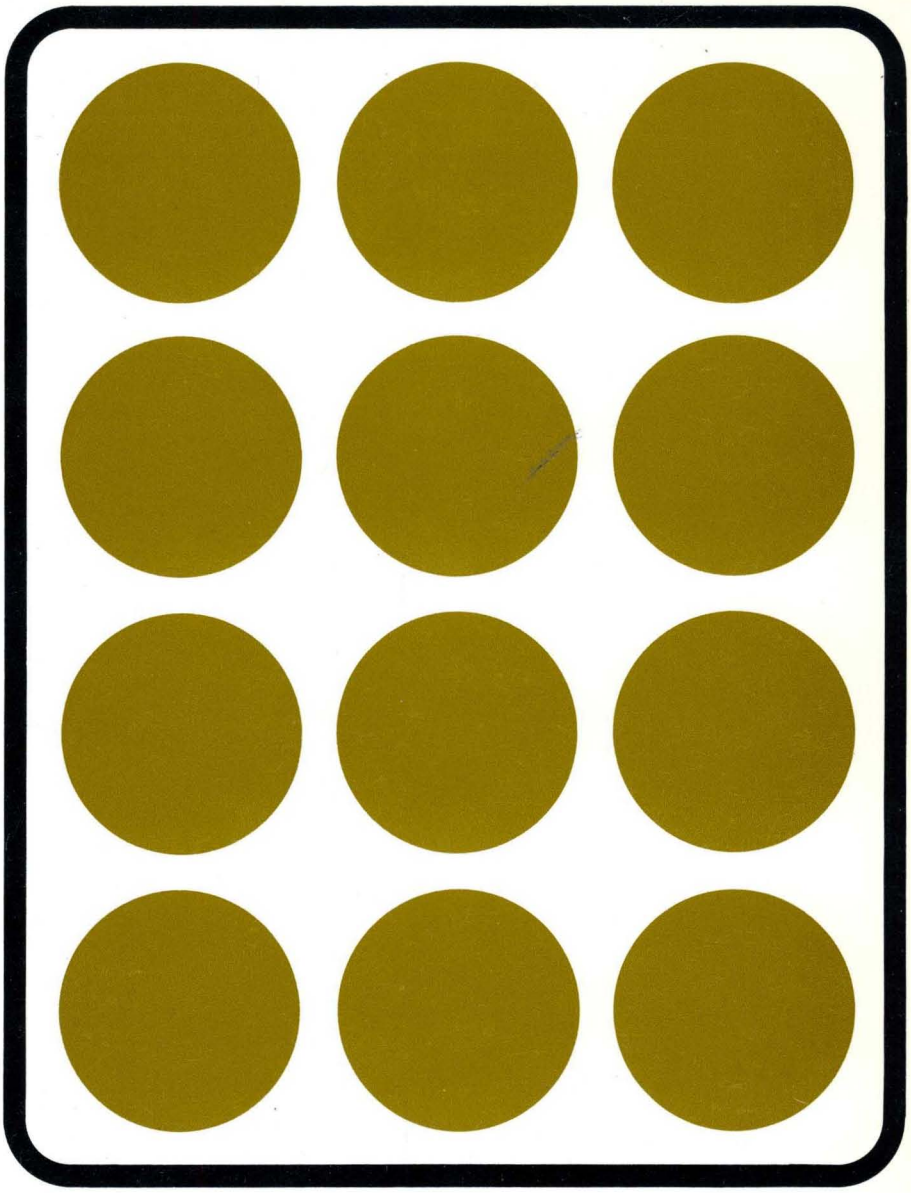
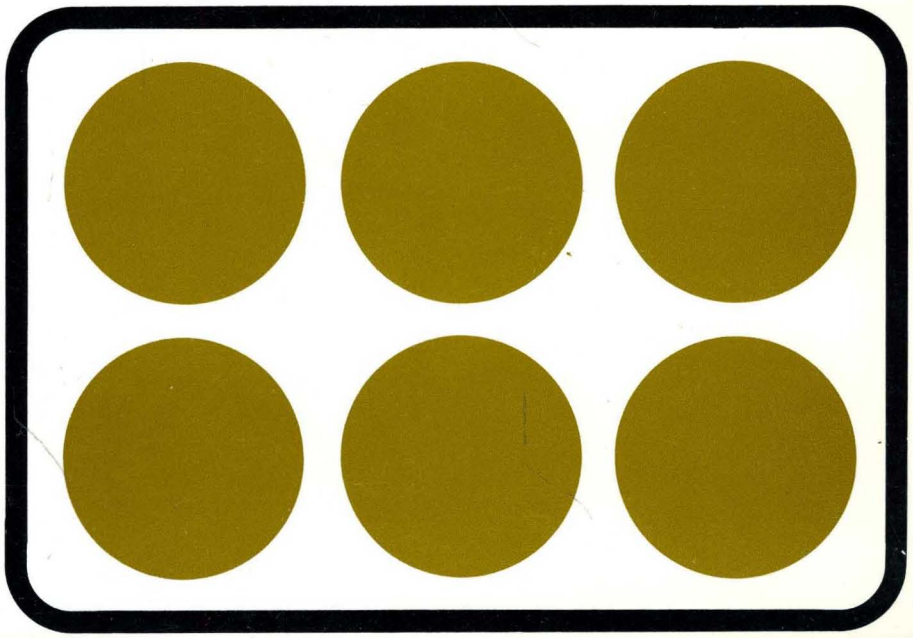


1990 DISK/TREND® REPORT



OPTICAL DISK DRIVES

1990 DISK/TREND® REPORT

OPTICAL DISK DRIVES

July, 1990

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FOREWORD

It has taken a long time for the optical data storage industry to become an important part of the computer industry, but it looks like that status has been achieved in 1990. Revenue growth has been good in all categories and shipment growth has been excellent for CD-ROMs and rewritable drives. It has been a good year for optical libraries, too, with shipments up strongly and many new, innovative products appearing in the marketplace.

Still, there are those nagging problems: Standards, media shortages, product proliferation, reliability, system integration, and profitability all present challenges. So does the next wave of drive component improvements, with better lasers, media, heads and other elements not too far in the offing. For those who appreciate a dynamic industry, full of challenge...you are in the right place.

DISK/TREND ON DISK, statistical and specification tables on floppy disks, is again offered, but only 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

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INTRODUCTION

1990 is the fifth year of publication for the DISK/TREND Report on optical disk drives, and coverage of optical disk libraries is being added this year. For those readers unfamiliar with DISK/TREND reports, a few useful points will help in interpreting the information presented.

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

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

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

* Market share tables, usually included in DISK/TREND reports, are omitted for some sections of this report, because the 1989 market was too small for market share figures to be meaningful.

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

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

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

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

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

SUMMARY: OPTICAL DISK DRIVES AND LIBRARIES

Industry size

The optical storage segment of the computer industry grew well in 1989 in both the drive and library categories. All product groups showed substantial revenue increases and all categories except drives over 1 gigabyte showed healthy unit shipment increases.

704,400 drives were shipped in 1989, an increase of 146.3% over 1988. Shipments of optical libraries were 1,444 units. Revenues for drives reached $677.1 million, while optical library revenues were $66.3 million. (The library revenues do not include the revenues of associated drives, to avoid double counting.)

U.S. manufacturers captured 3.8% of worldwide revenues, about half of their 1988 share. The significant increases in CD-ROM shipments boosted the revenue growth for non-U.S. manufacturers at a higher rate of increase. The situation for U.S. firms was better with libraries, as 72.4% of revenues went to U.S. firms in 1989. The U.S. share of drive unit shipments was only .9%, and while it is expected to grow somewhat, will not exceed 5% within the period of the forecast. Again, this is the result of U.S. non-participation in the CD-ROM market. U.S. firms held 52.2% of library unit shipments in 1989.

Of total industry drive revenues, 38.3% were generated by sales in the United States, while sales to U.S. firms accounted for 65.3% of library revenues. In 1993, the U.S. market is expected to be more significant, yielding 51.7% of a $2.8 billion drive market. The U.S. proportion of the library market is expected to stay about the same.

IBM has not yet entered the optical storage arena except as a pur-

chaser of drives and libraries to integrate into its systems. When IBM does enter as a manufacturer, the U.S. manufacturers' share of the overall market will increase. The U.S. firms producing libraries have done well because of their strengths in system integration and software support, and because libraries are used mostly on multiuser systems, a technology well understood by many U.S. companies. Non-U.S. firms have major strengths in optical drive component technology and have emerged as the major drive producers as a result.

