ET, N-5160MP, N-5160MS

12" and 14" disk diameter

Borett Automation Technology	VLC
Cygnet Systems	1800
Eastman Kodak	6800 ADL
Filenet	OSAR models GTX, 144, 288, 340

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 appearing in increasing numbers, and the number of competitors in this corner of the 5.25" arena is expected to increase.

Market status

546 units were shipped in 1991, a whopping 101% increase from 1990, but almost all of the increase was in 5.25" models, which accounted for nearly 46% of shipments. By comparison, in 1990, only 31 units were 5.25" models.

Worldwide revenues rose 97.2% to 49.5 million, up from $25.1 million in 1990. 79.5% of this product category's revenues were generated from sales in the U.S., and 95.3% of worldwide revenues were generated by U.S. manufacturers, the highest U.S. manufacturer revenue percentage among the library product groups.

Hewlett-Packard was the shipment leader for the group in 1991, followed by Filenet and Cygnet. 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. Filenet and Cygnet dominate the 12" segment, accounting for 81% of 12" library shipments.

67.8% of 1991 shipments went through the OEM/Integrator channel, with captive shipments accounting for 31.1%. 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 are expected to increase their participation in this product group, but gaining share against the aggressive U.S. competitors will be difficult. The strongest challenge from non-U.S. firms is expected to be in the 5.25" optical library segment, where competition from NKK will begin in 1992.

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

Worldwide shipments of 4,519 units are anticipated for 1995, with most of the growth being 5.25" units and most being consumed in the U.S. market. U.S. suppliers are expected to remain predominant because of their very strong system support capabilities for larger computing systems. No 3.5" libraries in this product group are anticipated through 1995.

1995 revenue will grow to expand to $257 million, 62.9% of which will be generated in the U.S., reflecting a trend toward larger system configurations and a much greater use of 5.25" systems. The average price per system will decline throughout the forecast period, reflecting the increasing presence of the less

expensive 5.25" systems in the product group.

12" libraries should be able to retain 15.8% of the unit shipments in 1995, but will account for 45.5% of 1995 revenue. The lower prices of the 5.25" libraries will produce a much stronger growth rate for 5.25" libraries than for 12" libraries throughout the forecast period.

Most 12" libraries will use write-once media. 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, the desire to retain compatibility with the installed base, 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 1995 library sales.

Libraries using rewritable disk drives are expected to increase their share of the market from 40.2% in 1991 to 79% in 1995. Most of the rewritable drives will be 5.25" diameter drives, but after 1993 the availability of rewritable 12" drives that have been designed for use in optical libraries is anticipated.

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 tape libraries 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 tape libraries, but IBM's 1992 announcement of support for the 3995 as a virtual 3390-2 disk subsystem under System Managed Storage is expected to significantly increase the appeal of the 3995 optical library.

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. Some library designers are attempting a silo design similar in concept to the tape cartridge library developed by Storage Technology. In Borett's unusual design, the use of an industrial robot permits mixing of various types of media within the library. The robotic mechanism serves a mix of optical and tape drives, and is capable of exchanging its picking mechanism on the fly as necessary to handle the selected type of cartridge.

5.25" drives with higher capacities of 2 gigabytes (1 gigabyte per side) are expected to appear within the forecast period, probably in 1994. 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 systems where multiple accesses for the same mounted data are likely to occur.

Modular systems are becoming increasingly prominent in this product class. Manufacturers including DISC, Docupoint, DSM and others offer a semi-custom configuration permitting a mix of drives and media that balance the need for capacity and library performance. Customers can specify the number and location of drives and cartridge storage modules to optimize performance for their application.

Forecasting assumptions

1. Governments, financial institutions and other large users will continue to be the primary market for libraries in this product group.

2. 5.25", having become the dominant format, will retain that status. 12" is the only other format 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 continue to promote 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.

6. IBM support of the 3995 as a virtual 3390-2 is expected to increase demand for the 3995 and for other libraries in this product class if similar capabilities are provided for them.

TABLE 47

OPTICAL LIBRARIES, 70 OR MORE DISKS

REVENUE SUMMARY

	LIBRARY REVENUES, BY SHIPMENT DESTINATION ($M)									
	1991 Revenues		Forecast 1992		1993		1994		1995	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	20.9	27.7	25.5	49.7	37.7	70.9	49.9	95.8	64.4	122.1
TOTAL U.S. CAPTIVE	20.9	27.7	25.5	49.7	37.7	70.9	49.9	95.8	64.4	122.1
PCM/Reseller	.1	.1	.3	.3	.4	.6	.5	.7	.6	.8
OEM/Integrator	18.2	19.4	47.1	61.1	59.1	78.6	73.1	97.9	91.6	124.1
TOTAL U.S. NONCAPTIVE	18.3	19.5	47.4	61.4	59.5	79.2	73.6	98.6	92.2	124.9
TOTAL U.S. REVENUES	39.2	47.2	72.9	111.1	97.2	150.1	123.5	194.4	156.6	247.0
Non-U.S. Manufacturers										
Captive	--	.4	--	.4	--	.4	--	.3	--	.3
PCM/Reseller	--	.4	.1	.6	.1	.7	.3	.9	.5	1.1
OEM/Integrator	.2	1.5	1.2	3.1	1.9	4.0	4.2	7.7	4.6	8.6
TOTAL NON-U.S. REVENUES	.2	2.3	1.3	4.1	2.0	5.1	4.5	8.9	5.1	10.0
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	39.4	49.5	74.2	115.2	99.2	155.2	128.0	203.3	161.7	257.0
OEM Average Price ($000)		56.8		45.0		40.8		38.1		35.9

TABLE 48

OPTICAL LIBRARIES, 70 OR MORE DISKS

UNIT SHIPMENT SUMMARY (SINGLE UNITS)

	LIBRARY UNIT SHIPMENTS, BY SHIPMENT DESTINATION									
	1991		Forecast							
	Shipments		1992		1993		1994		1995	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	119.0	160.0	160.0	298.0	244.0	439.0	326.0	609.0	426.0	794.0
TOTAL U.S. CAPTIVE	119.0	160.0	160.0	298.0	244.0	439.0	326.0	609.0	426.0	794.0
PCM/Reseller	2.0	2.0	5.0	6.0	6.0	9.0	8.0	11.0	9.0	13.0
OEM/Integrator	321.0	341.0	1,023.0	1,345.0	1,417.0	1,906.0	1,847.0	2,501.0	2,449.0	3,347.0
TOTAL U.S. NONCAPTIVE	323.0	343.0	1,028.0	1,351.0	1,423.0	1,915.0	1,855.0	2,512.0	2,458.0	3,360.0
TOTAL U.S. SHIPMENTS	442.0	503.0	1,188.0	1,649.0	1,667.0	2,354.0	2,181.0	3,121.0	2,884.0	4,154.0
Non-U.S. Manufacturers										
Captive	--	10.0	--	10.0	--	9.0	--	8.0	--	7.0
PCM/Reseller	--	6.0	2.0	7.0	2.0	7.0	4.0	9.0	6.0	12.0
OEM/Integrator	7.0	27.0	41.0	83.0	60.0	120.0	148.0	274.0	186.0	346.0
TOTAL NON-U.S. SHIPMENTS	7.0	43.0	43.0	100.0	62.0	136.0	152.0	291.0	192.0	365.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	449.0	546.0	1,231.0	1,749.0	1,729.0	2,490.0	2,333.0	3,412.0	3,076.0	4,519.0
Cumulative Shipments (Single units)										
IBM	--	--	--	--	--	--	--	--	--	--
Non-IBM	839.0	1,070.0	2,070.0	2,819.0	3,799.0	5,309.0	6,132.0	8,721.0	9,208.0	13,240.0
WORLDWIDE TOTAL	839.0	1,070.0	2,070.0	2,819.0	3,799.0	5,309.0	6,132.0	8,721.0	9,208.0	13,240.0

TABLE 49

OPTICAL LIBRARIES, 70 OR MORE DISKS

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1991 Revenues		Forecast							
			1992		1993		1994		1995	
	12"	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"	5.25"
U.S. MANUFACTURERS										
Other U.S. Captive	26.1	1.6	43.5	6.2	59.9	11.0	79.2	16.6	99.4	22.7
PCM/Reseller	.1	--	.2	.1	.4	.2	.5	.2	.5	.3
OEM/Integrator	10.1	9.3	11.4	49.7	12.8	65.8	14.5	83.4	16.2	107.9
TOTAL U.S. REVENUES	36.3	10.9	55.1	56.0	73.1	77.0	94.2	100.2	116.1	130.9
NON-U.S. MANUFACTURERS										
Captive	--	.4	--	.4	--	.4	--	.3	--	.3
PCM/Reseller	.3	.1	.5	.1	.5	.2	.7	.2	.9	.2
OEM/Integrator	--	1.5	--	3.1	--	4.0	--	7.7	--	8.6
TOTAL NON-U.S. REVENUES	.3	2.0	.5	3.6	.5	4.6	.7	8.2	.9	9.1
WORLDWIDE RECAP										
Captive	26.1 +193.3%	2.0 +900.0%	43.5 +66.7%	6.6 +230.0%	59.9 +37.7%	11.4 +72.7%	79.2 +32.2%	16.9 +48.2%	99.4 +25.5%	23.0 +36.1%
PCM/Reseller	.4 -20.0%	.1 -75.0%	.7 +75.0%	.2 +100.0%	.9 +28.6%	.4 +100.0%	1.2 +33.3%	.4 --	1.4 +16.7%	.5 +25.0%
OEM/Integrator	10.1 -31.8%	10.8 --	11.4 +12.9%	52.8 +388.9%	12.8 +12.3%	69.8 +32.2%	14.5 +13.3%	91.1 +30.5%	16.2 +11.7%	116.5 +27.9%
Total Revenues	36.6 +51.2%	12.9 --	55.6 +51.9%	59.6 +362.0%	73.6 +32.4%	81.6 +36.9%	94.9 +28.9%	108.4 +32.8%	117.0 +23.3%	140.0 +29.2%
ANNUAL SHARE, BY DIAMETER	74.0%	26.0%	48.3%	51.7%	47.4%	52.6%	46.7%	53.3%	45.5%	54.5%

Note: 12" libraries include 14" libraries.

TABLE 50

OPTICAL LIBRARIES, 70 OR MORE DISKS

WORLDWIDE SHIPMENTS (UNITS)

BREAKDOWN BY DISK DIAMETER

	1991 Shipments		Forecast							
			1992		1993		1994		1995	
	12"	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"	5.25"
U.S. MANUFACTURERS										
Other U.S. Captive	141.0	19.0	222.0	76.0	298.0	141.0	388.0	221.0	478.0	316.0
PCM/Reseller	2.0	--	3.0	3.0	5.0	4.0	6.0	5.0	7.0	6.0
OEM/Integrator	150.0	191.0	167.0	1,178.0	186.0	1,720.0	208.0	2,293.0	225.0	3,122.0
TOTAL U.S. SHIPMENTS	293.0	210.0	392.0	1,257.0	489.0	1,865.0	602.0	2,519.0	710.0	3,444.0
NON-U.S. MANUFACTURERS										
Captive	--	10.0	--	10.0	--	9.0	--	8.0	--	7.0
PCM/Reseller	2.0	4.0	3.0	4.0	3.0	4.0	4.0	5.0	5.0	7.0
OEM/Integrator	--	27.0	--	83.0	--	120.0	--	274.0	--	346.0
TOTAL NON-U.S. SHIPMENTS	2.0	41.0	3.0	97.0	3.0	133.0	4.0	287.0	5.0	360.0
WORLDWIDE RECAP										
Captive	141.0 +187.8%	29.0 +314.3%	222.0 +57.4%	86.0 +196.6%	298.0 +34.2%	150.0 +74.4%	388.0 +30.2%	229.0 +52.7%	478.0 +23.2%	323.0 +41.0%
PCM/Reseller	4.0 +33.3%	4.0 -66.7%	6.0 +50.0%	7.0 +75.0%	8.0 +33.3%	8.0 +14.3%	10.0 +25.0%	10.0 +25.0%	12.0 +20.0%	13.0 +30.0%
OEM/Integrator	150.0 -20.2%	218.0 --	167.0 +11.3%	1,261.0 +478.4%	186.0 +11.4%	1,840.0 +45.9%	208.0 +11.8%	2,567.0 +39.5%	225.0 +8.2%	3,468.0 +35.1%
Total Shipments	295.0 +22.9%	251.0 +709.7%	395.0 +33.9%	1,354.0 +439.4%	492.0 +24.6%	1,998.0 +47.6%	606.0 +23.2%	2,806.0 +40.4%	715.0 +18.0%	3,804.0 +35.6%
ANNUAL SHARE, BY DIAMETER	54.1%	45.9%	22.6%	77.4%	19.8%	80.2%	17.8%	82.2%	15.8%	84.2%

Note: 12" libraries include 14" libraries.

TABLE 51

OPTICAL LIBRARIES, 70 OR MORE DISKS

WORLDWIDE SHIPMENTS (SINGLE UNITS)

ERASABLE/WRITE-ONCE DRIVE ANALYSIS

	1991 --Shipments--		Forecast							
			1992		1993		1994		1995	
	Units	%	Units	%	Units	%	Units	%	Units	%
U.S. MANUFACTURERS										
Captive Total	160.0		298.0		439.0		609.0		794.0	
Write-Once	141.0	88.2%	222.0	74.6%	298.0	68.0%	388.0	63.8%	478.0	60.3%
Erasable	19.0	11.8%	76.0	25.4%	141.0	32.0%	221.0	36.2%	316.0	39.7%
OEM/PCM Total	343.0		1,351.0		1,915.0		2,512.0		3,360.0	
Write-Once	154.0	44.9%	190.0	14.1%	230.0	12.0%	267.0	10.6%	303.0	9.0%
Erasable	189.0	55.1%	1,161.0	85.9%	1,685.0	88.0%	2,245.0	89.4%	3,057.0	91.0%
Total U.S.	503.0		1,649.0		2,354.0		3,121.0		4,154.0	
Write-Once	295.0	58.7%	412.0	25.0%	528.0	22.4%	655.0	21.0%	781.0	18.8%
Erasable	208.0	41.3%	1,237.0	75.0%	1,826.0	77.6%	2,466.0	79.0%	3,373.0	81.2%
NON-U.S. MANUFACTURERS										
Captive Total	10.0		10.0		9.0		8.0		7.0	
Write-Once	10.0	100.0%	10.0	100.0%	9.0	100.0%	8.0	100.0%	7.0	100.0%
OEM/PCM Total	33.0		90.0		127.0		283.0		358.0	
Write-Once	21.0	63.7%	59.0	65.7%	63.0	49.6%	112.0	39.6%	163.0	45.5%
Erasable	12.0	36.3%	31.0	34.3%	64.0	50.4%	171.0	60.4%	195.0	54.5%
Total Non-U.S.	43.0		100.0		136.0		291.0		365.0	
Write-Once	31.0	72.2%	69.0	69.1%	72.0	53.0%	120.0	41.2%	170.0	46.6%
Erasable	12.0	27.8%	31.0	30.9%	64.0	47.0%	171.0	58.8%	195.0	53.4%
WORLDWIDE RECAP										
Total Worldwide Shipments	546.0		1,749.0		2,490.0		3,412.0		4,519.0	
	+101.4%		+220.3%		+42.3%		+37.0%		+32.4%	
Write-Once	326.0	59.8%	481.0	27.5%	600.0	24.1%	775.0	22.7%	951.0	21.0%
	+21.6%		+47.5%		+24.7%		+29.1%		+22.7%	
Erasable	220.0	40.2%	1,268.0	72.5%	1,890.0	75.9%	2,637.0	77.3%	3,568.0	79.0%
	--		+476.3%		+49.0%		+39.5%		+35.3%	

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

1992 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. For multifunction drives, an abbreviated form is used: e.g. "Wr. Once,Rewrit".

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

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.

Data transfer rate: The data transfer rate given is the rate from the disk during reading. If two rates are given, the second rate is the maximum data transfer rate from the drive controller to the data bus.

1992 DISK/TREND optical disk product groups

For the 1992 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 following specification section for optical library data.