TABLE 1

CONSOLIDATED WORLDWIDE REVENUES

OPTICAL DISK DRIVES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1989		Forecast							
	Revenues		1990		1991		1992		1993	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	.3	.6	2.2	3.0	21.7	30.3	35.0	50.0	55.2	77.0
Other U.S. Captive	--	--	--	--	1.8	1.8	1.8	1.8	3.6	5.4
TOTAL U.S. CAPTIVE	.3	.6	2.2	3.0	23.5	32.1	36.8	51.8	58.8	82.4
PCM/Reseller	6.0	7.1	38.3	48.9	71.4	94.0	99.6	127.4	120.7	164.4
OEM/Integrator	14.1	17.7	32.4	44.8	67.6	90.7	104.2	144.5	128.9	187.3
TOTAL U.S. NON-CAPTIVE	20.1	24.8	70.7	93.7	139.0	184.7	203.8	271.9	249.6	351.7
TOTAL U.S. REVENUES	20.4	25.4	72.9	96.7	162.5	216.8	240.6	323.7	308.4	434.1
Non-U.S. Manufacturers										
Captive	6.3	276.4	49.8	414.5	91.8	569.3	93.1	640.2	123.1	765.2
PCM/Reseller	69.5	108.5	130.8	205.0	224.6	338.8	294.4	439.9	364.9	549.0
OEM/Integrator	163.1	266.8	297.5	488.9	405.8	659.4	541.5	853.9	651.3	1,050.1
TOTAL NON-U.S. REVENUES	238.9	651.7	478.1	1,108.4	722.2	1,567.5	929.0	1,934.0	1,139.3	2,364.3
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	259.3	677.1	551.0	1,205.1	884.7	1,784.3	1,169.6	2,257.7	1,447.7	2,798.4

TABLE 2

CONSOLIDATED WORLDWIDE REVENUES

OPTICAL LIBRARIES

REVENUE SUMMARY

	LIBRARY REVENUES, BY SHIPMENT DESTINATION (M)									
	1989		Forecast							
	Revenues		1990		1991		1992		1993	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Other U.S. Captive	16.6	21.5	30.5	38.5	41.3	54.5	54.5	72.9	69.4	94.5
TOTAL U.S. CAPTIVE	16.6	21.5	30.5	38.5	41.3	54.5	54.5	72.9	69.4	94.5
PCM/Reseller	.2	.2	.9	1.1	1.3	1.7	1.7	2.2	2.0	2.6
OEM/Integrator	21.9	26.3	31.5	39.1	55.9	74.0	71.9	97.6	82.1	115.2
TOTAL U.S. NON-CAPTIVE	22.1	26.5	32.4	40.2	57.2	75.7	73.6	99.8	84.1	117.8
TOTAL U.S. REVENUES	38.7	48.0	62.9	78.7	98.5	130.2	128.1	172.7	153.5	212.3
Non-U.S. Manufacturers										
Captive	--	7.0	1.0	7.4	1.8	9.8	2.4	11.0	3.0	13.2
PCM/Reseller	--	--	2.0	3.2	3.2	5.2	4.5	7.4	5.9	9.5
OEM/Integrator	4.6	11.3	14.2	24.3	25.8	43.3	36.5	61.6	45.8	77.8
TOTAL NON-U.S. REVENUES	4.6	18.3	17.2	34.9	30.8	58.3	43.4	80.0	54.7	100.5
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	43.3	66.3	80.1	113.6	129.3	188.5	171.5	252.7	208.2	312.8

Figure 1

CHANGING PRODUCT MIX

Worldwide Optical Disk Drive Revenue

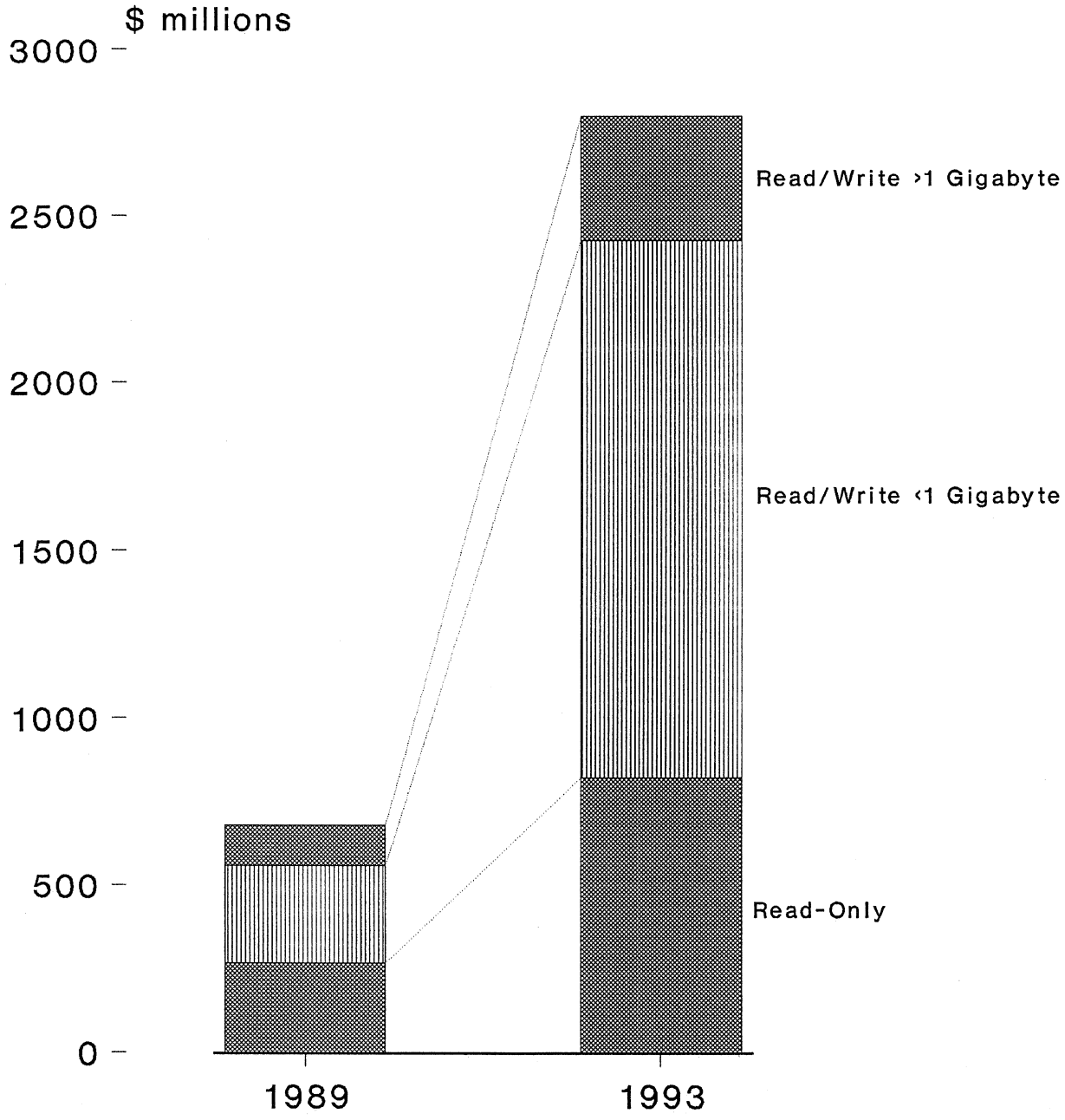
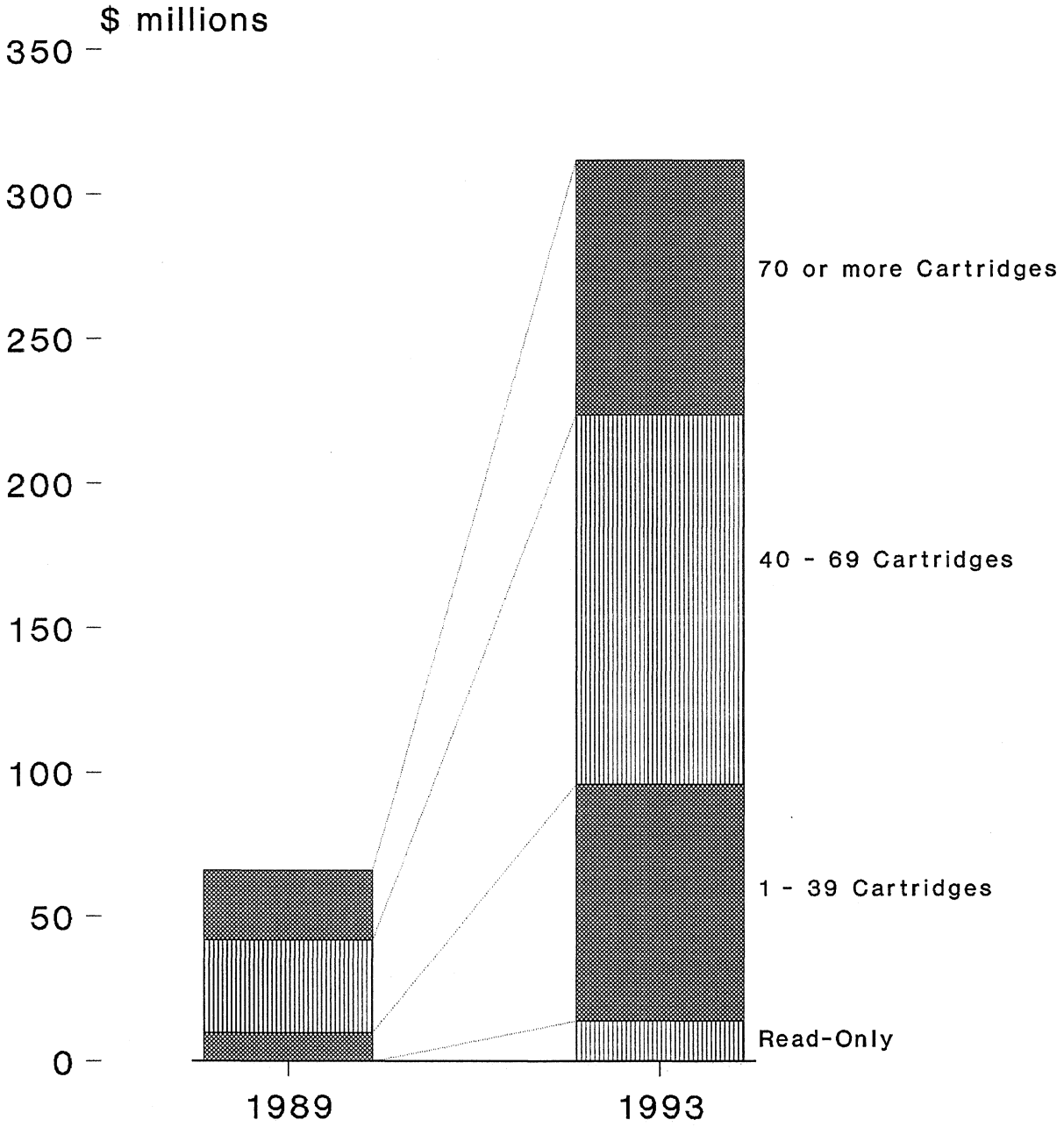


Figure 2

CHANGING PRODUCT MIX

Worldwide Optical Library Revenue



Marketing channels

The marketing channels used by optical drive manufacturers are defined in this report as captive, PCM/Reseller, and OEM/integrator. Captive drives are sold with systems also manufactured by the same company. The PCM/Reseller channel includes drives used in add-on subsystems for use with computer systems of all types and sizes, plus aftermarket distribution through wholesalers, dealers and other resellers. The OEM/Integrator channel includes drives 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.

In 1989, drive OEM/Integrator revenues accounted for 42% of the worldwide total, followed closely by captive revenues at 40.9%. PCM/Reseller revenues were 17.1%. Total revenue was $677.1 million. In 1993, of the $2.798 billion total revenues expected, the OEM/Integrator share will be up slightly, to 44.2% and PCM/Reseller revenue is projected to grow to 25.5%, at the expense of captive revenues, which are forecasted to decline to 30.3% share. Most of the anticipated growth in the PCM/Reseller channel will be from add-ons to existing systems.

Library revenues in 1989 amounting to $66.3 million were derived 56.7% from OEM/Integrators and 43% from captive sales. The PCM/Reseller content was negligible. 1993 library revenues of $312.8 million are expected to be split 61.7% to OEM/Resellers, 34.4% to captive sales, with only 3.9% through PCM/Resellers. Because of the complex system integration and support requirements of libraries, only the simplest types will be offered through the reseller channel.

Projected revenues include allowance for IBM optical disk drives, judged to have a high probability of introduction in the 1990/1991 time

frame, but do not include any allowance for IBM-manufactured libraries because IBM's intentions regarding libraries are much less clear.

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

TABLE 3

CONSOLIDATED WORLDWIDE REVENUES
OPTICAL DISK DRIVES
MARKET CLASS REVIEW

REVENUE SUMMARY

WORLDWIDE REVENUES BY MANUFACTURER TYPE	1989 Revenues $M	1989 Revenues %	Forecast 1990 $M	Forecast 1990 %	Forecast 1991 $M	Forecast 1991 %	Forecast 1992 $M	Forecast 1992 %	Forecast 1993 $M	Forecast 1993 %
U.S. Manufacturers										
IBM Captive	.6 -75.0%	--	3.0 +400.0%	.2%	30.3 +910.0%	1.6%	50.0 +65.0%	2.2%	77.0 +54.0%	2.7%
Other U.S. Captive	-- --	--	-- --	--	1.8 --	.1%	1.8 --	--	5.4 +200.0%	.1%
PCM/Reseller	7.1 +82.1%	1.0%	48.9 +588.7%	4.0%	94.0 +92.2%	5.2%	127.4 +35.5%	5.6%	164.4 +29.0%	5.8%
OEM/Integrator	17.7 +2.3%	2.6%	44.8 +153.1%	3.7%	90.7 +102.5%	5.0%	144.5 +59.3%	6.4%	187.3 +29.6%	6.6%
Total U.S. Manufacturers	25.4 +7.6%	3.6%	96.7 +280.7%	7.9%	216.8 +124.2%	11.9%	323.7 +49.3%	14.2%	434.1 +34.1%	15.2%
Non-U.S. Manufacturers										
Captive	276.4 +180.3%	40.8%	414.5 +50.0%	34.3%	569.3 +37.3%	31.9%	640.2 +12.5%	28.3%	765.2 +19.5%	27.3%
PCM/Reseller	108.5 +113.6%	16.0%	205.0 +88.9%	17.0%	338.8 +65.3%	18.9%	439.9 +29.8%	19.4%	549.0 +24.8%	19.6%
OEM/Integrator	266.8 +118.3%	39.6%	488.9 +83.2%	40.8%	659.4 +34.9%	37.3%	853.9 +29.5%	38.1%	1,050.1 +23.0%	37.9%
Total Non-U.S. Manufacturers	651.7 +139.9%	96.4%	1,108.4 +70.1%	92.1%	1,567.5 +41.4%	88.1%	1,934.0 +23.4%	85.8%	2,364.3 +22.2%	84.8%
Worldwide Recap										
Captive	277.0 +174.3%	40.9%	417.5 +50.7%	34.6%	601.4 +44.0%	33.7%	692.0 +15.1%	30.7%	847.6 +22.5%	30.3%
PCM/Reseller	115.6 +111.3%	17.1%	253.9 +119.6%	21.1%	432.8 +70.5%	24.3%	567.3 +31.1%	25.1%	713.4 +25.8%	25.5%
OEM/Integrator	284.5 +103.9%	42.0%	533.7 +87.6%	44.3%	750.1 +40.5%	42.0%	998.4 +33.1%	44.2%	1,237.4 +23.9%	44.2%
Total All Manufacturers	677.1 +129.4%	100.0%	1,205.1 +78.0%	100.0%	1,784.3 +48.1%	100.0%	2,257.7 +26.5%	100.0%	2,798.4 +23.9%	100.0%

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	1989 Revenues $M	1989 Revenues %	Forecast 1990 $M	1990 %	1991 $M	1991 %	1992 $M	1992 %	1993 $M	1993 %
U.S. Manufacturers										
Other U.S. Captive	21.5	32.4%	38.5	33.8%	54.5	28.9%	72.9	28.8%	94.5	30.2%
	--		+79.1%		+41.6%		+33.8%		+29.6%	
PCM/Reseller	.2	.3%	1.1	.9%	1.7	.9%	2.2	.8%	2.6	.8%
	--		+450.0%		+54.5%		+29.4%		+18.2%	
OEM/Integrator	26.3	39.6%	39.1	34.4%	74.0	39.2%	97.6	38.6%	115.2	36.8%
	--		+48.7%		+89.3%		+31.9%		+18.0%	
Total U.S. Manufacturers	48.0	72.3%	78.7	69.1%	130.2	69.0%	172.7	68.2%	212.3	67.8%
	--		+64.0%		+65.4%		+32.6%		+22.9%	
Non-U.S. Manufacturers										
Captive	7.0	10.5%	7.4	6.5%	9.8	5.1%	11.0	4.3%	13.2	4.2%
	--		+5.7%		+32.4%		+12.2%		+20.0%	
PCM/Reseller	--	--	3.2	2.8%	5.2	2.7%	7.4	2.9%	9.5	3.0%
	--		--		+62.5%		+42.3%		+28.4%	
OEM/Integrator	11.3	17.2%	24.3	21.6%	43.3	23.2%	61.6	24.6%	77.8	25.0%
	--		+115.0%		+78.2%		+42.3%		+26.3%	
Total Non-U.S. Manufacturers	18.3	27.7%	34.9	30.9%	58.3	31.0%	80.0	31.8%	100.5	32.2%
	--		+90.7%		+67.0%		+37.2%		+25.6%	
Worldwide Recap										
Captive	28.5	43.0%	45.9	40.4%	64.3	34.1%	83.9	33.2%	107.7	34.4%
	--		+61.1%		+40.1%		+30.5%		+28.4%	
PCM/Reseller	.2	.3%	4.3	3.8%	6.9	3.7%	9.6	3.8%	12.1	3.9%
	--		--		+60.5%		+39.1%		+26.0%	
OEM/Integrator	37.6	56.7%	63.4	55.8%	117.3	62.2%	159.2	63.0%	193.0	61.7%
	--		+68.6%		+85.0%		+35.7%		+21.2%	
Total All Manufacturers	66.3	100.0%	113.6	100.0%	188.5	100.0%	252.7	100.0%	312.8	100.0%
	--		+71.3%		+65.9%		+34.1%		+23.8%	

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

Product mix

Read-only drives continued to increase their share of total optical drive unit shipments in 1989, moving from 1988's 81.5% share to 85.6% in 1989. Read/write drives under 1 gigabyte declined from 14.9% to 13.0%, while read/write drives over 1 gigabyte declined from 3.6% to 1.4%.

1989 may be the peak year for revenue leadership of the optical disk drive market by the read-only product group, as increasing sales of re-writable small diameter drives in 1990 and later are expected to result in a 23.4% share for the small capacity read/write drive segment in 1993. Almost 90% of that product group will be erasable or multifunction drive shipments. In 1993, read-only drive shipments will have exceeded the 3.1 million unit mark, 76% of the total market. High capacity read/write drives over 1 gigabyte will hold a .6% share, with 27,400 units shipped, but will generate 13.3% of total revenue, due to high relative prices.

All application categories for read-only drives are expanding, but the consumer oriented game and automotive segments are projected to be the fastest growing markets. Another factor driving growth is expected sales increases as multimedia drives, controllers and titles become available in volume after 1991.

For optical libraries, the largest segment in 1989 was the 40 to 69 disk category, with 696 units shipped, out of a total of 1,444, for a 48.2% share. In 1993, read-only library units will have captured the unit shipment lead, with 11,180 units out of a total of 24,998, and a 44.7% share. Among the read/write library types, the 1 to 39 disk category will lead with 8,275 units shipped, and a 33.1% share.

Customer desires for shared databases, graphic image processing and document image storage are spurring library demand and the development of

less expensive storage subsystems for small scale computing systems and networks. The pattern emerging is that of a rapidly expanding market for low-end libraries for use with personal computers and small workstations that will swamp the classical library market in terms of unit shipments. However, while 1993 unit shipment statistics will favor the bottom of the line, the bulk of library revenues, 68.8%, will be generated from the two top of the line categories.

Industry participation

Nine U.S. companies, 25 Asian firms and 2 European organizations compete in the optical disk drive market. The number of U.S. firms has declined by 2, due to facility closings and mergers, while the number of Asian companies has climbed by 2, with Shinano Kenshi and MOST being the new entrants. The European roster remains unchanged from last year.