MANUFACTURER	ATG GIGADISC	ATG GIGADISC	ATG GIGADISC	ATG GIGADISC	ATG GIGADISC
DRIVE	GD 90-MO	GD 1002	GD 6000	GD 6001	GD 9001
DISK/TREND GROUP	11	12	12	12	12
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	86 mm	300 mm	300 mm	300 mm	300 mm
Recording medium	RE-TM Alloy	Au-Cr-Polymer	Au-Cr-Polymer	Au-Cr-Polymer	Au-Cr-Polymer
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Rewritable-(MO)	Write Once	Write Once	Write Once	Write Once
Interface	SCSI-2	SCSI	SCSI	SCSI	SCSI, SCSI-2
Speed control	MCAV	CAV	CAV	CAV	MCAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 250	F: 1,000	F: 3,200	F: 3,200	F: 4,500
Capacity per track (Bytes)	*	F: 25,600	F: 52,428	F: 52,428	*
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	16384	40000	62500	62500	82000
Track density (TPI)	19863	15200	25400	25400	25400
Maximum linear density (BPI)	NS	14514	28200	28200	25400
Rotational speed (RPM)	3000	1121.5	1143	1143	914
PERFORMANCE					
Positioner type	Crs: Linear Motor Fine: Lens Actuator	Crs: Voice Coil Fine: Galvonom.	Crs: Linear Motor Fine: Galvonom.	Crs: Linear Motor Fine: Galvonom.	Crs: Linear Motor Fine: Galvonom.
Servo type	Sampled	Sampled	Sampled	Sampled	Sampled
Average positioning time (msec)	12	110	90	90	90
Within fine band (msec)	NS	8	0.8	0.8	NS
Fine band capacity (Mbytes)	NS	78	16	16	NS
Average rotational delay (msec)	10	26.7	26.2	26.2	33
Average access time (msec)	22	136.7	116.2	116.2	123
Data transfer rate (KBytes/sec)	1000	480	1000	1000	1000
FIRST CUSTOMER SHIPMENT		2Q88	3Q89	4Q90	1991
COMMENTS	*Varies by zone Preliminary specification			Differs from GD 6000 in the cartridge (single operation loading)	*Varies by zone Can read GD 6000 disks

MANUFACTURER	ATG GIGADISC	CANON	CANON	CHEROKEE DATA SYSTEMS	CHEROKEE DATA SYSTEMS
DRIVE	GD 9001/S	MO-5001S	OM-500D	CR6000 CR6120 CR6221/22 CR6300	CR6800 CR6822 CR6835/36 CR6841/42/44 CR6880
DISK/TREND GROUP	12	11	11	11	11
MARKET	OEM	Captive, OEM	Captive, OEM	OEM	OEM
MEDIA: Nominal disk diameter	300 mm	130 mm	130 mm	130 mm	130 mm
Recording medium	Au-Cr-Polymer	Tb-Fe-Co	Bilayer RE-TM	Te-Ox	Te-Ox
Track format	Spiral	Spiral	Spiral	Spiral	Concentric
DRIVE: Operating mode	Write Once	Rewritable-(MO)	Rewritable-(MO)	Write Once	Write Once
Interface	SCSI, SCSI-2	SCSI	Modified ESDI	SCSI	SCSI
Speed control	MCAV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 5,100	F: 256	F: 256	F: 320	F: 320
Capacity per track (Bytes)	*	F: 16,384	F: 16,384	F: 17,408	F: 17,408
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	82000	15728	15728	18750	18750
Track density (TPI)	25400	15875	15875	15875	15875
Maximum linear density (BPI)	25400	21082	21082	24924	24924
Rotational speed (RPM)	914	3000	3000	1800	1800
PERFORMANCE					
Positioner type	Crs: Linear Motor Fine: Galvonom.	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Rack & Pinion Fine: Lens Actuator	Crs: Rack & Pinion Fine: Lens Actuator
Servo type	Sampled	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	90	80	80	112	112
Within fine band (msec)	NS	18	18	50	50
Fine band capacity (Mbytes)	NS	1	1	1.7	1.7
Average rotational delay (msec)	33	10	10	16.5	16.5
Average access time (msec)	123	90	90	128.5	128.5
Data transfer rate (KBytes/sec)	1000	1138	1138	522	522
FIRST CUSTOMER SHIPMENT	2Q92	3/90	4Q88	3/89	1989
COMMENTS	*Varies by zone Can read GD 6000 disks and read/write GD 9001	SCSI controller available. Exchange coupled MO media. External mount	SCSI controller available Exchange coupled MO media		For use in harsh environments

MANUFACTURER	CHINON	EASTMAN KODAK	FUJITSU	FUJITSU	FUJITSU
DRIVE	CDA-431 CDC-431 CDN-431 CDS-431 CDX-431	6800	M2507B	M2511A	F6443
DISK/TREND GROUP	10	12	11	11	12
MARKET	OEM	Captive, OEM	Captive, OEM	Captive, OEM	Captive
MEDIA: Nominal disk diameter	120 mm	14"	130 mm	86 mm	200 mm
Recording medium	Aluminum	Phase Change	RE-TM Alloy	RE-TM Alloy	Tb-Fe-Co
Track format	Spiral	Spiral (Zone)	Spiral	Spiral	Spiral
DRIVE: Operating mode	Read Only	Write Once	Rewritable-(MO)	Rewritable-(MO)	Rewritable-(MO)
Interface	SCSI	SCSI	SCSI-2	SCSI-2	Modified SMD
Speed control	CLV	MCAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 550	F: 5,100	F: 326.4	F: 128	F: 8,900
Capacity per track (Bytes)	F: N/A	F: N/A	F: 17,408	F: 12,800	F: 24,576
Data surfaces per spindle	1	1	1	1	16
Tracks per surface	20750	87354	18751	10000	23640
Track density (TPI)	15875	21160	15875	15875	15875
Maximum linear density (BPI)	27600	21000	24923	24400	19098
Rotational speed (RPM)	500-200	800-1600	5400	3600	1800
PERFORMANCE					
Positioner type	Crs: Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Stepping Motor Fine: Lens Actuator
Servo type	Continuous	Sampled	Continuous	Continuous	Continuous
Average positioning time (msec)	350	500	35	30	200*
Within fine band (msec)	N/A	100	NS	NS	NS
Fine band capacity (Mbytes)	N/A	N/A	NS	NS	NS
Average rotational delay (msec)	110	27	5.6	8.3	16.6
Average access time (msec)	450	527	40.6	38.3	216.6
Data transfer rate (KBytes/sec)	153.6	1000	2080 4100 synch.	1090 4000 synch.	979
FIRST CUSTOMER SHIPMENT	1Q90	1991	6/92	1992	6/89
COMMENTS	41.3 mm high External mount, except CDS-431 Audio output		82 mm high Direct overwrite, 3 beam head	25.4 mm high	8 fixed disks per spindle. 2 actuators, 4 heads/spindle. *Media to media seek is 5 sec.

MANUFACTURER	HEWLETT-PACKARD	HEWLETT-PACKARD	HITACHI	HITACHI	HITACHI
DRIVE	C1716A/M	C1716C	CDR 1600S CDR 1650S	CDR 1700S	CDR 1750S
DISK/TREND GROUP	11	11	10	10	10
MARKET	Captive,OEM,PCM	Captive,OEM,PCM	Captive,OEM,PCM	OEM, PCM	OEM, PCM
MEDIA: Nominal disk diameter	130 mm	130 mm	120 mm	120 mm	120 mm
Recording medium	Tb-Fe-Co	Tb-Fe-Co	Aluminum	Aluminum	Aluminum
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Wr.Once,Rewrit.	Wr.Once,Rewrit.	Read Only	Read Only	Read Only
Interface	SCSI	SCSI-2	SCSI, Prop.	Proprietary	SCSI
Speed control	CAV	CAV	CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 325	F: 325	F: 552.9	F: 682	F: 682
Capacity per track (Bytes)	F: 17,408	F: 17,408	F: N/A	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	18751	18751	20750	20750	20750
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	24902	24902	27600	27600	27600
Rotational speed (RPM)	2400	3600	535-200	530-200	530-200
PERFORMANCE					
Positioner type	Crs: Linear, Voice Coil Fine: NS	Crs: Linear, Voice Coil Fine: NS	Crs: Linear Motor Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Linear Motor Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	95	27	320	320	320
Within fine band (msec)	22	8	N/A	NS	N/A
Fine band capacity (Mbytes)	2.2	2.2	N/A	NS	N/A
Average rotational delay (msec)	12.5	8.3	110	110	110
Average access time (msec)	107.5	35.3	430	430	430
Data transfer rate (KBytes/sec)	680	1000	153.6	153.6	153.6
FIRST CUSTOMER SHIPMENT	2Q89	1Q92	11/89	2Q91	10/91
COMMENTS	Magneto-optic WORM Single-ended interface	Magneto-optic WORM DSP servo	CDR-1650S has SCSI interface	72 mm high External mount	72 mm high External mount

MANUFACTURER	HITACHI	HITACHI	HITACHI	HITACHI	HITACHI
DRIVE	CDR 3600U	CDR 3650U	CDR 3700	CDR 3750	OD 101-1
DISK/TREND GROUP	10	10	10	10	11
MARKET	Captive,OEM,PCM	Captive,OEM,PCM	Captive,OEM,PCM	Captive,OEM,PCM	Captive, OEM
MEDIA: Nominal disk diameter	120 mm	120 mm	120 mm	120 mm	130 mm
Recording medium	Aluminum	Aluminum	Aluminum	Aluminum	Te Alloy
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Read Only	Read Only	Read Only	Read Only	Write Once
Interface	Proprietary	SCSI	Proprietary	SCSI-2	SCSI
Speed control	CLV	CLV	CLV	CLV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 682	F: 682	F: 682	F: 682	F: 300
Capacity per track (Bytes)	F: N/A	F: N/A	F: N/A	F: N/A	F: 16,400
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	20750	20750	20750	18624
Track density (TPI)	15875	15875	15875	15875	16000
Maximum linear density (BPI)	27600	27600	27600	27600	24000
Rotational speed (RPM)	535-200	530-200	530-200	530-200	1800
PERFORMANCE					
Positioner type	Crs: Linear Motor Fine: Lens Actuator	Crs: Linear Motor Fine: Lens Actuator	Crs: Linear Motor Fine: Lens Actuator	Crs: Linear Motor Fine: Lens Actuator	Crs: Voice Coil Fine: Galvonom.
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	380	380	300	300	93
Within fine band (msec)	N/A	N/A	N/A	N/A	NS
Fine band capacity (Mbytes)	N/A	N/A	N/A	N/A	NS
Average rotational delay (msec)	110	110	110	110	16.7
Average access time (msec)	490	490	410	410	109.7
Data transfer rate (KBytes/sec)	153.6	153.6	153.6	153.6	690
FIRST CUSTOMER SHIPMENT	10/89	10/90	2Q92	2Q92	2Q87
COMMENTS	41.3 mm high	41.3 mm high	41.3 mm high	41.3 mm high	

MANUFACTURER	HITACHI	HITACHI	HITACHI	HONEYWELL	IBM
DRIVE	OD 112-1	OD 301A-1	OD 321-1 OD 321-2	AN/MU-928	0162
DISK/TREND GROUP	11	12	12	11	11
MARKET	Captive, OEM	Captive, OEM	Captive, OEM	OEM	Captive
MEDIA: Nominal disk diameter	130 mm	300 mm	300 mm	130 mm	86 mm
Recording medium	Tb-Fe-Co	Te Alloy	Te Alloy	Te Alloy	RE-TM Alloy
Track format	Spiral	Spiral	Spiral	Concentric	Spiral
DRIVE: Operating mode	Rewritable-(MO)	Write Once	Write Once	Write Once	Rewrit/Read On.
Interface	SCSI	SCSI, GPIB, SMD	SCSI	Modified SCSI	SCSI
Speed control	CAV	CAV	MCAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 322	F: 1,310	F: 3,500	F: 260	F: 127/122
Capacity per track (Bytes)	F: 17,408	F: 31,700	F: N/A	F: 20,480	F:12,700/12,200
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	18751	41300	48035	12695	10000
Track density (TPI)	16000	16000	17000	NS	15900
Maximum linear density (BPI)	24000	19500	33200	NS	24400
Rotational speed (RPM)	2400	600	1000	1800	1800
PERFORMANCE					
Positioner type	Crs: Voice Coil Fine: Galvonom.	Crs: Voice Coil Fine: Galvonom.	Crs: Voice Coil Fine: Galvonom	Crs: Stepping Motor Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Sector	Continuous
Average positioning time (msec)	62.5	200	120	125	66
Within fine band (msec)	NS	NS		NS	NS
Fine band capacity (Mbytes)	NS	NS		NS	1
Average rotational delay (msec)	12.5	50	30	17	16.7
Average access time (msec)	75	250	150	142	82.7
Data transfer rate (KBytes/sec)	925	440	1160-2220	562	543.8 4000 synch.
FIRST CUSTOMER SHIPMENT	7/89	3Q85	1Q91	2Q89	4/91
COMMENTS	ISO standard		Pit edge recording Glass substrate	Embedded controller Militarized	41.3 mm high 122 MB with read only media PS/2 series

MANUFACTURER	IBM	IBM	IBM	JVC	KAWASAKI STEEL
DRIVE	MD 3125A	MD 3125B	0632	XR-W1001	KL1200S
DISK/TREND GROUP	11	11	11	11	11
MARKET	OEM	OEM	Captive, OEM	OEM	OEM
MEDIA: Nominal disk diameter	86 mm	86 mm	130 mm	120 mm	130 mm
Recording medium	RE-TM Alloy	RE-TM Alloy	RE-TM Alloy	Organic Dye	Te Alloy
Track format	Spiral	Spiral	Spiral	Spiral	Concentric
DRIVE: Operating mode	Rewrit/Read On.	Rewrit/Read On.	Rewritable-(MO)	Write Once	Write Once
Interface	SCSI	SCSI	SCSI	SCSI	SCSI, PC
Speed control	CAV	CAV	CAV	CLV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 127/122	F: 127/122	F: 325	F: 580	F: 630
Capacity per track (Bytes)	F:12,700/12,200	F:12,700/12,200	F: 17,408	F: N/A	F: 20,480
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	10000	10000	18750	20750	31500
Track density (TPI)	15900	15900	15900	15875	36000 max.
Maximum linear density (BPI)	24400	24400	15900	27600	27000 max.
Rotational speed (RPM)	1800	3000	2400	530-200	1800
PERFORMANCE					
Positioner type	Crs: Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine:	Crs: Stepping Motor Fine: Galvonom.
Servo type	Continuous	Continuous	Continuous	Continuous	Sampled
Average positioning time (msec)	66	40	70	300	90
Within fine band (msec)	NS	--	--	NS	8
Fine band capacity (Mbytes)	1	--	--	NS	4
Average rotational delay (msec)	16.7	10	12.5	110	16.7
Average access time (msec)	82.7	50	82.5	410	106.7
Data transfer rate (KBytes/sec)	543.8 4000 synch.	906 5000 synch.	696 4000 synch.	153.6	600
FIRST CUSTOMER SHIPMENT	4/91	3Q92	2Q92	4/92	3Q89
COMMENTS	41.3 mm high 122 MB with read only media	41.3 mm high 122 MB with read only media		41.3 mm high Embedded SCSI	Grooveless tracking system

MANUFACTURER	LASER MAGNETIC STORAGE	LASER MAGNETIC STORAGE	LASER MAGNETIC STORAGE	LASER MAGNETIC STORAGE	LASER MAGNETIC STORAGE
DRIVE	CM 205 CM 225	CM 214 CM 234	510	1200E 1250E	LD 4100
DISK/TREND GROUP	10	10	11	12	12
MARKET	OEM	OEM	OEM, PCM	OEM, PCM	Captive,OEM,PCM
MEDIA: Nominal disk diameter	120 mm	120 mm	130 mm	12"	12"
Recording medium	Aluminum	Aluminum	Te Alloy	Te Alloy	Te Alloy
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Read Only	Read Only	Write Once	Write Once	Write Once
Interface	PC AT, Prop.	PC AT, Prop.	SCSI	SCSI, ISI	SCSI-2
Speed control	CLV	CLV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 553	F: 553	F: 326.5	F: 1,049.6	F: 5,600
Capacity per track (Bytes)	F: N/A	F: N/A	F: 16,384	F: 32,800	F: 49,808
Data surfaces per spindle	1	1	1	1	2
Tracks per surface	20750	20750	19928	32000	57219
Track density (TPI)	15875	15875	NS	15875	16925-23132
Maximum linear density (BPI)	27600	27600	NS	14111	NS
Rotational speed (RPM)	500-200	500-200	2160	480	855
PERFORMANCE					
Positioner type	Crs: Fine:	Crs: Fine:	Linear, Voice Coil	Linear, Voice Coil	Crs: Linear, Voice Coil Fine: Lens Actuator
Servo type	Continuous	Continuous	Sampled	Sampled	Sampled
Average positioning time (msec)	265	265	61.3	150	80
Within fine band (msec)	--	--	N/A	N/A	NS
Fine band capacity (Mbytes)	--	--	N/A	N/A	NS
Average rotational delay (msec)	110	110	13.7	62.5	35
Average access time (msec)	375	375	75	212.5	130*
Data transfer rate (KBytes/sec)	153.6	153.6	590	313	700
FIRST CUSTOMER SHIPMENT	1992	1992	4Q88	3Q83	2Q90
COMMENTS	41.3 mm high CM 225 is external mount Audio output	41.3 mm high CM 234 is external mount		1250E is rack mounted Has Direct Read During Write	*Includes command latency Has Direct Read During Write