15 companies offer read-only drives, all of which are non-U.S. firms and 13 of which are Japanese organizations. 25 manufacturers are making read/write drives under 1 gigabyte: 12 of these have rewritable or multi-function drives on the market. There are two more suppliers than last year, and the number with rewritable drives has doubled. The number of firms with drives of 1 gigabyte or more has declined from 14 to 12.

TABLE 5

CONSOLIDATED WORLDWIDE REVENUES
OPTICAL DISK DRIVES
PRODUCT CATEGORY REVIEW

REVENUE SUMMARY

WORLDWIDE REVENUES	1989		Forecast							
ALL MANUFACTURERS	Revenues		1990		1991		1992		1993	
	$M	%	$M	%	$M	%	$M	%	$M	%
READ-ONLY	263.6	38.9%	395.0	32.8%	537.2	30.1%	646.9	28.7%	822.4	29.4%
ALL CAPACITIES	+176.3%		+49.8%		+36.0%		+20.4%		+27.1%	
READ/WRITE	293.9	43.4%	654.3	54.3%	1,001.9	56.2%	1,300.3	57.6%	1,602.7	57.3%
LESS THAN 1 GIGABYTE	+144.5%		+122.6%		+53.1%		+29.8%		+23.3%	
READ/WRITE	119.6	17.7%	155.8	12.9%	245.2	13.7%	310.5	13.7%	373.3	13.3%
MORE THAN 1 GIGABYTE	+50.3%		+30.3%		+57.4%		+26.6%		+20.2%	
Total Worldwide Revenue	677.1	100.0%	1,205.1	100.0%	1,784.3	100.0%	2,257.7	100.0%	2,798.4	100.0%
	+129.4%		+78.0%		+48.1%		+26.5%		+23.9%	
% U.S. Mfg.	3.7%		8.0%		12.1%		14.3%		15.5%	

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	1989		Forecast							
ALL MANUFACTURERS	Revenues		1990		1991		1992		1993	
	$M	%	$M	%	$M	%	$M	%	$M	%
OPTICAL LIBRARIES	.4	.6%	5.1	4.5%	7.3	3.9%	10.8	4.3%	14.2	4.5%
Read-Only	--		--		+43.1%		+47.9%		+31.5%	
OPTICAL LIBRARIES	10.0	15.1%	30.3	26.7%	53.2	28.2%	72.4	28.7%	83.4	26.7%
1-39 Disks	--		+203.0%		+75.6%		+36.1%		+15.2%	
OPTICAL LIBRARIES	32.2	48.6%	48.2	42.4%	77.6	41.2%	100.6	39.8%	127.6	40.8%
40-69 Disks	--		+49.7%		+61.0%		+29.6%		+26.8%	
OPTICAL LIBRARIES	23.7	35.7%	30.0	26.4%	50.4	26.7%	68.9	27.2%	87.6	28.0%
70 or more Disks	--		+26.6%		+68.0%		+36.7%		+27.1%	
Total Worldwide Revenue	66.3	100.0%	113.6	100.0%	188.5	100.0%	252.7	100.0%	312.8	100.0%
	--		+71.3%		+65.9%		+34.1%		+23.8%	
% U.S. Mfg.	72.4%		69.2%		69.0%		68.3%		67.8%	

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

TABLE 7

CONSOLIDATED WORLDWIDE SHIPMENTS
OPTICAL DISK DRIVES
PRODUCT CATEGORY REVIEW

UNIT SHIPMENT SUMMARY

UNIT SHIPMENTS IN THOUSANDS	1989 Shipments Units	1989 Shipments %	1990 Forecast Units	1990 Forecast %	1991 Forecast Units	1991 Forecast %	1992 Forecast Units	1992 Forecast %	1993 Forecast Units	1993 Forecast %
READ-ONLY	602.5	85.6%	1,074.2	82.2%	1,651.1	79.2%	2,212.3	76.6%	3,136.7	76.0%
ALL CAPACITIES	+158.8%		+78.3%		+53.7%		+34.0%		+41.8%	
READ/WRITE	91.5	13.0%	222.9	17.0%	418.4	20.0%	656.8	22.7%	967.9	23.4%
LESS THAN 1 GIGABYTE	+114.8%		+143.6%		+87.7%		+57.0%		+47.4%	
READ/WRITE	10.4	1.4%	12.0	.8%	17.6	.8%	22.8	.7%	27.4	.6%
MORE THAN 1 GIGABYTE	-1.9%		+15.4%		+46.7%		+29.5%		+20.2%	
Total Worldwide Shipments	704.4	100.0%	1,309.1	100.0%	2,087.1	100.0%	2,891.9	100.0%	4,132.0	100.0%
	+146.3%		+85.8%		+59.4%		+38.6%		+42.9%	
% U.S. Mfg.	.9%		1.9%		3.4%		4.2%		4.4%	

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 (SINGLE UNITS)

SHIPMENTS IN SINGLE UNITS	1989 Shipments Units	1989 Shipments %	1990 Forecast Units	1990 Forecast %	1991 Forecast Units	1991 Forecast %	1992 Forecast Units	1992 Forecast %	1993 Forecast Units	1993 Forecast %
OPTICAL LIBRARIES	14.0	1.0%	4,305.0	49.0%	6,185.0	44.4%	8,615.0	44.0%	11,180.0	44.7%
Read-Only	--		--		+43.7%		+39.3%		+29.8%	
OPTICAL LIBRARIES	481.0	33.3%	2,819.0	32.1%	4,730.0	34.0%	6,756.0	34.5%	8,275.0	33.1%
1-39 Disks	--		+486.1%		+67.8%		+42.8%		+22.5%	
OPTICAL LIBRARIES	696.0	48.2%	1,352.0	15.4%	2,449.0	17.6%	3,393.0	17.3%	4,496.0	18.0%
40-69 Disks	--		+94.3%		+81.1%		+38.5%		+32.5%	
OPTICAL LIBRARIES	253.0	17.5%	307.0	3.5%	567.0	4.0%	806.0	4.1%	1,047.0	4.2%
70 or more Disks	--		+21.3%		+84.7%		+42.2%		+29.9%	
Total Worldwide Shipments	1,444.0	100.0%	8,783.0	100.0%	13,931.0	100.0%	19,570.0	100.0%	24,998.0	100.0%
	--		+508.2%		+58.6%		+40.5%		+27.7%	
% U.S. Mfg.	52.2%		35.0%		37.3%		37.1%		36.0%	