MANUFACTURER	LITERAL	LITERAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL
DRIVE	525 GB+ 525 GBX2+	I-525 MF S-525 MF	CR-501B CR-501S	CR-521B CR-521S	LK-MC501B LK-MC501S
DISK/TREND GROUP	11	11	10	10	10
MARKET	OEM, PCM	OEM, PCM	OEM	OEM	Captive, OEM
MEDIA: Nominal disk diameter	130 mm	130 mm	120 mm	120 mm	120 mm
Recording medium	Te Alloy	TeX/Tb-Fe-Co	Aluminum	Aluminum	Aluminum
Track format	Concentric	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Write Once	Wr.Once/Rewrit.	Read Only	Read Only	Read Only
Interface	SCSI-2	SCSI	SCSI	PC AT	SCSI
Speed control	CAV	CAV	CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 640	F: 326.4	F: 540	F: 540	F: 540
Capacity per track (Bytes)	F: 20,000	F: 17,920	F: N/A	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	32000	20000	20750	20750	20750
Track density (TPI)	35000	16900	15875	15875	15875
Maximum linear density (BPI)	32000	17662	27600	27600	27600
Rotational speed (RPM)	1800	1800	530-200	530-200	530-200
PERFORMANCE					
Positioner type	Crs: Stepping Motor Fine: Lens Actuator	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
Servo type	Sector	Sampled	Continuous	Continuous	Continuous
Average positioning time (msec)	90	53	390	390	390
Within fine band (msec)	8	NS	N/A	N/A	N/A
Fine band capacity (Mbytes)	4	NS	N/A	N/A	N/A
Average rotational delay (msec)	16.7	16.7	110	110	110
Average access time (msec)	106.7	69.7	500	500	500
Data transfer rate (KBytes/sec)	812.5	475	153.6	153.6	153.6
FIRST CUSTOMER SHIPMENT	4/88	2Q91	1Q90	1989	6/91
COMMENTS	525 GBX2+ is external mount; dual drive available	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

MANUFACTURER	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL
DRIVE	LK-MC521B LK-MC521S	LF-3000E LF-3002 LF-3004 LF-3090	LF-3100 LF-3104	LF-5000 LF-5001	LF-5010 LF-5012 LF-5014 LF-5110 LF-5210
DISK/TREND GROUP	10	11	11	11	11
MARKET	Captive, OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	120 mm	86 mm	86 mm	130 mm	130 mm
Recording medium	Aluminum	RE-TM	Tb-Fe-Co	Te-Ox	Te-Ox
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Read Only	Rewritable-(MO)	Rewritable-(MO)	Write Once	Write Once-(PC)
Interface	PC AT	SCSI-2	SCSI	SCSI	SCSI-2
Speed control	CLV	CAV	CAV	CAV	MCAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 540	F: 128	F: 128	F: 200	F: 470
Capacity per track (Bytes)	F: N/A	F: 12,800	F: 12,800	F: 11,776	F: 25,600 avg.
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	10000	10000	17100	18360
Track density (TPI)	15875	15875	15875	15875	16925
Maximum linear density (BPI)	27600	24440	24440	21166	NS
Rotational speed (RPM)	530-200	3000	3000	875	1200
PERFORMANCE					
Positioner type	Crs: DC Motor Lead Screw Fine: Lens Actuator	Crs: Linear, Voice Coil Fine:	Crs: Fine:	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)	390	45	45	190	90
Within fine band (msec)	N/A	--		45	45
Fine band capacity (Mbytes)	N/A	--		.588	NS
Average rotational delay (msec)	110	10	10	34.3	25
Average access time (msec)	500	55	55	224.3	115
Data transfer rate (KBytes/sec)	153.6	937.5	906 1500 avg.	171	861.25
FIRST CUSTOMER SHIPMENT	6/91	4Q91	3Q91	2Q88	3Q89
COMMENTS	41.3 mm high S is external mount Embedded AT	41.3 mm high. LF-3090 is external mount.	41.3 mm high. LF-3100 is external mount.		LF-5010 is external mount. LF-51XX series sold in Japan. LF-52XX series sold in Europe.

MANUFACTURER	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRONIC COMPONENTS	MATSUSHITA ELECTRONIC COMPONENTS
DRIVE	LF-7010 LF-7014 LF-7110	LF-7012 LF-7090	LF-9000 LF-9004 LF-9100	EBP-103	EBP-201
DISK/TREND GROUP	11	11	11	10	10
MARKET	Captive, OEM	Captive, OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	130 mm	130 mm	130 mm	120 mm	120 mm
Recording medium	Ge-Tb-Se	Ge-Tb-Se	Tb-Fe-Co	Aluminum	Aluminum
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Rewritable-(PC)	Rewritable-(PC)	Rewritable-(MO)	Read Only	Read Only
Interface	SCSI-2	SCSI-2	SCSI-2	SCSI, PC	Centronics
Speed control	MCAV	MCAV	CAV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 500/470*	F: 500/470*	F: 326	F: 540	F: 540
Capacity per track (Bytes)	F: NS	F: NS	F: 17,408	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	19968/18360*	19968/18360*	18727	20750	20750
Track density (TPI)	16925	16925	15875	15875	15875
Maximum linear density (BPI)	30480	30480	24937	27600	27600
Rotational speed (RPM)	1800	1800	2400	530-200	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: DC Motor Rack & Pinion Fine: Lens Actuator	Crs: DC Motor Lead Screw Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	90	90	62.5	1590	1590
Within fine band (msec)	45	45	13	N/A	N/A
Fine band capacity (Mbytes)	NS	NS	1.6	N/A	N/A
Average rotational delay (msec)	16.7	16.7	12.5	110	110
Average access time (msec)	106.7	106.7	75	1700	1700
Data transfer rate (KBytes/sec)	990	752 avg. 983 max.	925	153.6	153.6
FIRST CUSTOMER SHIPMENT	4Q90	1991	1Q91	1Q89	1Q89
COMMENTS	*Will operate with WORM media: 470 MB capacity. LF-7110 sold in Japan.	*Will operate with WORM media: 470 MB capacity. LF-7090 is external mount.	Glass substrate LF-9000 is external mount. LF-9100 sold only in Japan.	50 mm high Pop up loading model	55 mm high Stand-alone model

MANUFACTURER	MATSUSHITA ELECTRONIC COMPONENTS	MATSUSHITA ELECTRONIC COMPONENTS	MATSUSHITA ELECTRONIC COMPONENTS	MAXIMUM STORAGE	MAXIMUM STORAGE
DRIVE	EBP-302	EBP-401	EBP-501	APX-3200	APX-5100 APX-5200
DISK/TREND GROUP	10	10	10	11	11
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	120 mm	120 mm	120 mm	130 mm	130 mm
Recording medium	Aluminum	Aluminum	Aluminum	Te Alloy	Te Alloy
Track format	Spiral	Spiral	Spiral	Concentric	Concentric
DRIVE: Operating mode	Read Only	Read Only	Read Only	Write Once	Write Once
Interface	SCSI	Proprietary	Proprietary	Mod. ESDI, PC	Modified ESDI
Speed control	CLV	CLV	CLV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 540	F: 540	F: 540	F: 122	F: 501.8
Capacity per track (Bytes)	F: N/A	F: N/A	F: N/A	F: 8,192	F: 16,384
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	20750	20750	14901	30626
Track density (TPI)	15875	15875	15875	14100	26458
Maximum linear density (BPI)	27600	27600	27600	11400	17665
Rotational speed (RPM)	530-200	530-200	530-200	1800	1800
PERFORMANCE					
Positioner type	Crs: Stepping Motor Fine: Lens Actuator	Crs: DC Motor, Lead Screw Fine: Lens Actuator	Crs: DC Motor, Lead Screw Fine: Lens Actuator	Crs: Stepping Motor Fine: Lens Actuator	Crs: Stepping Motor Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Sector	Sector
Average positioning time (msec)	440	1590	1590	118	NS
Within fine band (msec)	N/A	N/A	N/A	20	NS
Fine band capacity (Mbytes)	N/A	N/A	N/A	1.31	NS
Average rotational delay (msec)	110	110	110	16.7	16.7
Average access time (msec)	550	1700	1700	134.7	NS
Data transfer rate (KBytes/sec)	153.6	153.6	153.6	312.5	625
FIRST CUSTOMER SHIPMENT	1Q91	2Q91	3Q91	3Q87	10/89
COMMENTS	41.3 mm high Caddy loading model	52 mm high For automobile use	50 mm high Drawer loading model		APX-5200 is external mount Rack & Pinion coarse positioner

MANUFACTURER	MAXOPTIX	MAXOPTIX	MAXOPTIX	MITSUBISHI ELECTRIC CORPORATION	MITSUBISHI ELECTRIC CORPORATION
DRIVE	Tahiti II Tahiti II SD	Tahiti IIM	Tahiti I	ME-3E1 ME-3U1	ME-5E1 ME-5U1
DISK/TREND GROUP	11	11	11	11	11
MARKET	OEM, PCM	OEM, PCM	OEM, PCM	OEM	OEM
MEDIA: Nominal disk diameter	130 mm	130 mm	130 mm	86 mm	130 mm
Recording medium	RE-TM Alloy	RE-TM Alloy	RE-TM Alloy	Tb-Fe-Co	Tb-Fe-Co
Track format	Spiral, (Zone)	Spiral, (Zone)	Spiral, (Zone)	Spiral	Spiral
DRIVE: Operating mode	Rewritable-(MO)	Wr.Once,Rewrit.	Rewritable-(MO)	Rewritable-(MO)	Rewritable-(MO)
Interface	SCSI-2	SCSI-2	SCSI	SCSI	ESDI, SCSI
Speed control	CAV, MCAV	CAV, MCAV	CAV, MCAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 512/326.4	F: 512/326.4	F: 512/326.4	F: 128	F: 297/326
Capacity per track (Bytes)	F:25,000/17,408	F:25,000/17,408	F:25,000/17,408	F: 12,800	F:15,872/17,408
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	25000	25000	25000	10000	18750
Track density (TPI)	16933	16933	16933	15875	15875
Maximum linear density (BPI)	25000*	25000*	25000*	24500	25000
Rotational speed (RPM)	2200	2200	2200	3000	2400
PERFORMANCE					
Positioner type	Crs: Voice Coil 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	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	35	35	35	42	35.5
Within fine band (msec)	20.5/16	20.5/16	20.5/16	2.0	1.5
Fine band capacity (Mbytes)	2	2	2	0.4	.317
Average rotational delay (msec)	13.6	13.6	13.6	10	12.5
Average access time (msec)	48.6	48.6	48.6	52	48
Data transfer rate (KBytes/sec)	1200/840	1200/840	500/350	906	925
FIRST CUSTOMER SHIPMENT	1/91	5/92	11/89	3Q91	2Q90
COMMENTS	SD version is for library use *2,7 RLL Code	CCW WORM media per DIS 11560 *2,7 RLL Code	*2,7 RLL Code	41.3 mm high ME-3U1 is external mount	ME-5U1 is external mount

MANUFACTURER	MITSUBISHI ELECTRIC CORPORATION	MITSUBISHI ELECTRIC CORPORATION	MITSUMI ELECTRIC	MITSUMI ELECTRIC	MITSUMI ELECTRIC
DRIVE	MW-5D1 MW-5U1	MW-5E3 MW-5U3	CRMC-FRO	CRMC-LUO	CRS-UF
DISK/TREND GROUP	11	11	10	10	10
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	130 mm	130 mm	120 mm	120 mm	120 mm
Recording medium	Te-Se	Te-Se	Aluminum	Aluminum	Aluminum
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Write Once	Write Once	Read Only	Read Only	Read Only
Interface	ESDI, SCSI	SCSI	PC XT	PC XT	PC XT
Speed control	CAV	CAV	CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 297	F: 297/326	F: 540	F: 540	F: 540
Capacity per track (Bytes)	F: 15,872	F:15,872/17,408	F: N/A	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	18750	18750	20750	20750	20750
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	25000	25000	27600	27600	27600
Rotational speed (RPM)	1800	2400	500-200	500-200	500-200
PERFORMANCE					
Positioner type	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Motor, Lead Screw Fine: Lens Actuator	Crs: Motor, Lead Screw Fine: Lens Positioner	Crs: Motor, Lead Screw Fine: Lens Positioner
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	63	35.5	430	385	540
Within fine band (msec)	1.5	1.5	N/A	N/A	N/A
Fine band capacity (Mbytes)	.317	.317	N/A	N/A	N/A
Average rotational delay (msec)	17	12.5	110	110	110
Average access time (msec)	80	48	540	490	650
Data transfer rate (KBytes/sec)	687.5	925	153.6	153.6	153.6
FIRST CUSTOMER SHIPMENT	1Q88	4Q91	10/91	2/91	8/91
COMMENTS	MW-5U1 includes controller; free standing package	MW-5U3 is external mount	73.5 mm high Front loading	41.3 mm high Top Loading	External model Front loading

MANUFACTURER	MITSUMI ELECTRIC	MOST	MOST	MOUNTAIN OPTECH	MOUNTAIN OPTECH
DRIVE	CRS-XP	RMD 5100-S	RMD 5200-S	SI-250 R/W	CS-1000 R/W SE-1000 R/W SS-1000 R/W
DISK/TREND GROUP	10	11	11	11	11
MARKET	OEM	OEM, PCM	OEM, PCM	OEM	OEM
MEDIA: Nominal disk diameter	120 mm	86 mm	86 mm	86 mm	130 mm
Recording medium	Aluminum	RE-TM Alloy	RE-TM Alloy	RE-TM Alloy	RE-TM Alloy
Track format	Spiral	Spiral	Spiral	Spiral	Spiral (Zone)
DRIVE: Operating mode	Read Only	Rewritable-(MO)	Rewritable-(MO)	Rewritable-(MO)	Rewritable-(MO)
Interface	PC XT	SCSI	SCSI-1/2	SCSI	SCSI
Speed control	CLV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 540	F: 127.3	F: 127.3/254*	F: 128	F: 512/326.4
Capacity per track (Bytes)	F: N/A	F: 12,800	F: 12,800/**	F: 12,800	F:25,000/17,408
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	10000	10000	10000	25000
Track density (TPI)	15875	15875	15875	15900	16933
Maximum linear density (BPI)	27600	15875	15875/39625	24400	25000
Rotational speed (RPM)	500-200	2400	2400	1800	2200
PERFORMANCE					
Positioner type	Crs: Motor, Lead Screw Fine: Lens Positioner	Crs: Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator	Crs: NS Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	900	35.2	35.2	60	35
Within fine band (msec)	N/A	12	12	NS	20.5/16
Fine band capacity (Mbytes)	N/A	1.63	1.63/**	1.0	2
Average rotational delay (msec)	110	12.5	12.5	16.6	13.6
Average access time (msec)	1010	47.7	47.7	76.6	48.6
Data transfer rate (KBytes/sec)	153.6	512	512/820-1200	543.8	1250/880
FIRST CUSTOMER SHIPMENT	9/91	4Q90	2Q92	4Q92	2Q91
COMMENTS	Portable model Top loading	41.3 mm high	41.3 mm high *Zoned recording **Varies by zone OROM support	Ruggedized Preliminary specification	Ruggedized version of Maxtor Tahiti SE-1000 is for military use

MANUFACTURER	MOUNTAIN OPTECH	MOUNTAIN OPTECH	MOUNTAIN OPTECH	NEC	NEC
DRIVE	CS-400	SE-400M	SEL-2C SEL-2-SAMS	CDR-25	CDR-37
DISK/TREND GROUP	11	11	11	10	10
MARKET	OEM	OEM	OEM	OEM, PCM	OEM, PCM
MEDIA: Nominal disk diameter	130 mm	130 mm	130 mm	120 mm	120 mm
Recording medium	Te Alloy	Te Alloy	Te Alloy	Aluminum	Aluminum
Track format	Concentric	Concentric	Concentric	Spiral	Spiral
DRIVE: Operating mode	Write Once	Write Once	Write Once	Read Only	Read Only
Interface	SCSI, PC AT	SCSI, PC AT	SCSI, PC AT	SCSI	SCSI
Speed control	CAV	CAV	CAV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 202	F: 202	F: 202	F: 540	F: 540
Capacity per track (Bytes)	F: 10,752	F: 10,752	F: 10,752	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	18826	18826	18826	20750	20750
Track density (TPI)	15625	15625	15625	15875	15875
Maximum linear density (BPI)	14620	14620	14620	27600	27600
Rotational speed (RPM)	1200	1200	1200	530-200	530-200
PERFORMANCE					
Positioner type	Crs: Stepping Motor Fine: Lens Actuator	Crs: Stepping Motor Fine: Lens Actuator	Crs: Stepping Motor 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	170	170	690	390
Within fine band (msec)	15	15	15	N/A	N/A
Fine band capacity (Mbytes)	.32	.32	.32	N/A	N/A
Average rotational delay (msec)	25	25	25	110	110
Average access time (msec)	195	195	195	800	500
Data transfer rate (KBytes/sec)	275	275	275	153.6	153.6
FIRST CUSTOMER SHIPMENT	1986	2Q91	1987	3Q92	4/91
COMMENTS		Designed to meet MIL-SPEC 883 for space applications	Ruggedized CS-400 MicroVax interface available	Portable model	Portable model For German market