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

Figure 3

WORLDWIDE SHIPMENT SUMMARY

Total Optical Disk Drives

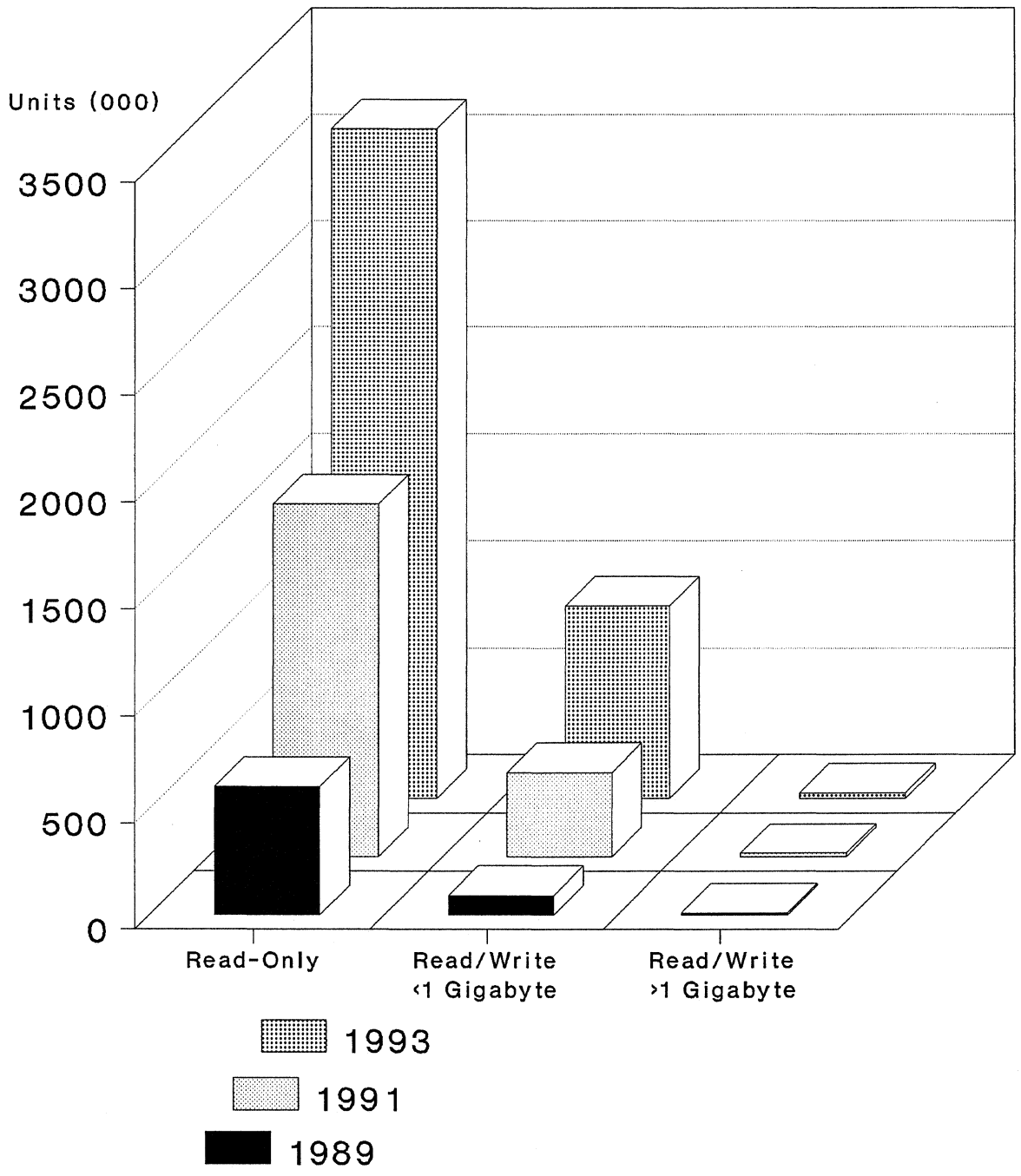
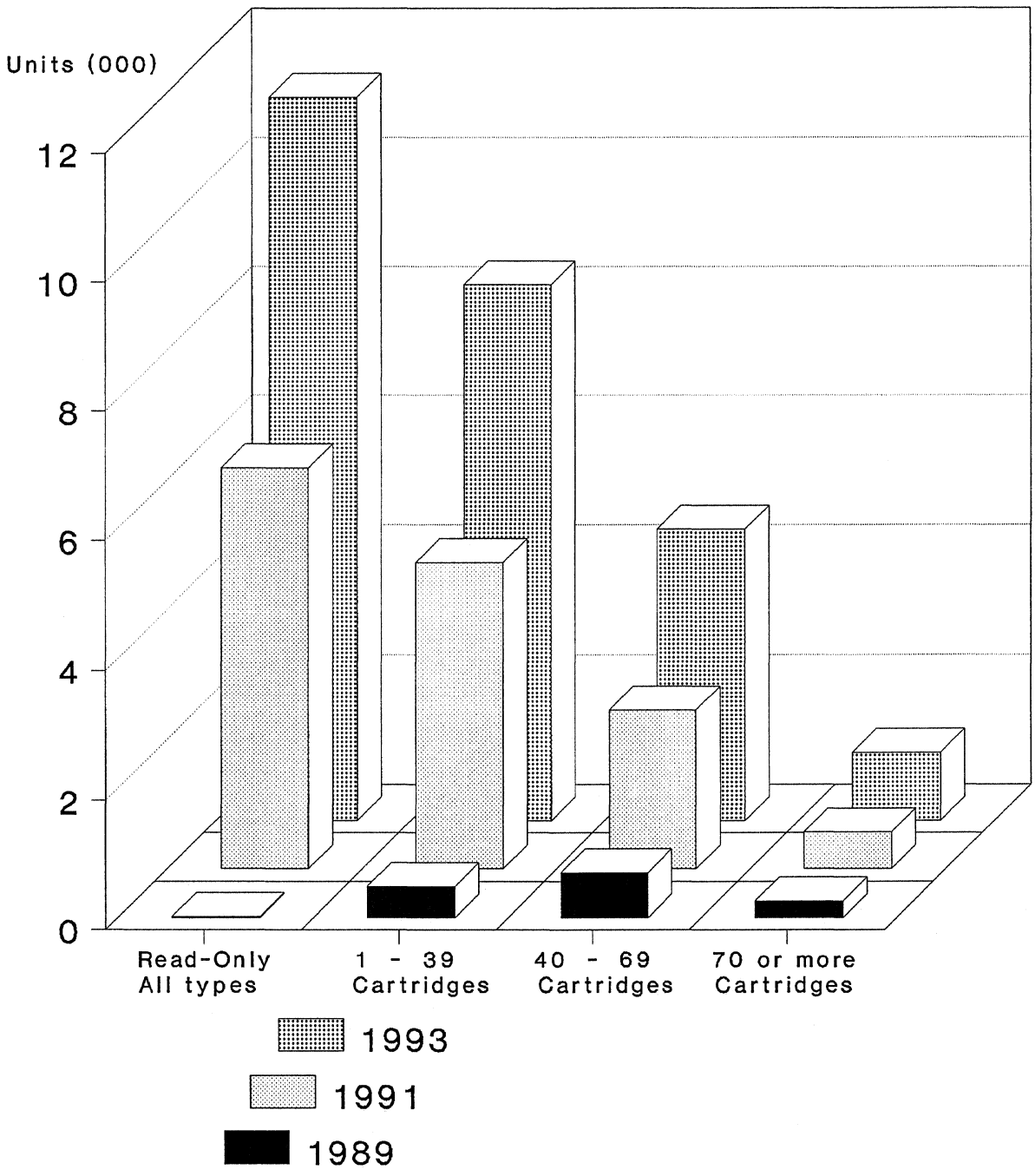


Figure 4

WORLDWIDE SHIPMENT SUMMARY

Total Optical Libraries



OEM/Integrator market

In the OEM/Integrator distribution channel, read-only drives represented 82.7% of shipments in 1989, followed by read/write drives less than 1 gigabyte, with 15.5% and read/write drives over 1 gigabyte with 1.8%. Increasing sales of rewritable drives are expected to expand the low capacity read/write drive share to 21.2% in 1993, with read-only drives retaining 78.3% and high capacity read/write drives shrinking to .5%.

OEM/Integrator drive revenues were led by the low capacity read/write product group with 42.5%, followed by read-only drives with 33.2% and high capacity read/write drives with 24.3%. The same pattern is expected in 1993, although the low capacity read/write drives will increase their revenue share to 56.4%, read-only will hold nearly steady at 30.4%, and high capacity read/write drives will retain 13.2%.

The major OEM/Integrator revenue producers in 1989 were Sony, Toshiba, LMSI and Ricoh in that order. These four companies accounted for 73.4% of total OEM/Integrator market value, although it should be noted that the contributions from each firm were not from similar products. U.S. producers captured only 6.2% of OEM/Integrator revenues in 1989, but their share is projected to increase to 15% in 1993. IBM captive revenues are assumed to be a significant portion of the increase.

For optical libraries sold in the OEM/Integrator market, 44% of 1989 shipments were generated by the 40 to 69 disk product group, followed by 36.5% in the 1 to 39 disk product group. In 1993, emphasis will have shifted to the low-end segments, with the 1 to 39 disk product group holding 40.4% share and read-only libraries nearly matching it with 37.2%.

Library OEM/Integrator revenues are weighted more heavily to high-end libraries. Essentially equal, the 40 to 69 disk and more than 70 disk

segments hold 79.8% of 1989 OEM/Integrator revenue. By 1993, the 40 to 69 disk category is projected to have the lead with 35.7%, followed by the 1 to 39 disk segment with 32%. As with the shipment shares, revenue is shifting to lower-end segments with time, although the read-only segment share reaches only 5.1% in 1993 because of different pricing levels for most of the products in this segment.

U.S. library OEMs captured 52.5% of the unit shipments in 1989, a percentage expected to diminish to 40.6% in 1993 as the result of higher CD-ROM library shipments from Asian companies. The U.S. share of OEM/Integrator revenues follows a similar pattern, declining from 69.9% in 1989 to 59.6% in 1993.

TABLE 9

OEM WORLDWIDE REVENUES
OPTICAL DISK DRIVES
PRODUCT CATEGORY REVIEW

REVENUE SUMMARY

WORLDWIDE REVENUES	1989		Forecast							
ALL MANUFACTURERS	Revenues		1990		1991		1992		1993	
	$M	%	$M	%	$M	%	$M	%	$M	%
READ-ONLY	94.4	33.2%	160.9	30.1%	227.3	30.3%	280.3	28.1%	376.4	30.4%
ALL CAPACITIES	+227.8%		+70.4%		+41.3%		+23.3%		+34.3%	
READ/WRITE	120.6	42.5%	289.2	54.3%	416.7	55.7%	578.7	58.0%	696.9	56.4%
LESS THAN 1 GIGABYTE	+68.7%		+139.8%		+44.1%		+38.9%		+20.4%	
READ/WRITE	69.5	24.3%	83.6	15.6%	106.1	14.0%	139.4	13.9%	164.1	13.2%
MORE THAN 1 GIGABYTE	+77.3%		+20.3%		+26.9%		+31.4%		+17.7%	
Total Worldwide Revenues	284.5	100.0%	533.7	100.0%	750.1	100.0%	998.4	100.0%	1,237.4	100.0%
	+103.9%		+87.6%		+40.5%		+33.1%		+23.9%	
% U.S. Mfg.	6.2%		8.3%		12.0%		14.4%		15.1%	

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

TABLE 10

OEM WORLDWIDE REVENUES
OPTICAL LIBRARIES
PRODUCT CATEGORY REVIEW

REVENUE SUMMARY

WORLDWIDE REVENUES	1989		Forecast							
ALL MANUFACTURERS	Revenues		1990		1991		1992		1993	
	$M	%	$M	%	$M	%	$M	%	$M	%
OPTICAL LIBRARIES	.4	1.1%	3.2	5.0%	4.6	3.9%	7.5	4.7%	9.8	5.1%
Read-Only	--		+700.0%		+43.8%		+63.0%		+30.7%	
OPTICAL LIBRARIES	7.2	19.1%	19.3	30.6%	37.8	32.3%	53.1	33.5%	61.7	32.0%
1-39 Disks	--		+168.1%		+95.9%		+40.5%		+16.2%	
OPTICAL LIBRARIES	15.0	40.0%	24.9	39.3%	44.2	37.7%	57.0	35.8%	68.9	35.7%
40-69 Disks	--		+66.0%		+77.5%		+29.0%		+20.9%	
OPTICAL LIBRARIES	15.0	39.8%	16.0	25.1%	30.7	26.1%	41.6	26.0%	52.6	27.2%
70 or more Disks	--		+6.7%		+91.9%		+35.5%		+26.4%	
Total Worldwide Revenues	37.6	100.0%	63.4	100.0%	117.3	100.0%	159.2	100.0%	193.0	100.0%
	--		+68.6%		+85.0%		+35.7%		+21.2%	
% U.S. Mfg.	69.9%		61.6%		63.0%		61.3%		59.6%	