MANUFACTURER	NEC	NEC	NEC	NEC	NEC
DRIVE	CDR-73M CDR-74 CDR-83M CDR-84	PC-CD10	PC-CD103 N5267-38 N7914-81	PI-CD1	N1137-04 N7915-11 N7915-84 PC-0D102
DISK/TREND GROUP	10	10	10	10	11
MARKET	OEM, PCM	Captive	Captive	Captive	Captive
MEDIA: Nominal disk diameter	120 mm	120 mm	120 mm	120 mm	130 mm
Recording medium	Aluminum	Aluminum	Aluminum	Aluminum	Tb-Fe-Co
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Read Only	Read Only	Read Only	Read Only	Rewritable-(MO)
Interface	SCSI	SCSI	SCSI	Proprietary	SCSI
Speed control	CLV	CLV	CLV	CLV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 540	F: 540	F: 540	F: 540	F: 305
Capacity per track (Bytes)	F: N/A	F: N/A	F: N/A	F: N/A	F: 17,408
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	20750	20750	20750	18751
Track density (TPI)	15875	15875	15875	15875	15375
Maximum linear density (BPI)	27600	27600	27600	27600	25000
Rotational speed (RPM)	1060-400	530-200	530-200	530-200	3000
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: Gear Mechanism Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	225	1390	240	1390	60
Within fine band (msec)	N/A	NS	N/A	N/A	NS
Fine band capacity (Mbytes)	N/A	NS	N/A	N/A	NS
Average rotational delay (msec)	55	110	110	110	10
Average access time (msec)	280	1500	350	1500	70
Data transfer rate (KBytes/sec)	307.2	153.6	153.6	153.6	1500
FIRST CUSTOMER SHIPMENT	1992	11/90	3Q90	12/88	1Q91
COMMENTS	CDR-73M is external mount CDR-74 is for German market	External model for PC 9800 series		Used with NEC PC engine	

MANUFACTURER	NEC	NEC	NEC	NEC	NEC
DRIVE	N5267-37 N7915	ND-3605-13	PC-OD301	N6513-20	N6513-23 N7913
DISK/TREND GROUP	11	11	11	12	12
MARKET	Captive	Captive	Captive	Captive	Captive
MEDIA: Nominal disk diameter	130 mm	130 mm	86 mm	12"	12"
Recording medium	Tb-Fe-Co	Te Alloy	Tb-Fe-Co	Te Alloy	Te Alloy
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Rewritable-(MO)	Write Once	Rewritable-(MO)	Write Once	Write Once
Interface	SCSI	SCSI	SCSI	SCSI, Prop.	Prop., SCSI
Speed control	CAV	CAV	CAV	Zone CLV	MCAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 305	F: 305	F: 128	F: 1,800	F: 2,500
Capacity per track (Bytes)	F: 17,408	F: 17,408	F: 12,800	F:29,500-56,500	F: NS
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	18751	18751	10000	41000	49000
Track density (TPI)	15875	15375	15375	15875	16940
Maximum linear density (BPI)	25000	25000	24500	20000	25000
Rotational speed (RPM)	1800	1800	3000	600-330	600
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: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	68	85	40	650	150
Within fine band (msec)	NS	NS	NS	NS	NS
Fine band capacity (Mbytes)	NS	NS	NS	NS	NS
Average rotational delay (msec)	16.7	16.6	10	70	50
Average access time (msec)	84.7	101.6	50	720	200
Data transfer rate (KBytes/sec)	1500	1500	1500	452	900
FIRST CUSTOMER SHIPMENT	8/89	7/90	1992	1Q87	6/90
COMMENTS					

MANUFACTURER	NIKON	OLYMPUS	PHILIPS CONSUMER ELECTRONICS	PHILIPS CONSUMER ELECTRONICS	PHILIPS CONSUMER ELECTRONICS
DRIVE	MO-DD120-1A	MOS300E	CDD401	CDD461 CDD461RS	CDI601 CDI602
DISK/TREND GROUP	12	11	10	10	10
MARKET	OEM	OEM	PCM	PCM	Captive
MEDIA: Nominal disk diameter	12"	86 mm	120 mm	120 mm	120 mm
Recording medium	Tb-Fe,Gd-Fe-Co	Tb-Fe-Co	Aluminum	Aluminum	Aluminum
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Rewritable-(MO)	Rewritable-(MO)	Read Only	Read Only	Read Only
Interface	SCSI	SCSI-2	Serial	Serial	Serial
Speed control	CAV	CAV	CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 1,750/2,000*	F: 128	F: 540	F: 645	F: 540
Capacity per track (Bytes)	F: 51721/59111*	F: 12,800	F: N/A	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	33755	10000	20750	20750	20750
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	30600	24440	27600	27600	27600
Rotational speed (RPM)	1500	3600	500-200	500-200	500-200
PERFORMANCE					
Positioner type	Crs: Voice Coil Fine: Galvonom.	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Rotary Galvonometer Fine:	Crs: Rotary Galvonometer Fine:	Crs: Rotary Galvonometer Fine:
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	69	38	500	700	800
Within fine band (msec)	5	8	N/A	N/A	N/A
Fine band capacity (Mbytes)	1.12	.320	N/A	N/A	N/A
Average rotational delay (msec)	20	8.3	110	110	110
Average access time (msec)	89	46.3	610	810	910
Data transfer rate (KBytes/sec)	1430	768 3000 synch.	153.6	153.6	153.6
FIRST CUSTOMER SHIPMENT	1/92	1/92	1990	4/91	1990
COMMENTS	*Sector size 512B/1024B	41.3 mm high	External mount	External mount	External mount CDI602 includes floppy disk drive CDI player

MANUFACTURER	PHILIPS CONSUMER ELECTRONICS	PHILIPS CONSUMER ELECTRONICS	PHILIPS CONSUMER ELECTRONICS	PINNACLE MICRO	PIONEER
DRIVE	CDI910	CDM50	CDD521	PMO-650	DRM-600/610
DISK/TREND GROUP	10	10	11	11	10
MARKET	Captive	PCM	OEM, PCM	OEM, PCM	OEM
MEDIA: Nominal disk diameter	120 mm, 80 mm	120 mm	120 mm	130 mm	120 mm
Recording medium	Aluminum	Aluminum	Aluminum	RE-TM Alloy	Aluminum
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Read Only	Read Only	Write Once	Rewritable-(MO)	Read Only
Interface	Proprietary	PC AT	SCSI	SCSI	SCSI
Speed control	CLV	CLV	CLV	CAV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 554	F: 540	F: 540	F: 326.4	F: 540
Capacity per track (Bytes)	F: N/A	F: N/A	F: N/A	F: 17,408	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	20750	20750	18751	20750
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	27600	27600	24902	27600
Rotational speed (RPM)	500-200	500-200	1000-400	3600	530-220
PERFORMANCE					
Positioner type	Crs: Rotary, Galvonometer Fine:	Crs: Rotary Galvonometer Fine:	Crs: Linear Motor 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)	--	690	1000	NA	600
Within fine band (msec)	--	N/A	N/A	NS	NS
Fine band capacity (Mbytes)	--	N/A	N/A	NS	NS
Average rotational delay (msec)	110	110	110	8.3	110
Average access time (msec)	--	800	1110	NA	710
Data transfer rate (KBytes/sec)	153.6	153.6	307.2	1400 4200 synch.	153.6
FIRST CUSTOMER SHIPMENT	10/91	6/91	3/92	1992	4Q89
COMMENTS	External mount CDI player	External mount Top loading LMSI mechanism	External mount CDR drive	Mechanism from Olympus	Integral with 6 disk changer. Disk change time is 7 sec. Includes audio output.

MANUFACTURER	PIONEER	PIONEER	PIONEER	PIONEER	PIONEER
DRIVE	DRM-604X	DD-M5101	DD-S5101 DD-U5101 DDJ-U5101	DDJ-U7001	DE-S7001 DE-U7001
DISK/TREND GROUP	10	11	11	11	11
MARKET	OEM, PCM	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: 540	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)	2120-880*	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)	300	60	60	60	53.3
Within fine band (msec)	NA	NS	NS	NS	27
Fine band capacity (Mbytes)	NA	NS	NS	NS	.819
Average rotational delay (msec)	28	16.7	16.7	16.7	16.7
Average access time (msec)	328	76.7	76.7	76.7	70
Data transfer rate (KBytes/sec)	614.4	742.5	742.5	491	491
FIRST CUSTOMER SHIPMENT	3Q92	2Q88	2Q88	4/91	6/90
COMMENTS	Includes 6 disk changer. *Optional RPM range 530-200. Multi-session compatible.	41.3 mm high Mechanism only. External SCSI controller board available	DD-S5101 is external mount DDJ for use with optical libraries	For use with optical libraries	DE-S7001 is external mount

MANUFACTURER	PIONEER	RICOH	RICOH	RICOH	RICOH
DRIVE	DEJ-U7001	RO-3010E RS-3100E	RO-5030E RO-5030E-II RS-9200E-II	RO-5031E RS-9200EX	RO-5043 RS-8200 RS-9100
DISK/TREND GROUP	11	11	11	11	11
MARKET	OEM	OEM	Captive, OEM	OEM	Captive, OEM
MEDIA: Nominal disk diameter	130 mm	86 mm	130 mm	130 mm	130 mm
Recording medium	Tb-Fe-Co/Dye	RE-TM Alloy	RE-TM(Tb-Fe-Co)	Tb-Fe-Co	Cyanine Dye
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Wr.Once/Rewrit.	Rewritable-(MO)	Rewritable-(MO)	Rewritable-(MO)	Write Once
Interface	SCSI	SCSI-2	SCSI	SCSI	SCSI
Speed control	CAV	CAV	CAV	CAV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 327	F: 127.4	F: 297/326	F: 297/326	F: 393
Capacity per track (Bytes)	F: 16,384	F: 12,740	F:15,872/17,408	F:15,872/17,408	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	19958	10000	18750	18750	18750
Track density (TPI)	15875	15875	18875	15875	15900
Maximum linear density (BPI)	15875	24440	24902	24923	32200
Rotational speed (RPM)	1800	3000	1800	3600	668-334
PERFORMANCE					
Positioner type	Crs: Linear, Voice Coil Fine: Galvonom.	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: Voice Coil	Linear, Voice Coil	Crs: Voice Coil Fine: Voice Coil
Servo type	Sampled	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	53.3	33	50	29	108
Within fine band (msec)	27		NS	NS	NS
Fine band capacity (Mbytes)	.819		NS	NS	N/A
Average rotational delay (msec)	16.7	10	16.7	8.3	60
Average access time (msec)	70	43	66.7	37.3	168
Data transfer rate (KBytes/sec)	491	640	625	1250	312.5
FIRST CUSTOMER SHIPMENT	4/91	12/91	1Q90	4Q91	2Q90
COMMENTS	For use with optical libraries	41.3 mm high RS-3100E is external version	Embedded SCSI controller. E-II supports ISO and E form. RS-9200E-II is external vers.	Embedded SCSI controller Split optics RS-9200EX is external version	41.3 mm high. SCSI controller included RS-8200 & 9100 are external versions

MANUFACTURER	SANYO	SANYO	SANYO	SANYO	SHARP
DRIVE	ROM-3000U ROM-3000US	ROM-4015U	ROM-4026U	ROM-PD1	JY-700 JY-7000
DISK/TREND GROUP	10	10	10	10	11
MARKET	OEM	OEM	OEM	OEM, PCM	OEM, PCM
MEDIA: Nominal disk diameter	120 mm	120 mm	120 mm	120 mm/180 mm	130 mm
Recording medium	Aluminum	Aluminum	Aluminum	Aluminum	RE-TM(Tb-Fe-Co)
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Read Only	Read Only	Read Only	Read Only	Rewritable-(MO)
Interface	Proprietary	Proprietary	SCSI	PC AT/Centronic	SCSI
Speed control	CLV	CLV	CLV	CLV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 540	F: 540	F: 540	F: 540/180	F: 326
Capacity per track (Bytes)	F: N/A	F: N/A	F: N/A	F: N/A	F: 17,408
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	20750	20750	20750	18751
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	27600	27600	27600	33200*
Rotational speed (RPM)	530-200	530-200	530-200	530-200	2400
PERFORMANCE					
Positioner type	Crs: Linear Fine: Lens Actuator	Crs: Linear Fine: Lens Actuator	Crs: Linear Fine: Lens Actuator	Crs: Fine:	Crs: Linear, Voice Coil Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	500	500	500	900	60
Within fine band (msec)	N/A	N/A	N/A	--	NS
Fine band capacity (Mbytes)	N/A	N/A	N/A	--	NS
Average rotational delay (msec)	108	108	108	110	12.5
Average access time (msec)	608	608	608	1010	72.5
Data transfer rate (KBytes/sec)	153.6	153.6	153.6	153.6	793
FIRST CUSTOMER SHIPMENT	2/88	5/89	8/89	6/91	1/90
COMMENTS	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	Has audio output External mount Top loading	*2,7 RLL Code JY-7000 is external mount

MANUFACTURER	SHARP	SONY	SONY	SONY	SONY
DRIVE	JY-750 JY-7500	CDU-31A	CDU-535	CDU-541	CDU-561
DISK/TREND GROUP	11	10	10	10	10
MARKET	OEM, PCM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	130 mm	120 mm	120 mm	120 mm	120 mm
Recording medium	RE-TM(Tb-Fe-Co)	Aluminum	Aluminum	Aluminum	Aluminum
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Rewritable(MO)*	Read Only	Read Only	Read Only	Read Only
Interface	SCSI, SCSI-2	Proprietary	Proprietary	SCSI	SCSI
Speed control	CAV	CLV	CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 326	F: 540	F: 540	F: 540	F: 540
Capacity per track (Bytes)	F: 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	18751	20750	20750	20750	20750
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	33200**	27600	27600	27600	27600
Rotational speed (RPM)	3000	530-230	500-200	500-200	*
PERFORMANCE					
Positioner type	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: DC Motor, Gear Fine: Lens Actuator	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)	40	380	230	270	240
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)	10	110	110	110	55/110
Average access time (msec)	50	490	340	380	295/350
Data transfer rate (KBytes/sec)	870 4000 synch.	150	150	150	307.2/153.6
FIRST CUSTOMER SHIPMENT	3Q92	1992	1990	1989	1992
COMMENTS	41.3 mm high *CCW compatible **2,7 RLL Code JY-7500 is external mount		Has audio output	Has audio output	*2 speed ranges: 1160-460 530-230

MANUFACTURER	SONY	SONY	SONY	SONY	SONY
DRIVE	CDU-6205	CDU-6211 CDU-7211	CDU-6251	DD-1EX DD-10X Data Discman	DD-DR1 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	80 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	Proprietary	RS232C
Speed control	CLV	CLV	CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 540	F: 540	F: 540	F: 184	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	9062	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	500-300	500-300
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: DC Motor Fine: Lens Actuator	Crs: DC Motor Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	230	270	270	NS	NS
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	65	65
Average access time (msec)	340	380	380	NS	NS
Data transfer rate (KBytes/sec)	150	150	150	9.4	9.4
FIRST CUSTOMER SHIPMENT	1990	1989	1989	7/90	
COMMENTS	External mount Has audio output	External mount Has audio output	External mount 2 drives in a single mount		

MANUFACTURER	SONY	SONY	SONY	SONY	SONY
DRIVE	CDW-900E	SMO-D301 SMO-P301 SMO-S301	SMO-E501	SMO-E511	SMO-S501A
DISK/TREND GROUP	11	11	11	11	11
MARKET	Captive	OEM	Captive, OEM	Captive, OEM	Captive, OEM
MEDIA: Nominal disk diameter	120 mm	86 mm	130 mm	130 mm	130 mm
Recording medium	Dye Polymer	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)	Wr.Once/Rewrit.	Rewritable-(MO)
Interface	SCSI	SCSI, SCSI-2	SCSI, ESDI	SCSI	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)	1000-200	3000	2400	2400	2400
PERFORMANCE					
Positioner type	Crs: Linear, Voice Coil Fine: Lens Actuator	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	70	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	92.5	92.5	92.5
Data transfer rate (KBytes/sec)	150-300	625	680	680	680
FIRST CUSTOMER SHIPMENT	1992	1991	3Q90	1991	2Q88
COMMENTS	Sold only with mastering system	41.3 mm high. P301 has integrated controller. S301 is external mount	Embedded SCSI controller	Embedded SCSI controller	ISO standard External mount

MANUFACTURER	SONY	SONY	SONY	TEAC	TEXEL (SHINANO KENSHI)
DRIVE	WDD-3000	WDD-600	WDD-931	OD-3000	DM-3011 DM-3021 DM-5011 DM-5021
DISK/TREND GROUP	12	12	12	11	10
MARKET	Captive, OEM	Captive, OEM	Captive, OEM	OEM	OEM
MEDIA: Nominal disk diameter	12"	12"	12"	86 mm	120 mm
Recording medium	Se-Sb, Bi-Te	Se-Sb, Bi-Te	Se-Sb, Bi-Te	Tb-Fe-Co	Aluminum
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Write Once	Write Once	Write Once	Rewritable-(MO)	Read Only
Interface	SCSI	SCSI	SCSI-2	SCSI-2	SCSI
Speed control	CAV, CLV	CAV, CLV	CAV, CLV	CAV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 1,100/1,600	F: 2,180/3,275	F: 2,180/3,275	F: 128	F: 599
Capacity per track (Bytes)	F: 25,600/N/A	F: NS	F: NS	F: 12,800	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	43750	43750	43750	10000	20750
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	24937	49874	49874	24440	25400
Rotational speed (RPM)	720/720-360	720/720-360	1080/1080-540	3000	530-200
PERFORMANCE					
Positioner type	Crs: Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine:	Crs: Voice Coil Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	250/620	180/400	180/400	42	340
Within fine band (msec)	25	20	20		N/A
Fine band capacity (Mbytes)	1.25	1.25	1.25		N/A
Average rotational delay (msec)	42/62.5	41/55	27/36.7	10	110
Average access time (msec)	292/682.5	221/455	221/455	52	450
Data transfer rate (KBytes/sec)	300	600	900	640	153.6
FIRST CUSTOMER SHIPMENT	1Q85	3Q89	2Q92	4Q91	2/90
COMMENTS		Downward compatible with WDD 3000	Downward compatible with WDD-600 & WDD-3000	41.3 mm high 128K buffer	41.3 mm high Uses Sony caddy DM-5XXX is external mount

MANUFACTURER	TEXEL (SHINANO KENSHI)	TOSHIBA	TOSHIBA	TOSHIBA	TOSHIBA
DRIVE	DM-3110 DM-3120 DM-5110 DM-5120 DM-7120	TXM-3301A1 TXM-3301E1 TXM-3301P1	XM-3301B XM-3301BC	XM-8100B	OD-D300
DISK/TREND GROUP	10	10	10	10	11
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	120 mm	120 mm	120 mm	80 mm	86 mm
Recording medium	Aluminum	Aluminum	Aluminum	Aluminum	RE-TM
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Read Only	Read Only	Read Only	Read Only	Rewritable-(MO)
Interface	SCSI	SCSI-2	SCSI-2	SCSI-2	SCSI-2
Speed control	CLV	CLV	CLV	CLV	CAV/MCAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 599	F: 647	F: 647	F: 203	F: 128/160
Capacity per track (Bytes)	F: N/A	F: N/A	F: N/A	F: N/A	F: 12,800
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	21250	21250	8750	10000
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	25400	25400	25400	25400	24440
Rotational speed (RPM)	530-200	530-200	530-200	530-300	3600
PERFORMANCE					
Positioner type	Crs: Lead Screw Fine: Lens Actuator	Crs: Rack & Pinion Fine: Lens Actuator	Crs: Rack & Pinion Fine: Lens Actuator	Crs: Rack & Pinion Fine: Lens Actuator	Crs: Linear, Voice Coil Fine:
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	700	207	207	206	25
Within fine band (msec)	N/A	N/A	N/A	N/A	25
Fine band capacity (Mbytes)	N/A	N/A	N/A	N/A	NS
Average rotational delay (msec)	110	118	118	84	8.3
Average access time (msec)	570	325	325	290	33.3
Data transfer rate (KBytes/sec)	153.6	153.6	153.6	153.6	--
FIRST CUSTOMER SHIPMENT	2/90	1Q91	1Q91	2Q92	4Q92
COMMENTS	41.3 mm high Uses Sony caddy DM-51XX and 71XX are external mount	External drive Embedded audio	41.3 mm high. Embedded audio	41.3 mm high Digital audio	41.3 mm high Will be sold only in Japan

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

1992 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.

Nonqueued 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.

1992 DISK/TREND optical disk product groups

For the 1992 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	ATG GIGADISC	BORETT AUTOMATION TECHNOLOGIES	BORETT AUTOMATION TECHNOLOGIES
LIBRARY	ODSR	JC2000	GF 6910	VLC (CD)	VLC (12")
DISK/TREND GROUP	51	51	51	50	53
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	12"	130 mm	300 mm	120 mm	12"
Nominal disk capacity (MB)	2,000	600-650	5100	600	Drive dependent
Cartridge type	LMSI	ANSI/ISO	Proprietary	Caddy	Any
DRIVE: Type	Write Once	Wr.Once,Rewrit.	Write Once	Read Only	Wr.Once,Rewrit.
Drive models	LMSI LD 1250E	Various	GD 6001 GD 9001 GD 9001S	Various	Various
LIBRARY MECHANISM					
Minimum disk capacity (units)	16*	20	6	NS	NS
Maximum disk capacity (units)	20	20	6	4620*	756
Number of drives: Maximum	2	2	1	48	10
Interface: Library Drive	RS232C SCSI	SCSI Drive dependent	SCSI SCSI-2	RS232C, SCSI-2 SCSI	RS232C, SCSI-2 SCSI
Library capacity (Gbytes) (with maximum disk capacity)	40	12-13	30.6	3000	7560
Import/export module (disks)	1	1	1	1	1
PERFORMANCE					
Positioner type	Y axis	Y axis	Y axis	Rotary Industrial Robot	Rotary Industrial Robot
Pickers per positioner	1	1	1	1	1
Average media exchange time (sec)	9	5	2.5	10	10
Spin-up + drive ready time (sec)	3	Drive dependent	3	Drive dependent	Drive dependent
Spin-down time (sec)	3	Drive dependent	2	Drive dependent	Drive dependent
Average drive access time (msec)	212.5	Drive dependent	Drive dependent	Drive dependent	Drive dependent
Non-queued access time (sec)	12	Drive dependent	5.5	Drive dependent	Drive dependent
Drive data transfer rate (KB/s)	1500	Drive dependent	1000	Drive dependent	Drive dependent
Number of drive data paths: Max.	2	1 or 2	1	NS	NS
FIRST CUSTOMER SHIPMENT	--	2Q88	1992	--	--
COMMENTS	*With 2 drives			Can mix media types *1540 with caddy	Can mix media types

MANUFACTURER	BORETT AUTOMATION TECHNOLOGIES	CYGNET	CYGNET	CYGNET	CYGNET
LIBRARY	VLC (5.25")	1602	5250/W	1800/A2	1800/H
DISK/TREND GROUP	53	51	51	53	53
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	130 mm	12"	130 mm	12"	12"
Nominal disk capacity (MB)	Drive dependent	Drive dependent	650	9,000	2,600
Cartridge type	Any	Drive dependent	ANSI/ISO, Other	ATG	Proprietary
DRIVE: Type	Wr.Once,Rewrit.	Write Once	Write Once	Write Once	Write Once
Drive models	Various	ATG LMS Sony	LMS LD510	ATG GD 9001	Hitachi OD301A1
LIBRARY MECHANISM					
Minimum disk capacity (units)	NS	29	25	61	61
Maximum disk capacity (units)	1540	29	25	141	141
Number of drives: Maximum	24	2	2	5	5
Interface: Library Drive	RS232C, SCSI-2 SCSI	RS232C, SCSI-2 SCSI	RS232C, SCSI-2 SCSI	RS232C, SCSI-2 SCSI	RS232C, SCSI SCSI
Library capacity (Gbytes) (with maximum disk capacity)	1540	261*	16.25	1269	366.6
Import/export module (disks)	1	1	1	1	1
PERFORMANCE					
Positioner type	Rotary Industrial Robot	Y axis	Rotary, with sliding disk tray	Y axis	Y axis
Pickers per positioner	1	2	2	2	2
Average media exchange time (sec)	10	6.5	4	7.2	8
Spin-up + drive ready time (sec)	Drive dependent	Drive dependent	5.9	2.6	4.5
Spin-down time (sec)	Drive dependent	Drive dependent	1.9	2.0	3.5
Average drive access time (msec)	Drive dependent	Drive dependent	75	116	250
Non-queued access time (sec)	Drive dependent	Drive dependent	8	7.1	10
Drive data transfer rate (KB/s)	Drive dependent	Drive dependent	1250	1500	1200
Number of drive data paths: Max.	NS	2	2	5 (1 per drive)	5 (1 per drive)
FIRST CUSTOMER SHIPMENT	--	10/91	4Q88	10/91	1987
COMMENTS	Can mix media types	*With ATG drive			

MANUFACTURER	CYGNET	CYGNET	CYGNET	CYGNET	DOCUMENT IMAGING SYSTEMS CORP.
LIBRARY	1800/L1	1800/L2	1800/S	1800/T	D75-1
DISK/TREND GROUP	53	53	53	53	53
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	12"	12"	12"	12"	130 mm
Nominal disk capacity (MB)	2,000	5,600	6,550	5,000	650-1200
Cartridge type	LMSI	LMSI	Sony	Toshiba WM7500	Drive dependent
DRIVE: Type	Write Once	Write Once	Write Once	Write Once	Wr.Once/Rewrit.
Drive models	LMSI LD1250	LMSI 4100	Sony WDD 600	Toshiba WMS500A	Various
LIBRARY MECHANISM					
Minimum disk capacity (units)	42	61	61	53	47
Maximum disk capacity (units)	95	141	141	124	77
Number of drives: Maximum	5	5	5	5	4
Interface: Library Drive	RS232C, SCSI SCSI	RS232C, SCSI SCSI	RS232C, SCSI SCSI	RS232C, SCSI SCSI	SCSI, RS232 SCSI-2
Library capacity (Gbytes) (with maximum disk capacity)	190.0	789.6	923.55	620	50-92
Import/export module (disks)	1	1	1	1	1
PERFORMANCE					
Positioner type	Y axis	Y axis	Y axis	Y axis	X-Y axis
Pickers per positioner	2	2	2	2	2
Average media exchange time (sec)	8.7	7.2	8	8.7	7
Spin-up + drive ready time (sec)	4	3.5	3.8	5 max.	Drive dependent
Spin-down time (sec)	4	1.5	2.1	5 max.	Drive dependent
Average drive access time (msec)	212.5	115	221	160	Drive dependent
Non-queued access time (sec)	10	7.1	9	11	Drive dependent
Drive data transfer rate (KB/s)	1200	1000	1000	1250	Drive dependent
Number of drive data paths: Max.	5 (1 per drive)	5 (1 per drive)	5 (1 per drive)	5 (1 per drive)	1
FIRST CUSTOMER SHIPMENT	1987	7/91	2Q89	1Q90	12/91
COMMENTS					Depopulated versions available

MANUFACTURER	DOCUMENT IMAGING SYSTEMS CORP.	DOCUMENT IMAGING SYSTEMS CORP.	DOCUMENT IMAGING SYSTEMS CORP.	DOCUPOINT	DSM GMBH & CO.
LIBRARY	D255-1	D510-2	D1050-2	DP 500	20/27/30
DISK/TREND GROUP	53	53	53	53	51
MARKET	OEM	OEM	OEM	Captive	Captive, OEM
MEDIA: Nominal disk diameter	130 mm	130 mm	130 mm	130 mm	12"
Nominal disk capacity (MB)	650-1200	650-1200	650-1200	650	2,000
Cartridge type	Drive dependent	Drive dependent	Drive dependent	ISO	Proprietary
DRIVE: Type	Wr.Once/Rewrit.	Wr.Once/Rewrit.	Wr.Once/Rewrit.	Wr.Once,Rewrit.	Write Once
Drive models	Various	Various	Various	Various	LMSI 1200
LIBRARY MECHANISM					
Minimum disk capacity (units)	80	80	190	240	20
Maximum disk capacity (units)	257	514	1054	288	30 (2 drives)
Number of drives: Maximum	12	24	40	10	2
Interface: Library Drive	SCSI, RS232 SCSI-2	SCSI, RS232 SCSI-2	SCSI, RS232 SCSI-2	RS232C SCSI	RS232C SCSI
Library capacity (Gbytes) (with maximum disk capacity)	167-308	334-616	685-1265	187	60
Import/export module (disks)	1	2	2	1	1
PERFORMANCE					
Positioner type	X-Y axis	X-Y axis	X-Y axis	X-Y axis	Y axis
Pickers per positioner	2	2	2	2	2
Average media exchange time (sec)	7	7	7	4*	6
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	Drive dependent	Drive dependent	4.5 + spin-up
Drive data transfer rate (KB/s)	Drive dependent	Drive dependent	Drive dependent	Drive dependent	Drive dependent
Number of drive data paths: Max.	1-8	1-8	1-8	4	2
FIRST CUSTOMER SHIPMENT	12/91	5/92	5/92	1992	4/90
COMMENTS	Depopulated versions available	Depopulated versions available	Depopulated versions available	*With 2 drives installed	Model 27 has 1 drive, 27 disks

MANUFACTURER	DSM GMBH & CO.	DSM GMBH & CO.	DSM GMBH & CO.	DSM GMBH & CO.	DSM GMBH & CO.
LIBRARY	28/38	4000	48	100-2000	5100 5200 5300 5400 5500
DISK/TREND GROUP	51	51	52	53	53
MARKET	Captive, OEM	OEM	Captive, OEM	Captive, OEM	Captive, OEM
MEDIA: Nominal disk diameter	12"	130 mm	12"	12"	130 mm
Nominal disk capacity (MB)	Drive dependent	Drive dependent	Drive dependent	Drive dependent	Drive dependent
Cartridge type	Proprietary	ANSI/ISO	Proprietary	Proprietary	ANSI/ISO
DRIVE: Type	Write Once	Wr.Once,Rewrit.	Write Once	Write Once	Wr.Once,Rewrit.
Drive models	ATG, Optimem Sony, Toshiba, LMSI 4100	Various	ATG Gigadisc, Optim.,LMSI4100 Sony WDD600	ATG, Optimem, Sony, Hitachi, LMSI, Toshiba	Various
LIBRARY MECHANISM					
Minimum disk capacity (units)	28	20	48	54	24 (5100)
Maximum disk capacity (units)	38	20	48	2380	134 (5500)
Number of drives: Maximum	2	2	2	120	8 (5300-5500)
Interface: Library Drive	RS232C SCSI	RS232C SCSI	RS232C SCSI	RS232C SCSI	RS232C SCSI
Library capacity (Gbytes) (with maximum disk capacity)	Drive dependent	Drive dependent	Drive dependent	Drive dependent	Drive dependent
Import/export module (disks)	1	1	1	Up to 119*	1
PERFORMANCE					
Positioner type	Y axis	Y axis	Y axis	X-Y axis	X-Y axis
Pickers per positioner	2	2	2	2	2
Average media exchange time (sec)	6	6	7	8-12	6-7
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	Drive dependent	Drive dependent	Drive dependent
Drive data transfer rate (KB/s)	Drive dependent	Drive dependent	Drive dependent	Drive dependent	Drive dependent
Number of drive data paths: Max.	2	1-2	2	Variable	2 to 8
FIRST CUSTOMER SHIPMENT	11/89	4/92	11/89	9/87	11/89
COMMENTS	Model 38 has 1 drive, 38 disks			*Custom configured	

MANUFACTURER	DSM GMBH & CO.	EASTMAN KODAK	EASTMAN KODAK	EASTMAN KODAK	FILENET
LIBRARY	6300 6400	560	560E	6800 ADL	Model 0140 OSAR GTX
DISK/TREND GROUP	53	52	52	53	53
MARKET	OEM	Captive,OEM,PCM	Captive,OEM,PCM	Captive, OEM	Captive, OEM
MEDIA: Nominal disk diameter	130 mm	130 mm	130 mm	14"	12"
Nominal disk capacity (MB)	Drive dependent	654	654/1,280	10,200	7,000
Cartridge type	ANSI/ISO	Various	Various	Proprietary	Hitachi
DRIVE: Type	Wr.Once,Rewrit.	Wr.Once,Rewrit.	Wr.Once,Rewrit.	Write Once	Write Once
Drive models	Various	Various	Various	Kodak 6800	Hitachi OD 301
LIBRARY MECHANISM					
Minimum disk capacity (units)	274 (6300)	36	36	50	96
Maximum disk capacity (units)	458 (6400)	60	60	100	125
Number of drives: Maximum	16	5	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	23.5	23.5/46.1	1020	875
Import/export module (disks)	1	1	1	1	1
PERFORMANCE					
Positioner type	X-Y axis	Y axis	Y axis	Y axis	X-Y axis
Pickers per positioner	2	2	2	2	2
Average media exchange time (sec)	8	5	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)	Drive dependent	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.	Various	5 (1 per drive)	5 (1 per drive)	2 (1 per drive)	6
FIRST CUSTOMER SHIPMENT	6/92	1Q91	3Q92	3Q88	6/91
COMMENTS				Expandable in modules of 50 disks	Maximum capacity with 2 drives

MANUFACTURER	FILENET	FILENET	FILENET	FUJITSU	FUJITSU
LIBRARY	Model 0150 OSAR 107/144 GT	Model 0161 OSAR 288 X	OSAR 340	F6445/10 M255X/10	F6445/20 M255X/20
DISK/TREND GROUP	53	53	53	53	53
MARKET	Captive, OEM	Captive, OEM	Captive, OEM	Captive, OEM	Captive, OEM
MEDIA: Nominal disk diameter	12"	12"	12"	130 mm	130 mm
Nominal disk capacity (MB)	5,600	7,000	5,600	644	644
Cartridge type	LMSI	Hitachi	LMSI	ANSI/ISO	ANSI/ISO
DRIVE: Type	Write Once	Write Once	Write Once	Rewritable-(MO)	Rewritable-(MO)
Drive models	LMSI LD 4100	Hitachi OD 321	LMSI LD 4100	M2507L	M2507L
LIBRARY MECHANISM					
Minimum disk capacity (units)	107	288	340	390	780
Maximum disk capacity (units)	144	288	340	390	780
Number of drives: Maximum	6	4	4	6	11
Interface: Library Drive	RS232, RS422 SCSI	RS232, RS422 SCSI	RS232, RS422 SCSI	SCSI-2, Prop.* SCSI-2, Prop.*	SCSI-2, Prop.* SCSI-2, Prop.*
Library capacity (Gbytes) (with maximum disk capacity)	806	2016	1904	251.2	502.3
Import/export module (disks)	1	1	1	10/10	10/10
PERFORMANCE					
Positioner type	X-Y axis	X-Y axis	X-Y axis	Rotary Drum Y Axis Picker	Rotary Drum (2) 2 Y Axis Picker
Pickers per positioner	2	2	2	1	1
Average media exchange time (sec)	4.0	8.3	7.8	10	10
Spin-up + drive ready time (sec)	3.0	3.0	3.0	5.5	5.5
Spin-down time (sec)	1.5	2.5	4.5	4.5	4.5
Average drive access time (msec)	130	150	130	40.6	40.6
Non-queued access time (sec)	6.0	9.5	9.3	10.5	10.5
Drive data transfer rate (KB/s)	4000	4000	4000	2080	2080
Number of drive data paths: Max.	6	4	4	2	2
FIRST CUSTOMER SHIPMENT	3/91	7/91	--	4Q91	4Q91
COMMENTS	Maximum capacity with 2 drives		Special order	Single pass write *With DIR (M109X/F1785)	Single pass write *With DIR (M109X/F1785)