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

TABLE 11

OEM WORLDWIDE SHIPMENTS
OPTICAL DISK DRIVES
PRODUCT CATEGORY REVIEW

UNIT SHIPMENT SUMMARY

UNIT SHIPMENTS	1989		Forecast							
IN THOUSANDS	Shipments		1990		1991		1992		1993	
	Units	%	Units	%	Units	%	Units	%	Units	%
READ-ONLY	304.8	82.7%	591.0	79.9%	947.0	79.2%	1,310.0	77.3%	1,950.0	78.3%
ALL CAPACITIES	+362.5%		+93.9%		+60.2%		+38.3%		+48.9%	
READ/WRITE	57.5	15.5%	142.1	19.2%	240.5	20.1%	374.5	22.0%	526.9	21.2%
LESS THAN 1 GIGABYTE	+75.3%		+147.1%		+69.2%		+55.7%		+40.7%	
READ/WRITE	6.9	1.8%	7.6	.9%	9.6	.7%	12.9	.7%	15.3	.5%
MORE THAN 1 GIGABYTE	--		+10.1%		+26.3%		+34.4%		+18.6%	
Total Worldwide Shipments	369.2	100.0%	740.7	100.0%	1,197.1	100.0%	1,697.4	100.0%	2,492.2	100.0%
	+249.6%		+100.6%		+61.6%		+41.8%		+46.8%	
% U.S. Mfg.	1.1%		1.4%		2.1%		2.8%		2.7%	

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

TABLE 12

OEM WORLDWIDE SHIPMENTS
OPTICAL LIBRARIES
PRODUCT CATEGORY REVIEW

UNIT SHIPMENT SUMMARY (SINGLE UNITS)

SHIPMENTS IN SINGLE UNITS	1989 Shipments Units	1989 Shipments %	1990 Forecast Units	1990 Forecast %	1991 Forecast Units	1991 Forecast %	1992 Forecast Units	1992 Forecast %	1993 Forecast Units	1993 Forecast %
OPTICAL LIBRARIES	14.0	1.3%	2,435.0	40.0%	3,585.0	35.6%	5,340.0	36.7%	6,830.0	37.2%
Read-Only	--		--		+47.2%		+49.0%		+27.9%	
OPTICAL LIBRARIES	396.0	36.5%	2,485.0	40.6%	4,210.0	41.7%	6,064.0	41.5%	7,440.0	40.4%
1-39 Disks	--		+527.5%		+69.4%		+44.0%		+22.7%	
OPTICAL LIBRARIES	478.0	44.0%	962.0	15.8%	1,844.0	18.3%	2,543.0	17.5%	3,300.0	17.9%
40-69 Disks	--		+101.3%		+91.7%		+37.9%		+29.8%	
OPTICAL LIBRARIES	199.0	18.2%	227.0	3.6%	455.0	4.4%	649.0	4.3%	838.0	4.5%
70 or more Disks	--		+14.1%		+100.4%		+42.6%		+29.1%	
Total Worldwide Shipments	1,087.0	100.0%	6,109.0	100.0%	10,094.0	100.0%	14,596.0	100.0%	18,408.0	100.0%
	--		+462.0%		+65.2%		+44.6%		+26.1%	
% U.S. Mfg.	52.5%		41.8%		43.4%		41.9%		40.6%	