MANUFACTURER	FUJITSU	HEWLETT-PACKARD	HEWLETT-PACKARD	HEWLETT-PACKARD	HEWLETT-PACKARD
LIBRARY	F6445/30 M255X/30	C1700 C1713C Mod. 10C C1713M Mod. 10C Model 10GB/A Model 10GB/M	C1703M C1710 Mod. 20C C1710C Mod. 20C Model 20GB/A Model 20GB/M	C1708C C1718C 10LC	C1704 C1714C Mod. 60C C1714M Mod.60
DISK/TREND GROUP	53	51	51	51	53
MARKET	Captive, OEM	Captive,OEM,PCM	Captive,OEM,PCM	Captive, OEM	Captive,OEM,PCM
MEDIA: Nominal disk diameter	130 mm	130 mm	130 mm	130 mm	130 mm
Nominal disk capacity (MB)	644	650	650	650	650
Cartridge type	ANSI/ISO	ANSI/ISO	ANSI/ISO	ANSI/ISO	ANSI/ISO
DRIVE: Type	Rewritable-(MO)	Wr.Once,Rewrit.	Wr.Once,Rewrit.	Rewritable-(MO)	Wr.Once,Rewrit.
Drive models	M2507L	H-P C1716C Sony SMO-D501 Sony SMO-E511	H-P C1716C Sony SMO-D501 Sony SMO-E511	HP C1716C	H-P C1716C Sony SMO-D501 Sony SMO-E511
LIBRARY MECHANISM					
Minimum disk capacity (units)	1560	16	32	16	88
Maximum disk capacity (units)	1560	16	32	16	88
Number of drives: Maximum	10	1	2	1	4
Interface: Library Drive	SCSI-2, Prop.* SCSI-2, Prop.*	SCSI-2 SCSI	SCSI-2 SCSI	SCSI-2 SCSI-2	SCSI-2 SCSI
Library capacity (Gbytes) (with maximum disk capacity)	10046	10.4	20.8	10.4	57.2
Import/export module (disks)	10/10	1	1	1	1
PERFORMANCE					
Positioner type	Rotary Drum (4) 4 Y Axis Picker	X-Y axis	X-Y axis	Y axis	X-Y axis
Pickers per positioner	1	1	1	1	1
Average media exchange time (sec)	10	7	7	8	8
Spin-up + drive ready time (sec)	5.5	2.5	2.5	2.5	2.5
Spin-down time (sec)	4.5	2.0	2.0	2.0	2.0
Average drive access time (msec)	40.6	27	27	35.3	2.5
Non-queued access time (sec)	10.5	6.0	6.0	6.5	6.5
Drive data transfer rate (KB/s)	2080	1000	1000	1000	1000
Number of drive data paths: Max.	2	1	2	1	4
FIRST CUSTOMER SHIPMENT	4Q91	1Q91	11/89	3Q92	1Q91
COMMENTS	Single pass write *With DIR (M109X/F1785)	Specifications with H-P drive	Specifications with H-P drive	Multifunction drive	Specifications with H-P drives Single-ended or differential SCSI

MANUFACTURER	HEWLETT-PACKARD	HITACHI	HITACHI	HITACHI	HITACHI
LIBRARY	C1705 C1715C Mod.100C C1715M Mod.100	OL101-11 OL101-21	OL112-11 OL112-21	OL301-11 OL301-21	OL301-12 OL301-22
DISK/TREND GROUP	53	51	51	51	51
MARKET	Captive,OEM,PCM	Captive, OEM	Captive, OEM	Captive, OEM	Captive, OEM
MEDIA: Nominal disk diameter	130 mm	130 mm	130 mm	12"	12"
Nominal disk capacity (MB)	650	600	644	2,620	2,620
Cartridge type	ANSI/ISO	ANSI/ISO	ANSI/ISO	Proprietary	Proprietary
DRIVE: Type	Wr.Once,Rewrit.	Write Once	Rewritable-(MO)	Write Once	Write Once
Drive models	H-P C1716C Sony SMO-D501 Sony SMO-E511	Hitachi OD101	Hitachi OD112-1	Hitachi OD301A1	Hitachi OD301A1
LIBRARY MECHANISM					
Minimum disk capacity (units)	144	24	24	16	32
Maximum disk capacity (units)	144	24	24	16	32
Number of drives: Maximum	4	2	2	2	2
Interface: Library Drive	SCSI-2 SCSI	SCSI SCSI	SCSI SCSI	SCSI SCSI	SCSI SCSI
Library capacity (Gbytes) (with maximum disk capacity)	93.6	14.4	15	42	83.9
Import/export module (disks)	1	1	1	1	1
PERFORMANCE					
Positioner type	X-Y axis	Y axis	Y axis	Y axis	Y axis
Pickers per positioner	1	1	1	1	1
Average media exchange time (sec)	8	7.7	7.7	8.7	8.7
Spin-up + drive ready time (sec)	2.5	2.5	4.0	4.3	4.3
Spin-down time (sec)	2.0	2.5	3.5	3.5	3.5
Average drive access time (msec)	27	110	70	250	250
Non-queued access time (sec)	6.5	7.8	7.8	8.8	8.8
Drive data transfer rate (KB/s)	1000	1500	1500	1500	1500
Number of drive data paths: Max.	4	1	1	1	1
FIRST CUSTOMER SHIPMENT	1Q91	1987	1989	1985	1985
COMMENTS	Specifications with H-P drives 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	-12 has single ended interface -22 has differential interface. IEEE-488 interface avail

MANUFACTURER	HITACHI	HITACHI	HITACHI	HITACHI	HITACHI
LIBRARY	OL101-12 OL101-22	OL112-12 OL112-22	OL114-12 OL114-22	OL321-22	OL321-32
DISK/TREND GROUP	52	52	52	52	52
MARKET	Captive, OEM	Captive, OEM	Captive, OEM	Captive, OEM	Captive, OEM
MEDIA: Nominal disk diameter	130 mm	130 mm	130 mm	12"	12"
Nominal disk capacity (MB)	600	644	644	7000	7000
Cartridge type	ANSI/ISO	ANSI/ISO	ANSI/ISO	Proprietary	Proprietary
DRIVE: Type	Write Once	Rewritable-(MO)	Wr.Once/Rewrit.	Write Once	Write Once
Drive models	Hitachi OD101	Hitachi OD112-1	Hitachi	Hitachi OD321	Hitachi OD321
LIBRARY MECHANISM					
Minimum disk capacity (units)	48	48	48	47	64
Maximum disk capacity (units)	48	48	48	47/127*	64/144*
Number of drives: Maximum	4	4	4	4	2
Interface: Library Drive	SCSI SCSI	SCSI SCSI	SCSI SCSI	SCSI SCSI	SCSI SCSI
Library capacity (Gbytes) (with maximum disk capacity)	28.8	30	30	329/889*	448/1008*
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	2	2
Average media exchange time (sec)	7.7	7.7	7.7	6.5	6.5
Spin-up + drive ready time (sec)	2.5	3.7	4.0	3	3
Spin-down time (sec)	2.5	2.7	3.5	3	3
Average drive access time (msec)	110	70	70	150	150
Non-queued access time (sec)	7.8	7.8	7.8	8.5	8.5
Drive data transfer rate (KB/s)	1500	1500	1500	1500/4000	1500/4000
Number of drive data paths: Max.	2	1	4	2	2
FIRST CUSTOMER SHIPMENT	1987	1989	1991	1Q91	1Q91
COMMENTS	-12 has single ended interface -22 has differential interface	-12 has single ended interface -22 has differential interface	-12 is single-ended SCSI -22 is differential SCSI Sold only in Japan	Dual picker *With expansion unit	Dual picker *With expansion unit

MANUFACTURER	IBM	INTERNATIONAL DATA ENGINEERING	INTERNATIONAL DATA ENGINEERING	INTERNATIONAL DATA ENGINEERING	K&S
LIBRARY	5558-B01	7000 7100	9000	LG-5	Megastore 1000
DISK/TREND GROUP	51	51	51	51	51
MARKET	Captive	OEM, PCM	OEM, PCM	OEM	OEM, PCM
MEDIA: Nominal disk diameter	86 mm	130 mm	130 mm	130 mm	130 mm
Nominal disk capacity (MB)	128	654	654	650	654/1024*
Cartridge type	ISO	ANSI/ISO	ANSI/ISO	ANSI/ISO	ISO, ZCAV*
DRIVE: Type	Rewritable	Wr.Once,Rewrit.	Wr.Once,Rewrit.	Rewritable-(MO)	Rewritable-(MO)
Drive models	IBM 3125B	Various	Various	Maxoptix Ricoh Sony	Various
LIBRARY MECHANISM					
Minimum disk capacity (units)	32	10	20	5	1
Maximum disk capacity (units)	32	10*	20	5	10
Number of drives: Maximum	1	1	2	1	1
Interface: Library Drive	Microchannel SCSI	SCSI-2 SCSI	SCSI-2 SCSI	SCSI-2 SCSI	SCSI SCSI
Library capacity (Gbytes) (with maximum disk capacity)	4.1	6.5	13.1	3.25	6.5/10.2*
Import/export module (disks)	32	1	1	5	1
PERFORMANCE					
Positioner type	Rotary Carousel	Y axis	X-Y axis	X axis	Y axis
Pickers per positioner	1	1	1	1	1
Average media exchange time (sec)	--	6	7	7	11
Spin-up + drive ready time (sec)	--	Drive dependent	Drive dependent	Drive dependent	Drive dependent
Spin-down time (sec)	--	Drive dependent	Drive dependent	Drive dependent	Drive dependent
Average drive access time (msec)	50	Drive dependent	Drive dependent	Drive dependent	Drive dependent
Non-queued access time (sec)	--	Drive dependent	Drive dependent	Drive dependent	Drive dependent
Drive data transfer rate (KB/s)	640	Drive dependent	Drive dependent	Drive dependent	Drive dependent
Number of drive data paths: Max.	1	1	1	1	1
FIRST CUSTOMER SHIPMENT	3Q92	1/90	3Q91	1Q92	9/91
COMMENTS		*11 with Panasonic drive 7100 is ruggedized version	105 MB Winchester buffer is optional	Microlibrary includes host adaptor	*With Maxoptix drive

MANUFACTURER	KUBIK ENTERPRISES	KUBIK ENTERPRISES	LASER MAGNETIC STORAGE	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL
LIBRARY	CDR240M	DDC-240	LF 4500 RapidChanger	LF-J5000A	LF-J7000A
DISK/TREND GROUP	50	50	51	52	52
MARKET	OEM	OEM	OEM, PCM	Captive, OEM	Captive, OEM
MEDIA: Nominal disk diameter	120 mm	120 mm	12"	130 mm	130 mm
Nominal disk capacity (MB)	550	550	5,600	940	1,000
Cartridge type	N/A	N/A	LMSI	ANSI/ISO	ANSI/ISO
DRIVE: Type	Read Only	Read Only	Write Once	Write Once	Rewritable-(MO)
Drive models	Toshiba	LMSI, Sony	LMSI LD 4100	MEI LF-5012Z	MEI LF-7012Z
LIBRARY MECHANISM					
Minimum disk capacity (units)	240	240	5	50	50
Maximum disk capacity (units)	240	240	5	50	50
Number of drives: Maximum	4	1	1	2	2
Interface: Library Drive	RS232C SCSI	RS232C SCSI	SCSI-2 SCSI-2	SCSI-2 SCSI-2	SCSI-2 SCSI-2
Library capacity (Gbytes) (with maximum disk capacity)	132	132	28	47	50
Import/export module (disks)	1	1	5	1	1
PERFORMANCE					
Positioner type	Rotary	Rotary	Moving Magazine	Y axis	Y axis
Pickers per positioner	1	1	N/A	1	1
Average media exchange time (sec)	7	7	3	13	8
Spin-up + drive ready time (sec)	1	1	2.5	5	4
Spin-down time (sec)	1	1	1.5	5	2.5
Average drive access time (msec)	Drive dependent	Drive dependent	130*	115	107
Non-queued access time (sec)	NS	NS	5.5	12	8
Drive data transfer rate (KB/s)	153.6	153.6	1800**	1500/4000*	1500/4000*
Number of drive data paths: Max.	4	1	1	1	1/2
FIRST CUSTOMER SHIPMENT	1992	1990	2Q90	1/90	7/91
COMMENTS			*Includes command overhead **Asynchronous mode	*SCSI synchronous mode	*SCSI synchronous mode

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)	594/652	594/652	594	594/652	594/652
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 Drive	SCSI SCSI	SCSI SCSI	SCSI 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	3Q92
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	N1137-06	N7923	N5817-31/32 N7925-82
DISK/TREND GROUP	53	53	51	51	52
MARKET	Captive, OEM	Captive, OEM	Captive	Captive	Captive
MEDIA: Nominal disk diameter	130 mm	130 mm	130 mm	12"	130 mm
Nominal disk capacity (MB)	594	594	610	5,000	610
Cartridge type	Proprietary	Proprietary	ANSI/ISO	Proprietary	ANSI/ISO
DRIVE: Type	Write Once	Write Once	Rewritable-(MO)	Write Once	Rewritable-(MO)
Drive models	Mitsub. MW-5D1	Mitsub. MW-5D1	NEC N1137-04	NEC N7913	NEC N7915 NEC N5817-11
LIBRARY MECHANISM					
Minimum disk capacity (units)	150	134	4	36	46
Maximum disk capacity (units)	150	134	4	36	67
Number of drives: Maximum	2	4	1	2	4
Interface: Library Drive	SCSI SCSI	SCSI SCSI	SCSI SCSI	NEC Proprietary	SCSI SCSI
Library capacity (Gbytes) (with maximum disk capacity)	90	80	2.4	180	40
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	2	1
Average media exchange time (sec)	9.5	9.5	10	14	10
Spin-up + drive ready time (sec)	3	3	4	8	4
Spin-down time (sec)	2.5	2.5	4	8	4
Average drive access time (msec)	85	85	60	200	60
Non-queued access time (sec)	8	8	8	15	9
Drive data transfer rate (KB/s)	480	480	1500	900	1500
Number of drive data paths: Max.	1	2	1	2	1
FIRST CUSTOMER SHIPMENT	3Q90	3Q90	1991	6/90	1992
COMMENTS					

MANUFACTURER	NEC	NEC	NKK	NKK	NKK
LIBRARY	N7925-81	ND3605-19	N-556E	N-556ET	N-556MP
DISK/TREND GROUP	52	52	52	52	52
MARKET	Captive	Captive	OEM	OEM	OEM
MEDIA: Nominal disk diameter	130 mm	130 mm	130 mm	130 mm	130 mm
Nominal disk capacity (MB)	610	610	654	650/1000*	654
Cartridge type	ANSI/ISO	ANSI/ISO	ANSI/ISO	ANSI/ISO*	ANSI/ISO
DRIVE: Type	Rewritable-(MO)	Write Once	Rewritable-(MO)	Rewritable-(MO)	Wr.Once,Rewrit.
Drive models	NEC N7915-81	NEC ND3605-13	Sony SMO-D501	Maxoptix-Tahiti SD	Pioneer DEJ-U7001
LIBRARY MECHANISM					
Minimum disk capacity (units)	46	46	56	56	56
Maximum disk capacity (units)	67	60	56	56	56
Number of drives: Maximum	4	4	2	2	2
Interface: Library Drive	SCSI SCSI	SCSI SCSI	SCSI-2 SCSI	SCSI-2 SCSI	SCSI-2 SCSI
Library capacity (Gbytes) (with maximum disk capacity)	40	36.6	36	36.4/56*	36.6
Import/export module (disks)	1	1	16	16	16
PERFORMANCE					
Positioner type	Y axis	Y axis	Y axis	Y axis	Y axis
Pickers per positioner	2	2	1	1	1
Average media exchange time (sec)	10	10	4	4	4
Spin-up + drive ready time (sec)	3.5	3.5	7	4/4.5*	6
Spin-down time (sec)	3.5	3.5	4	1.5/1.6*	3
Average drive access time (msec)	84.7	84.7	67	35	70
Non-queued access time (sec)	9	9	9.0	6/6.5*	8.0
Drive data transfer rate (KB/s)	1500	1500	1200	1500	1500
Number of drive data paths: Max.	1	1	1/2	1/2	1/2
FIRST CUSTOMER SHIPMENT	1990	9/90	12/89	2Q92	3Q91
COMMENTS				*Maxoptix ZCAV media Non-ANSI non-ISO standard	