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

Figure 5

WORLDWIDE SHIPMENT SUMMARY

OEM/Integrator Optical Disk Drives

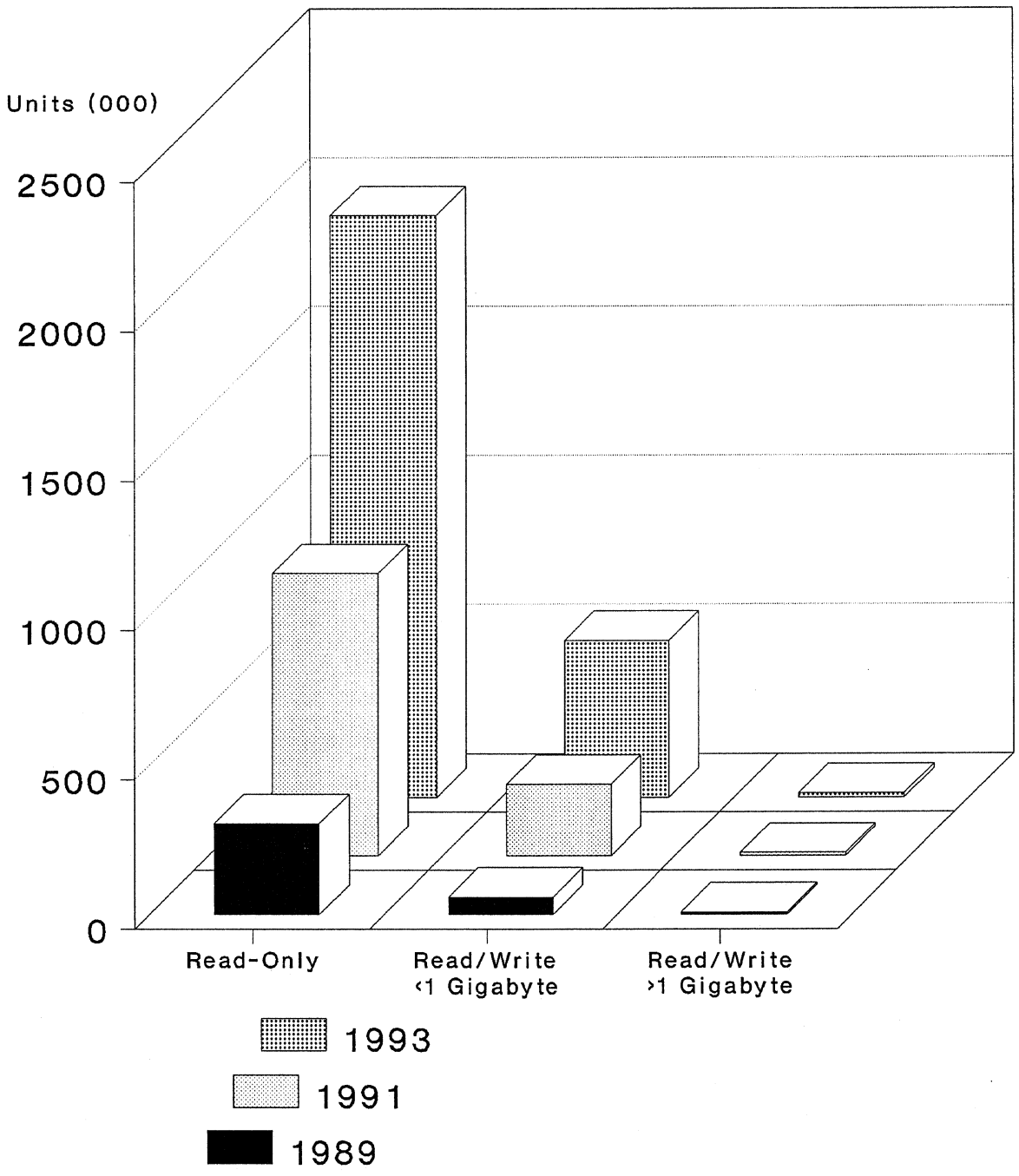


Figure 6

WORLDWIDE SHIPMENT SUMMARY

OEM/Integrator Optical Libraries

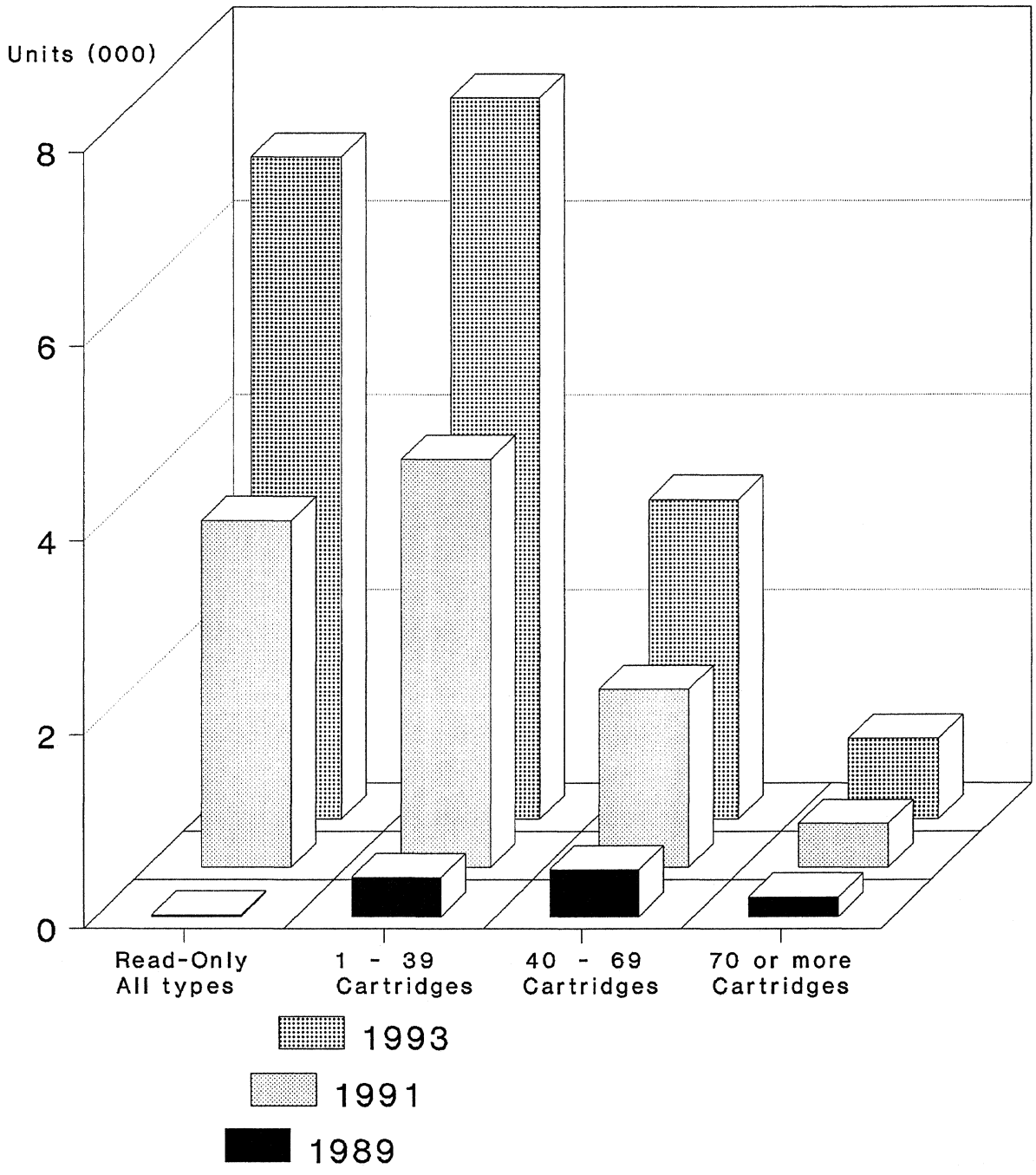


TABLE 13

1989 ESTIMATED MARKET SHARES

WORLDWIDE REVENUES OF ALL OPTICAL DISK DRIVES
(Value of non-U.S. currencies estimated at average 1989 rates)

	CAPTIVE		PCM/RESELLER		OEM/INTEGRATOR		TOTAL INDUSTRY	
	$M	%	$M	%	$M	%	$M	%
U.S. MANUFACTURERS								
Other U.S.	.6	.2	7.1	6.1	17.7	6.2	25.4	3.8
U.S. Total	.6	.2	7.1	6.1	17.7	6.2	25.4	3.8
NON-U.S. MANUFACTURERS								
ATG Gigadisc	--	--	3.6	3.1	7.2	2.5	10.8	1.6
Hitachi	29.3	10.6	48.0	41.5	13.1	4.6	90.4	13.4
LMSI	--	--	8.6	7.4	51.7	18.2	60.3	8.9
Matsushita Electric	4.1	1.5	6.6	5.7	14.7	5.2	25.4	3.8
NEC	107.3	38.7	1.0	.9	--	--	108.3	16.0
Pioneer	--	--	2.0	1.7	9.7	3.4	11.7	1.7
Ricoh	7.4	2.7	11.3	9.8	33.2	11.7	51.9	7.7
Sony	93.4	33.7	25.2	21.8	66.6	23.4	185.2	27.4
Toshiba	18.8	6.8	--	--	57.1	20.1	75.9	11.2
Other Non-U.S.	16.1	5.8	2.2	1.9	13.5	4.7	31.8	4.7
Non-U.S. Total	276.4	99.8	108.5	93.9	266.8	93.8	651.7	96.2
WORLDWIDE TOTAL	277.0	100.0	115.6	100.0	284.5	100.0	677.1	100.0

TABLE 14

1989 ESTIMATED MARKET SHARES

WORLDWIDE REVENUES OF ALL OPTICAL LIBRARIES
(Value of non-U.S. currencies estimated at average 1989 rates)

	CAPTIVE		PCM/RESELLER		OEM/INTEGRATOR		TOTAL INDUSTRY	
	$M	%	$M	%	$M	%	$M	%
U.S. MANUFACTURERS								
Cygnet Systems	--	--	--	--	15.7	41.8	15.7	23.7
Eastman Kodak	5.4	18.9	--	--	3.3	8.8	8.7	13.1
Filenet	13.8	48.4	--	--	4.3	11.4	18.1	27.3
Other U.S.	2.3	8.1	.2	100.0	3.0	8.0	5.5	8.3
U.S. Total	21.5	75.4	.2	100.0	26.3	69.9	48.0	72.4
NON-U.S. MANUFACTURERS								
Hitachi	.4	1.4	--	--	5.5	14.6	5.9	8.9
Other Non-U.S.	6.6	23.2	--	--	5.8	15.4	12.4	18.7
Non-U.S. Total	7.0	24.6	--	--	11.3	30.1	18.3	27.6
WORLDWIDE TOTAL	28.5	100.0	.2	100.0	37.6	100.0	66.3	100.0

TABLE 15

CURRENT PRODUCT LINES
MANUFACTURERS OF OPTICAL DISK DRIVES

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

DISK/TREND PRODUCT GROUP:		10	11	12
U.S. Manufacturers (9)	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
Honeywell	O		5.25	
IBM	C		5.25	
Literal	O,P		5.25	
Maximum Storage	O		5.25	
Maxoptix	O		5.25 E	
Mountain Optech	O		5.25	
Optimem	O			12
Asian Manufacturers (25)				
Canon	C,O		5.25 E	
Chinon	O	4.72		
Fujitsu, Ltd.	C,O		5.25	8, 12
Goldstar Telecommunication	O	4.72	5.25, 5.25 E	
Hitachi, Ltd.	C,O,P	4.72	5.25, 5.25 E	12
JVC	O	4.72		
Kawasaki Steel	O		5.25	
Matsushita Electric Ind.	O	4.72	5.25, 5.25 E	
Matsushita Electronic Comp.	C,O	4.72		
Matsushita Graphic Commun.	C,O		8	
Mitsubishi Electric	O		5.25, 5.25 E	
Mitsumi Electric	O	4.72		
MOST	O		3.5 E	
NEC	C,O	4.72	5.25 E	12
Nikon	O			12 E
Nippon Columbia	O	4.72		
Pentax Teknologies	O		5.25	
Pioneer Electronic	O	4.72	5.25, 5.25 E	
Ricoh	C,O		5.25, 5.25 E	
Sanyo	C,O	4.72		
Sharp	O		5.25 E	
Shinano Kenshi	O	4.72		
Sony	C,O	4.72	4.72, 5.25 E	12
Toshiba	C,O	4.72	5.25	12
Yamaha	C		4.72	
European Manufacturers (2)				
ATG Gigadisc	O			12
Laser Magnetic Storage	O	4.72	5.25	12

Numbers in table are diameters in inches.

TABLE 16

CURRENT PRODUCT LINES
MANUFACTURERS OF OPTICAL LIBRARIES

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

DISK/TREND PRODUCT GROUP:		50	51	52	53
U.S. Manufacturers (8)	Type	Read-Only Optical Libraries	Read/Write Optical Libraries 1-39 Disks	Read/Write Optical Libraries 40-69 Disks	Read/Write Optical Libraries 70+ Disks
Access	O		12		
Cygnet Systems	O		5.25		12
Document Imaging Systems	O			5.25	5.25
Eastman Kodak	C,O			5.25	14
Filenet	C,O			12	12
Hewlett-Packard	C,O		5.25		
International Data Engin.	O		5.25		
Kubik Enterprises	O	4.72			
Asian Manufacturers (11)					
Aisin Seiki	O		5.25		
Fujitsu	C		12		
Hitachi	C,O		5.25	5.25	
Matsushita Electric Indus.	C,O			5.25	
Matsushita Graphic Commun.	C,O			8	
Mitsubishi	C,O			5.25	5.25
NEC	C		12	5.25, 12	
NKK	O,P			5.25	
Pioneer	O	4.72			
Ricoh	C		5.25	5.25	
Sony	C,O		8	12	
European Manufacturers (3)					
DSM	O,C		12	5.25, 12	5.25, 12
Laser Magnetic Storage	O		12		
Next Technology	O	4.72			

Numbers in table are diameters in inches.

TECHNICAL REVIEW

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

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

Optical storage is still relatively young and there are many areas in which improvements need to be made. Some of the more significant are:

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

These and other problem areas are actively being addressed, resulting in a measured improvement in optical disk drive capabilities. Significant 1989 and 1990 milestones include announcements of "multi-function" drives capable of using write-once and rewritable media, the first optical drive capable of reading both sides of the disk simultaneously, rewritable phase change media and drives, 3.5" magneto-optic drives and the availability of 5.25" optical libraries at reasonable cost. Finally, it is necessary to realize that optical storage is only one of several technologies to be considered as a potential solution in a given application. One

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 technique for distributing system documentation and software as well as application packages.

The success of read-only optical disks depends upon the existence and timely development of a data base publishing industry willing to make use of the CD-ROM format to support its clients. As of mid-1990, there were about 1500 titles available for purchase on CD-ROM, (up from about 700 in mid-1989) and of these, only Microsoft's "Bookshelf" and games for home systems appear to have any prospects for broad acceptance. An equivalent number of titles have been developed for in-house use by companies wishing to distribute catalogs, procedure manuals, training materials, software and documentation within their organizations.

Apple Computer's announcement of a CD-ROM drive for its Macintosh line has stimulated new publishing activity aimed at Apple users, but the applications to date are narrow in scope. IBM's 1990 announcement of systems incorporating CD-ROM broke no new technical ground, but widely anticipated "multimedia" offerings incorporating data, audio and video on CD-ROM drives are raising expectations for improvement in CD-ROM costs and prices, as sales of multimedia products grow. Training and education are expected to be the early major applications for multimedia products.

Mass production of read-only optical disks must be done by a mastering and mass replication process, rather than by recording directly on the disk. While the cost per disk can be low, mast ering costs and replication turn-around time make production of single disks or short runs economically unattractive.

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

Because they have track densities typically in the range of 16,000 tracks per inch, write-once drives are capable of higher areal densities than magnetic recording drives now in use. 12" and 14" drives can provide several gigabytes on a single removable disk. Writing techniques involve changing the reflectivity of an area of the disk, either by making a small hole or causing a 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.

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 what type of media formulation is in use and adjust power levels to the appropriate level.