NKK	NKK	NKK	NKK	NKK
N-556MS	N-556W	N-5160ET	N-5160MP	N-5160MS
52	52	53	53	53
OEM	OEM	OEM	OEM	OEM
130 mm	130 mm	130 mm	130 mm	130 mm
650	900	650/1000*	654	650
ANSI/ISO	ANSI/ISO	ANSI/ISO*	ANSI/ISO	ANSI/ISO
Wr.Once,Rewrit.	Write Once	Rewritable-(MO)	Wr.Once/Rewrit.	Wr.Once/Rewrit.
Sony SMO-E511 E501	Toshiba D070	Maxoptix-Tahiti SD	Pioneer DEJ-U7001	Sony E501 E511
56	56	144	144	144
56	56	160	160	160
2	2	4	4	4
SCSI-2 SCSI	RS232C, SCSI-2 SCSI	SCSI-2 SCSI	SCSI-2 SCSI	SCSI-2 SCSI
36.4	50	160	104.6	104
16	16	16	16	16
Y axis	Y axis	Y axis	Y axis	Y axis
1	1	1	1	1
4	4	5	5	5
7	7	4	6	7
4	5	1.5	3	4
67	100	35	70	67
9.0	9.0	6.5	8.5	9.0
1200	1200	1500	1500	1200
1/2	1/2	1	1	1
3Q91	1/90	4Q92	3Q92	3Q92
		*1000 MB in non-ISO format		

MANUFACTURER	NKK	NKK	NKK	NKK	NKK
LIBRARY	N-556MS	N-556W	N-5160ET	N-5160MP	N-5160MS
DISK/TREND GROUP	52	52	53	53	53
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	130 mm	130 mm	130 mm	130 mm	130 mm
Nominal disk capacity (MB)	650	900	650/1000*	654	650
Cartridge type	ANSI/ISO	ANSI/ISO	ANSI/ISO*	ANSI/ISO	ANSI/ISO
DRIVE: Type	Wr.Once,Rewrit.	Write Once	Rewritable-(MO)	Wr.Once/Rewrit.	Wr.Once/Rewrit.
Drive models	Sony SMO-E511 E501	Toshiba DO70	Maxoptix-Tahiti SD	Pioneer DEJ-U7001	Sony E501 E511
LIBRARY MECHANISM					
Minimum disk capacity (units)	56	56	144	144	144
Maximum disk capacity (units)	56	56	160	160	160
Number of drives: Maximum	2	2	4	4	4
Interface: Library Drive	SCSI-2 SCSI	RS232C, SCSI-2 SCSI	SCSI-2 SCSI	SCSI-2 SCSI	SCSI-2 SCSI
Library capacity (Gbytes) (with maximum disk capacity)	36.4	50	160	104.6	104
Import/export module (disks)	16	16	16	16	16
PERFORMANCE					
Positioner type	Y axis	Y axis	Y axis	Y axis	Y axis
Pickers per positioner	1	1	1	1	1
Average media exchange time (sec)	4	4	5	5	5
Spin-up + drive ready time (sec)	7	7	4	6	7
Spin-down time (sec)	4	5	1.5	3	4
Average drive access time (msec)	67	100	35	70	67
Non-queued access time (sec)	9.0	9.0	6.5	8.5	9.0
Drive data transfer rate (KB/s)	1200	1200	1500	1500	1200
Number of drive data paths: Max.	1/2	1/2	1	1	1
FIRST CUSTOMER SHIPMENT	3Q91	1/90	4Q92	3Q92	3Q92
COMMENTS			*1000 MB in non-ISO format		

MANUFACTURER	NSM	PIONEER	PIONEER	RICOH	RICOH
LIBRARY	CDR-100/S	DRM-600 DRM-600A DRM-610	DRM-604X	RJ5160	RJ5330E
DISK/TREND GROUP	50	50	50	51	52
MARKET	OEM	OEM	OEM, PCM	OEM	OEM
MEDIA: Nominal disk diameter	120 mm	120 mm	120 mm	130 mm	130 mm
Nominal disk capacity (MB)	600	540	540	800	646
Cartridge type	NSM	N/A	N/A	Proprietary	ANSI/ISO
DRIVE: Type	Read Only	Read Only	Read Only	Write Once	Rewritable
Drive models	Philips	Pioneer (integrated with drive)	Pioneer (integrated with drive)	Ricoh RO-5040WL	Ricoh RO-5030EII
LIBRARY MECHANISM					
Minimum disk capacity (units)	100	6	6	20	56
Maximum disk capacity (units)	100	6	6	20	56
Number of drives: Maximum	1	1	1	2	2
Interface: Library Drive	SCSI, RS422 SCSI	SCSI SCSI	SCSI SCSI	SCSI SCSI	SCSI SCSI
Library capacity (Gbytes) (with maximum disk capacity)	60	3.24	3.24	16	36.2
Import/export module (disks)	50/1	6	6	1	16
PERFORMANCE					
Positioner type	X-Y axis	NS	NS	Y axis	Y axis
Pickers per positioner	2	1	1	1	1
Average media exchange time (sec)	5.5	7	5	7	5
Spin-up + drive ready time (sec)	1.5	NS	NS	.5	9.0
Spin-down time (sec)	1.0	NS	NS	.5	5.0
Average drive access time (msec)	500	600	300	168	67
Non-queued access time (sec)	9	NS	NS	8.2	11.5
Drive data transfer rate (KB/s)	153.6	153	614.4	1400	1400
Number of drive data paths: Max.	1	1	1	1/2	1/2
FIRST CUSTOMER SHIPMENT	7/91	4Q89	3Q92	2Q88	4Q89
COMMENTS					

MANUFACTURER	SONY	SONY	SONY		
LIBRARY	WDA-E330	WDA-3000	WDA-610		
DISK/TREND GROUP	51	52	52		
MARKET	OEM	Captive, OEM	OEM		
MEDIA: Nominal disk diameter	12"	12"	12"		
Nominal disk capacity (MB)	6,550	3,200	6,550		
Cartridge type	Proprietary	Proprietary	Proprietary		
DRIVE: Type	Write Once	Write Once	Write Once		
Drive models	WDD 930	WDD 3000	WDD 600-01		
LIBRARY MECHANISM					
Minimum disk capacity (units)	12	50	50		
Maximum disk capacity (units)	12	50	50		
Number of drives: Maximum	1	2	2		
Interface: Library Drive	SCSI-2 SCSI-2	SCSI SCSI	SCSI SCSI		
Library capacity (Gbytes) (with maximum disk capacity)	78.6	160	327.5		
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)	3.0	7	5		
Spin-up + drive ready time (sec)	2.5	2.5	2.5		
Spin-down time (sec)	2.5	2.5	1.1		
Average drive access time (msec)	221/655*	500	400		
Non-queued access time (sec)	4	4	5		
Drive data transfer rate (KB/s)	900	300	600		
Number of drive data paths: Max.	1	1	1		
FIRST CUSTOMER SHIPMENT	3Q92	1/85	9/89		
COMMENTS	*CAV/CLV mode dependent	Can attach 7 units to 1 SCSI port	Can attach 7 units to 1 SCSI port		

MANUFACTURER PROFILES

1992 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 1991, this figure is reported explicitly only for firms with major 1991 sales. "1991 total net sales" covers the fiscal year ending in 1991 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, 1991, 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 1991 is used, as cited by the Federal Reserve Bulletin.

Country	Currency	Currency units/U.S. dollar
France	Franc	5.65
Japan	Yen	135.0
Netherlands	Guilder	1.87
South Korea	Won	737.0
Germany	Deutschmark	1.66

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 engineering document image 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.

APPLIED MAGNETICS CORPORATION
Optical Products Division
18960 Base Camp Road
Monument, CO 80132

Applied Magnetics, which is best known for its magnetic disk drive heads, has had an optical disk drive component development operation for several years. In July, 1992, AMC announced a corporate restructuring and that the Optical Products Division was up for sale.

The firm currently is supplying both complete mechanisms and subassemblies to a number of optical disk drive manufacturers. Both 3.5" and 5.25" mechanisms are in current production. Some consulting and design work for customers is also performed.

BORETT AUTOMATION TECHNOLOGIES
31324 Via Colinas
Westlake Village, CA 91362

Founded in 1988, Borett Automation is working on a modular library system capable of simultaneously handling optical or tape media units in multiple cartridge sizes. The library is equipped with appropriate drives and storage bays for the cartridges to be used. A general purpose industrial robot capable of exchanging its picking mechanism on the fly permits handling of different cartridge types. Borett announced its product at the 1992 AIIM show, and production shipments began in 1992.

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

Cherokee Data was founded in March, 1984. The firm's key founders include

managers previously with Storage Technology Corporation and Sperry Corporation. Cherokee 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 has shipped a modest number of drives since 1988. Increased government purchasing activity is expected by Cherokee to gradually improve shipments. A nonruggedized version of the drive became available in late 1989, which is expected by Cherokee to eventually increase 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 Y-axis positioning 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 12" libraries remain Cygnet's main area of activity.

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

DIGITAL EQUIPMENT CORPORATION
146 Main Street
Maynard, MA 01754

1991 total net sales: $13,911,004,000 (FY ending 6/30/91 Net income: ($617,427,000)

Digital was the first major system supplier to offer the CD-ROM as a system peripheral, using a Philips drive with the Micro-VAX product line. In 1988, DEC announced the RV20, which incorporates a 12", 1 gigabyte per side, write-once drive supplied by Laser Magnetic Storage. Digital also announced the RV64 jukebox (externally procured), which can handle up to four 12" drives, in 1989. In 1991, Digital announced a complete document imaging system, but continues to procure drives and libraries externally. As optical drive demand increases, Digital is a candidate for internal production of its own read/write optical drives.

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. Trade-offs 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. Shipments began in 1991, with production volumes beginning in 1992.

DOCUPOINT CORPORATION
2701 Bayview Drive
Fremont, CA 94538

Docupoint, a document imaging systems manufacturer, is also manufacturing modular 5.25" optical library systems. The firm was founded in 1988. The present configuration holds 10 drives and 288 5.25" cartridges. Formal introduction of the library was made at the 1992 AIIM conference, with production shipments scheduled for the second half of 1992.

EASTMAN KODAK COMPANY
343 State Street
Rochester, NY 14650

1991 total net sales: $19,419,000,000 Net income: $17,000,000

Eastman Kodak has had two publicly announced optical disk drive produc-

tion 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. Laserdrive was merged into Literal Corporation in 1990. Verbatim, which was sold to Mitsubishi Kasei in 1990, retained optical media and head development responsibilities.

The Eastman Kodak Photo CD system, which permits photo processing centers to transfer photographic images to write-once CD disks, will begin shipping in the last half of 1992. CD-ROM players, operating as part of a CD-I system, will be supplied by Philips (and other companies) to attach to consumer TV sets for playback of the images.

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 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 various product lines.

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

1991 total net sales: $122,451,000 Net income: $8,126,000

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. The company is emphasizing its system business and de-emphasizing OEM library sales.

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 noncustomized 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 500 systems, mostly 12", as of mid-1992. The firm also sells 5.25" libraries 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.

GENERAL ELECTRIC AEROSPACE
Front and Cooper Streets
Building 13-3-1
Camden, New Jersey 08102

GE has been developing 14" optical drive based storage systems for the U.S. Air Force and NASA since the mid-eighties. Only a few high performance drives have been sold and the GE effort is more of an ongoing R&D program than an attempt to create a product for general sale. The original systems were write-once, but rewritable technology is scheduled for delivery in 1993. Write-once media has been supplied by Eastman Kodak, while 3M has supplied experimental 14" rewritable media. Special 14" optical libraries are also under development.

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

1991 total net sales: $14,541,000,000 (FY ending 10/31/91) Net income: $755,000,000

Hewlett-Packard announced a high performance 5.25" magneto-optic disk drive in 1991 for volume delivery in 1992. The firm had acquired some rewritable drive technology and related assets from Optotech in 1989. The drives are produced in the Greeley, Colorado, facility, which has also been producing optical libraries since 1989. Some related work on optical and rigid drive technology is being done at H-P Laboratories. H-P is a major producer of 5.25" optical libraries, with a product line spanning the range from 16 to 144 cartridge capacities. The libraries are used in H-P systems, but H-P also sells them to major OEM accounts.

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.

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. Write-once technology using magneto-optic media was proposed in 1990 by a group of 14 companies including H-P as the lead proponent. The media uses standard continuous composite servo format and uses information written in the media control track to identify media as write-once or rewritable.

HONEYWELL, INC.
Optical Storage Systems Operation
18401 North 25th Avenue
Phoenix, AZ 85023

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 Corporation. 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. Honeywell is currently developing a militarized rewritable magneto-optic drive for probable delivery in 1994. Capacity per side will be in the 400 to 600 megabyte range.

INTERNATIONAL BUSINESS MACHINES CORPORATION
Route 22
Armonk, NY 10504

1991 total net sales: $64,792,000,000 Net income: ($2,827,000,000)

IBM started slowly in the optical storage area, but now manufactures or remarkets a variety of products, including CD-ROMs, write-once and erasable drives and optical libraries. IBM has also become a very active participant in the optical drive and media standards committees.

IBM's optical program is directed from IBM facilities in Tucson, Arizona, but as a result of a mid-1988 reorganization, IBM's future optical products may be made in locations other than Tucson. The 5.25" optical drive development staff and laboratories remain in Tucson. Further development of 3.5" drives is under way in Fujisawa, Japan. Some advanced development is done at the Almaden research facilities.

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 judged unlikely to manufacture its own CD-ROM drives, with the possible exception of unique variants such as extended capacity versions targeted at selected markets.

IBM is actively involved in the design of systems using multimedia techniques, the XA architecture and the Intel DVI format. These efforts involve a variety of optical drive types, including CD-ROM and magneto-optic drives.

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, is being sold with some PS/2 system models and on an OEM basis. IBM's entry into the 3.5" drive marketplace encouraged other firms to announce similar optical disk drives in the 1991-1992 time period, but IBM's slow rate of adoption, lack of 3.5" OROM published titles, and media interchange problems hampered initial sales.

IBM's own 5.25" magneto-optic drive was shown at the 1991 COMDEX show and formally announced in 1992. This ISO standard drive is used in optical libraries sold by IBM and will also be sold on an OEM basis. It is likely to appear in other roles associated with IBM systems.

IBM and Sony are jointly proposing a 654 megabyte per side standard for next generation 5.25" optical drives and media. It is also widely believed in the industry that IBM is working on high performance 5.25" erasable optical technology for use with high performance workstations and optical library subsystems.

IBM has purchased 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 write-once drives have been shown with the libraries. IBM uses its own magneto-optic drives to provide rewritable storage for the libraries. The company offers its optical library systems as attachments to large and mid-range systems used in image management applications. In mid-1992, IBM announced it would also support the libraries as virtual 3390 Model 2 drives, opening up opportunities to use optical technology as general purpose data storage in hierarchical systems operating under IBM's System Managed Storage architecture.

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 and 1991 than any other producer. A five cartridge version was introduced 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 drive mechanisms are used. The libraries are unusual in that they employ a rotary mechanism, not unlike that used in many slide projectors, to store disks. Single drive and multiple drive configurations with up to four drives are available. Shipment levels remained low in 1991, but should increase in 1992 as the libraries are now being manufactured in California and in a facility in British Columbia. Kubik Technologies, located in Vancouver, is a separate organization authorized to manufacture Kubik Enterprises designs and use the Kubik name.

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 was started on a small diameter magneto-optic drive based

upon the Verbatim technology obtained from Laserdrive, but this effort has been suspended and the firm is concentrating its development efforts on higher capacity write-once 5.25" drives.

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 now 65% 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. Maxoptix has followed a strategy of emphasizing leading edge performance and capacity, as well as increasing the functional capabilities of its optical drives with each new product introduction.

Maxtor is a supplier of high performance 2.5", 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 flattened out.

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. In 1992, Maxoptix introduced a multifunction 5.25" drive and an upgraded version of the Ricoh write-once drive incorporating embedded data compression.

Maxoptix leverages its optical program through Maxtor's subsystem subsidiary, Storage Dimensions, which serves the personal computer and system inte-

grator markets. Storage Dimensions accounts for a substantial fraction of Maxtor and Maxoptix optical and rigid disk drives.

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 1992 production, as is a ruggedized version of a currently available 5.25" magneto-optic rewritable drive.

NEW VISION TECHNOLOGIES
3455 Morgan Avenue N.
Minneapolis, MN 55412

New Vision is a startup that is attempting to use the Capacitance Electronic Disk technology originally developed by RCA for videodisks to produce very high capacity read-only computer peripheral devices. CE-ROM, as the firm calls its intended product family, is still on the drawing board, but is being considered for further development on a partnership basis by several major firms.

OPTEX CORPORATION
2 Research Court
Rockville, MD 20850

Founded in 1986, Optex is working on development of rewritable optical disk drives using electron trapping as the recording technology. The materials used are capable of sustaining very high storage densities, but are sensitive to ambient light. However, write rates can be high because there are no thermal inertia effects as there are in magneto-optic or phase change systems. The drives are still in development, and there has been no indication from Optex as to an introduction date.

PINNACLE MICRO
19 Technology Drive
Irvine, CA 92718

Pinnacle Micro is best known as a subsystem producer and remarketer of optical drives and libraries, but in 1992 the firm began assembling a 5.25" rewritable drive using an Olympus mechanism and electronics supplied by Pinnacle.

Asian Manufacturers

(All fiscal years end in March, 1991, unless otherwise noted. All companies are in Japan unless otherwise noted.)

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

1991 total net sales: $5,693,467,000 Net income: $93,222,000

Aisin Seiki, a member of the Toyota Group, was established in 1949. The firm's primary activity, about 82% of revenues, is the production of automotive components, 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 shipped in 1990.

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

1991 total net sales: $3,423,874,000 Net income: $61,185,000

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 14% of revenues in 1991. 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

1991 total net sales: $13,843,881,000 (FY ending 12/31/91) Net income: $386,333,000

Canon is a major supplier of business machines, copiers, and cameras, but about 30% of the firm's business is in computer peripherals. Another 19% 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 Canon announced 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. Currently Canon ships most of its optical drives for use in its own document management systems.

The firm is considering a high capacity, high performance 3.5" drive, but will probably not commit to a firm program until it is clear what the generally accepted specifications for the next generation 3.5" magneto-optical drive will be.

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

1991 total net sales: $442,919,000 Net income: $615,000

Chinon is best known for its cameras and audio equipment, but 50% 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.

A 128 megabyte 3.5" magneto-optic drive was announced in 1992, but Chinon's actual date for delivery of production units had not been announced as of mid-1992.

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

1991 total net sales: $22,010,830,000 Net income: $612,393,000

Fujitsu is Japan's largest producer of computer systems and also manufactures a wide variety of other electronic equipment. Computer products represented about 73% of Fujitsu's 1991 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 yet announced such a product. 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. Officially announced in 1992, it is the first 5.25" optical drive to rotate at 5400 RPM. Fujitsu has also scored another "first" with its announcement of a 25.4 millimeter high 3.5" 128 megabyte magneto-optic disk drive.

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

1991 total net sales: $57,310,822,000 Net income: $1,705,074,000

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. About 49% of 1991 revenues were derived from computing and electronic equipment.

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. In addition to drives, Hitachi makes components used in optical drives such as lasers and special chips.

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. Later products have emphasized performance improvements and half high form factors. Hitachi is also a major producer of components used in CD-ROM drives.

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 introduced in late 1987 was not commercially 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. The firm is one of the active proponents of a 5.25" one gigabyte per side magneto-optic drive.

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. Hitachi's optical libraries have sold well in Japan, but have had difficulty capturing an appreciable share of the U.S. market.

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

1991 total net sales: $6,861,156,000 Net income: $118,593,000

JVC, as it is commonly known, is a major producer of consumer audio equipment, including CD players. Video tape recorders accounted for 48% of JVC sales in 1991, but JVC has been expanding into computer peripherals and has been shipping rigid disk drives since 1985. Computer related products now account for about 11% 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 went into sample production in late 1991, along with additional mastering subsystems. Full production began in the second quarter of 1992.

A 2.4" (61 millimeter) magneto-optic drive was shown at the 1991 Fall COMDEX show, but this was a preliminary showing intended to gather potential customer reaction. The capacity of the drive is 42.8 megabytes formatted, and it spins at 3600 RPM. The drive is packaged in a 25.4 millimeter high form factor. JVC hoped to find applications in portable computers and games, but has decided not to market the drive.

KAWASAKI STEEL CORPORATION
2-3 Uchisaiwai-cho, 2-chome
Chiyoda-ku, Tokyo 100

1991 total net sales: $9,736,244,000 Net income: $322,348,000

Kawasaki Steel entered the optical drive market through Kawatetsu Advantech, a subsidiary 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. Kawasaki Steel markets the drives under the Kawatetsu name 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. The firm also uses drives from other companies in a line of intelligent storage

subsystems that emulate hard disks. In addition to the write-once optical drives, Kawasaki manufactures hard disk emulators incorporating optical drives.

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

1991 total net sales: $2,866,778,000 Net Income: $193,000

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, for which MACO is a significant OEM supplier of CD-ROM drives.

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

1991 total net sales: $48,883,748,000 Net income: $1,917,881,000

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 was produced for IBM by Matsushita Electric's Disk Division. The product was not a commercial success, although MEI offered similar products under its own brand. The MEI branded product was similarly unsuccessful.

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. MEI has captured a major share of the 5.25" write-once market with this drive.

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, permitting it to operate as a multifunction drive as well. Because no overwrite pass is required, write throughput of this drive exceeds that of magneto-optic rewritable drives. However, its unique format and technology have inhibited broad industry acceptance.

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. The systems were marketed only in Japan, and the 8" line was phased out in 1991 in favor of 5.25" products produced by other Matsushita divisions.

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

1991 total net sales: $24,564,763,000 Net income: $590,815,000

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. All of Mitsubishi's library products are configured with 5.25" drives.

A 128 megabyte 3.5" magneto-optic drive was been announced by Mitsubishi in 1991, with shipments beginning in 1992. The drive rotates at 3,000 RPM.

A Mitsubishi 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 and this drive continued in the IBM product line in 1992.

MITSUMI ELECTRIC CO., LTD.
8-8-2 Kokuryo-cho
Chofu-shi, Tokyo

Mitsumi, founded in 1949, is primarily a manufacturer of electronic components, but 10% of 1991 revenues were derived from floppy disk drives and 10% from magnetic heads. The firm introduced CD-ROM drives in 1988, with most of the drives being sold as attachments to personal computers. Later models have been designed for use with games.

(MOST) MASS OPTICAL STORAGE TECHNOLOGIES
Subsidiary of Nakamichi Corporation
11205 Knott Avenue
Cypress, CA 90630

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 (nonexclusively) through Ocean Microsystems, another Nakamichi subsidiary. Production of a 128 megabyte 3.5" drive developed by MOST and Nakamichi began in late 1990. A 256 megabyte drive using a GCR recording format was announced in 1991, with shipments to begin in 1992.

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

1991 total net sales: $202,815,000 (FY ending 2/28/91) Net income: ($1,444,000)

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 4% of 1991 sales were computer related items. Nakamichi established or purchased 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, Nakamichi 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. Nakamichi markets the MOST drives in Japan.

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

1991 total new sales: $27,398,504,000 Net income: $402,837,000

NEC has defined its product area as communications and computers, with computer products accounting for about 49% of 1991 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, mostly sold in Japan.

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. A 1990 attempt to market a similar product in the U.S. has not been successful, but NEC is expected to try again with a more powerful game system.

NEC is one of the companies that introduced CD-ROMs in 1992 that operate with a doubled rotation and data transfer rate in order to accommodate multimedia video requirements. The firm also produces a series of portable CD-ROM units easily switched between computers.

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 a major producer of libraries for videodisks.

Having established itself as a manufacturer of optical libraries on a contract basis, Nikkyo is expected to eventually begin selling libraries under its own name.

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

1991 total net sales: $2,260,733,000 Net income: $128,126,000

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 has introduced the first 12" magneto-optic drive sold as a computer peripheral device. The 2 gigabyte per side erasable optical drive was announced in 1992. Additional 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.

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

1991 total net sales: $889,163,000 Net income: $4,563,000

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. The firm was unable to establish strong marketing channels for the drives and shipments ended in 1991. The company has experimented with 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

1991 total net sales: $14,378,459,000 Net income: $219,044,000

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 81% of the firm's revenues. The electronics division, which is responsible for libraries, was started in 1988.

NKK is offering optical libraries 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. In 1992, a larger library with a maximum capacity of 160 cartridges was added to the NKK product line.

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

1991 total net sales: $1,835,911,000 Net income: $54,563,000

Founded in 1919, Olympus Optical company is known primarily for its cam-

eras 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.

A 3.5" 128 megabyte drive is scheduled for shipment in 1992 as an Olympus product; the company is currently setting up marketing channels in the United States for the drives.

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

Pentax Teknologies was founded in 1985. Products included optical components, heads and a write-once drive, a 5.25" 326 megabyte per side unit introduced in late 1988. Basic drive mechanisms became available for delivery in 1989. The Pentax drive was unusually fast for a write-once drive when introduced, having a specified average seek time of 40 milliseconds, but Pentax was unsuccessful in selling it to other firms and the drive was withdrawn from the product line in 1991. Pentax continues to sell components and subassemblies for optical drives, but now sells mostly laser printers and scanners.

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

1991 total net sales: $4,442,170,000 Net income: $254,185,000

Pioneer, founded in 1947, is a major producer of consumer electronic equipment. 98% of Pioneer's 1991 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 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 shipments 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. A version with quadruple rotation and data transfer rate was announced in early 1992. Production for the quad-speed library is scheduled for October of 1992.

In 1990, Pioneer introduced a multifunction 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

1991 total net sales: $7,431,578,000 Net income: $100,422,000

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 accounted for 28% of 1991 revenues. This product line, which was started in 1979, includes a cartridge-type rigid disk originally 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 using magneto-optic rewritable media with 220 megabyte capacity per side and 393 megabyte per side write-once media. An ISO-standard high per-

formance 5.25" rewritable drive was introduced in 1991. A 3.5" 128 megabyte drive announced in 1991 is being made for Ricoh by another Japanese firm.

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

1991 total net sales: $11,969,533,000 (FY ending 11/30/91) Net income: $124,719,000

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 28% 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, Seiko Epson has continued its development program, announcing a 128 megabyte 3.5" drive in 1992.

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

1991 total net sales: $11,352,378,000 Net income: $347,541,000

Founded in 1935, Sharp was originally a producer of mechanical pencils. Sharp is now a supplier of electrical and electronic equipment. About 45% of sales are derived from computer or computer related products, including desk-top 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.

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

1991 total net sales: $27,339,081,000 Net income: $866,111,000

Sony is a leader in consumer electronics and has also earned a position as a leading supplier of 3.5" floppy disk drives. TV, VCR, and audio products make up 80% of revenues. Sony also holds the largest share of the magneto-optic disk drives and high performance CD-ROM drive markets.

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 3.3 gigabyte per side 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. A smaller library holding 12 cartridges was introduced in mid-1992.

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 was introduced in the U.S. in late 1991, although software availability is still limited.

In 1987, Sony announced and shipped its first few erasable 5.25" optical drive,using magneto-optical technology. Production units were shipped in late 1988, and Sony has been successful in capturing the largest market share for rewritable drives. From 1989 through 1992, Sony was the largest supplier of rewritable optical disk drives, and claimed over 150,000 cumulative shipments by mid-1992. Sony, with IBM and others, is a proponent of the 654 megabyte per side proposed standard, and has said it expects to ship such drives by late 1992.

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 the Mini-Disc, a 2.5" magneto-optic drive intended for use in a portable audio recorder. The Sony announcement was a technology announcement, and audio drive availability is expected in late 1992. Availability as a computer peripheral is uncertain. The new drive, which does not require a separate erase pass before recording, will also read CD-like read-only disks.

TEAC CORPORATION
3-7-3 Naka-cho
Mushashino, Tokyo 180

1991 total net sales: $943,370,000 Net Income: $32,800,000

TEAC is best known for its leadership position in the flexible disk drive industry, but the firm also has a development program for optical disk drives. A 3.5" 128 megabyte drive was announced in 1991, but production shipments did not begin until 1992.

TEXEL (SHINANO KENSHI)
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 firm's own label first shipped in 1990, but subsequently have appeared under the Texel brand. The half high drives are available in internal and external configurations. In 1992, Texel began shipping a double speed RPM drive in internal and external configurations.

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

1991 total net sales: $34,780,696,000 Net income: $895,200,000

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 54% of sales in 1991 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 never reached appreciable levels and the company withdrew from the write-once market in 1992. Toshiba showed a 3.5" rewritable drive rotating at 3600 RPM at the 1991 Tokyo Business show, and expects to be shipping this drive to Japanese customers in late 1992.

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 high performance 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. A 3.5" CD-ROM drive was announced in 1992.

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

1991 total net sales: $3,771,474,000 Net income: $56,585,000

Yamaha is the world's largest manufacturer of musical instruments, which account for 58% 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 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 12" write-once drives up to 5 gigabytes per side capacity; a preliminary announcement of a 3.5" 250 megabyte drive was made in early 1992. The firm designed a library storage unit containing a drive and six 12" disks, but has continued to market Cygnet's line of larger library units in order to concentrate its resources on its own product development and manufacturing while continuing to offer a full 12" product line.

DETERNER STEURERUNGS UND MACHINENBAU GMBH & CO. (DSM)
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.

K & S SYSTEMTECHNIK U. VERTRIEBSGES. MBH
Marienbergstrasse 80
W-8500 Nurnberg 10
Germany

K & S was founded in 1985 and began development of a family of tabletop optical libraries in 1990. A few evaluation units of a 10 cartridge 5.25" library were shipped in 1991, but formal introduction and the start of production shipments occurred in 1992. The libraries are sold mostly in Germany. 20 and 30 cartridge versions are planned for the future. Sony, Ricoh and Maxoptix drives are being used, but the libraries are adaptable for use with most 5.25" drives.

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 operations. 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. In 1992, LMSI was placed in the Philips Technologies Group and received new senior management.

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 latter part of 1991. LMSI has also begun marketing rewritable 5.25" and 3.5" drives made by Japanese companies 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.

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.

N. V. PHILIPS
5600 MD Eindhoven
The Netherlands

1991 total net sales: $30,473,797,000 Net income: $642,781,000

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. Magneto-optic recording has been under development at Philips for many years, but the effort has been intermittent. A 3.5" drive is presently in the development stage.

In 1985, Philips 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 was put up for sale in late 1990. The CD-ROM portion of PDO was sold to Disc Manufacturing, Inc. in mid-1991. Mitsubishi Kasei acquired U.S. manufacturing and marketing operations for plastic substrate writable media, while the remainder of PDO, including European marketing and the manufacture of 3.5", 5.25" and 12" glass substrate media, is now owned completely by Philips.

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 LMSI; Control Data held the other 49%. In 1990, Philips purchased Control Data's share and is now the sole owner of LMSI.

Philips' Professional Interactive Media Systems (IMS) is responsible for CD-ROM, CD-I, CD-ROM XA, CD-R, and supporting the Kodak Photo CD effort. Mechanisms are sold on an OEM basis by the Philips Key Module Group (KMG), which also provides drive mechanisms to other Philips business units. Organizationally, IMS and KMG are divisions of Philips Consumer Electronics.

Philips Consumer Electronics Company, a division of North American Philips, is expected to begin volume shipments of CD-I players in mid-1992. The players will be marketed under the Magnavox brand name. The firm is also selling free-standing CD-ROM drive subsystems bundled with software. Marketing under the Philips brand name will begin in late 1992. Write-Once compact disk drives, also known as CD-R (CD-Recordable) drives began shipping in 1992.

Sun Microsystems and Philips are involved in a joint effort 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.

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.

1992 DISK/TREND REPORT

DISK/TREND ON DISK

Introduction

DISK/TREND ON DISK is a licensed 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.

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 of the label of the 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 without difficulty.

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. 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 AutoIm-

port useful with other file translation tasks, it may be purchased independently from DISK/TREND or White Crane Systems, Inc.

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.

Note: Please read the license on the following page.

DISK/TREND ON DISK

Information License

DISK/TREND supplies diskettes containing selected information from the 1992 DISK/TREND Report as a separately purchased option to subscribers to the corresponding 1992 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 license terms and conditions of 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.

1992 DISK/TREND REPORT

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 AutoImport 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 megabyte 3.5" 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 (if you are using the Lotus 1-2-3 data parsing commands)
   COPY A:*.MSK (if you are using AutoImport)

   The utility files named FORMLIN?.PRN are specifically for usage 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

   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:

o 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 tables below which relate 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	1991 Rigid Report	1991 Flexible Report	1992 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	--
28	MASKA	MASKA	--
29	MASKA	--	MASKE
30	--	--	MASKD
31	--	MASKD	--
32	MASKD	MASKG	MASKA
33	--		MASKA
34	MASKA		MASKD
35	MASKA		MASKA
36	--		MASKA
37	--		MASKA
38	MASKD		MASKA
39	--		--
40	MASKA		--
41	MASKA		MASKE
42	--		MASKA
43	--		MASKA
44	MASKD		--
45	--		--
46	MASKA		MASKE
47	MASKA		MASKA

Cross reference (continued)

Mask File Name	1991 Rigid Report	1991 Flexible Report	1992 Optical Report
48	--		MASKA
49	--		--
50	MASKD		--
51	--		MASKE
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, <u>including the extension</u>, which will be of the form yy? where yy is the year of the report and ? is the report type as above.

   Examples: RT4.92R FT12.92F OT14.92O

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: OT50.92O

   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:

   o 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.

   o 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.

   o Now place the cursor in the 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 data base 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 for DISK/TREND ON DISK

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.