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 competitor to magnetic disk drives.

Although not yet demonstrated in field use, extensive accelerated testing indicates that write-once disks should provide archival lives which equal or exceed those of magnetic media, with 10 years being a commonly encountered specification for archival life of the media. Some firms specify a 30 year lifetime. 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 cap ability 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 the recording layer offer corrosion resistance, but may trade off write sensitivity for the improved longevity obtained.

The largest application for write-once recording technology is the archival storage of documents. The document is typically stored as a document image, rather than as character data. The write-once systems now available or entering the market use comparable, but differing technologies, with capacities per disk in the range of 100 megabytes to over 6 gigabytes. The smaller capacity products are being marketed initially as OEM drives for use in small systems; larger capacity drives are being used in captive systems and by a few system manufacturers. Later write-once systems have offered a higher degree of sophistication, such as LMSI's dual head 12" drive which offers 5.6 gigabytes of disk capacity and has two heads, allowing on-line access to both sides of the disk.

Obviously, the market for write-once optical disk systems will be limited to niche markets which can tolerate non-reversibility. These niches do exist and the low cost per byte of optical 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" multi-function drives now entering the market will probably displace dedicated write-once 5.25" drives since the user will be able to determine drive functionality simply by choice of media.

* Rewritable optical disks: The best possibility for eventual inroads into the market for magnetic disk drives exists with rewritable optical disk systems. Some, such as the Maxoptix 5.25" Tahiti drive are beginning to approach the performance of previous generations of magnetic drives and are being used in place of the venerable SMD-type removable disk pack drives. Magneto-optical recording has seen development activity for more than twenty 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 at the 1990 Spring Comdex conference. Rewritable optical recording based upon dye/polymer technology developed by Optical Data, Inc., and related drives from Tandy initially received much attention but did not prove workable. ODI has since ceased operations and Tandy has stated that their development effort is delayed.

  Small diameter rewritable optical drives offer the long-term promise of higher capacities and access times equivalent to those offered by many of today's small magnetic rigid drives. Such drives could be more reliable than magnetic disk drives due to the decreased chance of head crashes obtained through more head/disk separation, but are not yet able to offer the same cost/performance as magnetic drives. Very high capacity rewritable drives await the availability of larger diameter rewritable media, which is difficult to fabricate within the current state of the art.

  Especially impacted will be magnetic tape. The ability to add an optical disk for backup using the same controller used for other system disks offers the system OEM an attractive opportunity to reduce system complexity and cost while simultaneously improving performance. Rewritable disk drives using media with some tracks flagged as read-only may permit one type of device to be used for both backup and software distribution, potentially an attractive saving for system producers as drive prices decline.

  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 field. Changes in magnetic orientation are detected during reading, as the affected spot on the disk causes a small rotation in the polarized light reflected from the surface or transmitted through the disk.

Magneto-optic media require less laser power for writing than write-once media because there is no need to physically deform the writing layer or cause it to melt, permitting the disk to rotate faster for a given available laser power. The faster rotation (Canon is up to 3000 RPM) improves latency and data transfer rate. However, production magneto-optical disks have not yet shown the ability to overwrite in place: A complete sector must be erased before the sector can be rewritten. While several approaches offer technical solutions to this problem, all seem to add undesirable complexity and cost to the drive or media and none seem likely to be available in the market before 1992. However, Matsushita's rewritable phase change drive introduced in 1990 does not require a separate erase pass and thus can be faster than magneto-optic drives in write mode.

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

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

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 completion of the reversal cycle, limitations on the number of

reversals before degradation, poor shelf life, and low recording density.

Two other interesting, but low probability technologies have commercial possibilities. Film deformation is a rewritable recording process based upon the micro-deformation of a thin metal film as the result of laser irradiation. When irradiated at a higher power level, the deformed spot assumes its original shape. The films involved are typically Ni-Ti or Cu-Zn-Al alloys. The second approach, which is being developed by Optex Corporation, involves "electron trapping," by shifting the energy level of electrons in a material which holds them in a stable state for long periods in either the high or low energy state. A visible wavelength laser pulse moves an illuminated area to a high energy state. An infrared laser pulse causes the electrons to revert to the low energy state, emitting light as they do so. The presence or absence of light in response to a read (infrared) pulse yields a bit of information. The process is infinitely reversible, but is subject to interference from unwanted ambient light. Neither approach is close to being in a manufacturable status.

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, 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 could be applied to making a portion of the disk read-only, as has been done in the ANSI standard being prepared for 3.5" magneto-optic media.

* Optical libraries: Random-access libraries, commonly called "jukeboxes", are devices that automatically pick, load, unload and refile media units for an optical disk drive. While not part of the drive, they are frequently associated with the drive in high-end archival systems where very large amounts of data

must be accessed and maintained on-line. Current library units can store from 10 to over 200 disk units: Typical retrieval and load times are in the order of a few seconds. Some of these devices have multiple picking assemblies so that disk cartridge access/load operations can be overlapped, reducing the cartridge exchange time.

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

Drives designed for use in libraries must be able to withstand many thousands of cartridge insertions by robot pickers and must accommodate electrical control of cartridge loading and unloading. They should also minimize spin-up time, load time and unload time. However, in a library environment, average access time tends to be hidden by the much longer load/unload cycle time. Drives may also be subject to an unusual amount of shock and vibration associated with the operation of the library mech anism, which can cause reliability problems with mechanical and electronic components if not accounted for.

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

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

* Recording heads: The optical recording head is a relatively complex device incorporating a diode laser, detector, optics, and, frequently, a fine positioning mechanism. The result is a head assembly with relatively high mass, which slows access time and increases the power required to position the head. For the first generation of write-once optical drives, which were used with document storage systems, the long average access

time, typically in excess of 125 milliseconds, was not a critical factor. However, the desire of many firms to use optical drives in data processing systems is creating pressure for faster average access time. Considerable work is under way at many firms aimed at reducing the mass of optical head assemblies, and is beginning to bear fruit in such products as the Maxoptix 5.25" rewritable drive, which has an average seek time in the 35 millisecond range. This performance has been achieved by using a split optic system in which only the objective lens, focus and fine tracking mechanisms are mounted on the moving carriage, substantially reducing the total mass of the head assembly.

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

LMSI brought the first two-headed drive to market. The LMSI introduction 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. Pencom International produced small numbers of holographic heads but was unable to solve the laser power problem and develop a market for its heads. Molded glass aspheric lenses will be used in smaller drives. These lenses, some of which are molded using plastic rather than glass, substantially reduce cost, weight and complexity of the optical path in the head. Some advanced techniques currently being explored at Osaka University and other institutions have the potential to result in a monolithic assembly in which laser and lens are fabricated as a single unit.

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

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

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

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

* Recording disks: Although write-once optical media was originally in short supply, the manufacturing capacity problem has largely been resolved as new facilities have gone into production. The rewritable media first available was the magneto-optic type. There were media shortages in 1989 due to yield problems, but these should abate in 1990 as additional production capacity comes on line and manufacturing experience improves yields. Media suppliers were not prepared for the rapid ramp up in rewritable drive production that began in late 1988.

  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 several manufacturers can make disk media that are able to

withstand the range of temperatures and humidities likely to be experienced without undue media degradation. At present, there is over-capacity among media suppliers, in the aggregate. However, because write-once optical disks from different manufacturers are not widely interchangeable among drives, media availability is still a concern where specific pre-formatting is required and is available only from a single drive or media manufacturer. Manufacturers of rewritable drives claim that there will be a significant degree of media interchange capability between drives of differing manufacturers. While this is plausible, demonstration under field conditions has not always been successful.

Media manufacturers have yet to fully characterize the distribution of media defects so that designers of error correction electronics can design optimum chips. However, there is considerable improvement in the raw error rate. Hitachi, for instance, has reported that with suitable process precautions, a raw error rate of one bit in ten million is obtainable. This is a thousand times better than the raw error rates obtained with early optical media.

Some innovative products, such as the dye-based disks offered for use with the Pioneer and Ricoh write-once optical drive, offer potentially lower costs and improved environmental 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 applications.

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 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" mag-

neto-optic rewritable drive sold by Matsushita uses a glass substrate, and it is likely that many other rewritable drives will also use media built upon 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.

Media life is still a concern. Accelerated life tests indicate that rewritable media can be expected to have a useful life of 10 years or more, 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 seriously considered by standards committees.

  Drive manufacturers have not been able to reach a consensus as to a standard approach, and the result has been extended argument in standards committees, confusion and irritation on the part of prospective OEMs, and a significant contribution to delays in the growth of the markets for optical drives. The dispute has now been extended to rewritable drives. However, the leading 5.25" drive suppliers have so far elected to go with the continuous composite servo (CCS) tracking format. While there may be an extended delay in formulating an official standard, there is a fair chance that the continuous tracking format will become a de facto standard for the early generations of all sizes of drives. As track density increases, the sampled servo approach may prove to be more attractive in the long run.

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

* Packaging: Most early small optical drives were packaged to fit into a standard 5.25" form factor for easy mounting in personal computers widely produced in the second half of the 1980's. The next generation, offering 5.25" half-height profiles, is starting to appear. The first such products were CD-ROM drives, such as the ones introduced by Matsushita Electric and Toshiba, but half-high write-once and rewritable 5.25" optical drives are now being shipped. The 3.5" rewritable drives now entering the market will fit into a standard 41.3 millimeter high space, but pressures to go to even smaller form factors are already significant. Because small diameter optical disk drives are forced to conform to magnetic disk drive form factor standards, which continue to evolve, within a few years 3.5" optical drives will be required to achieve heights of 19 or 25.4 millimeters. Reduced drive height is necessary to be attractive to system integrators producing portable systems configured to accept magnetic drives in the small form factors.

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

  Some larger diameter drives are table-top or rack mounted. 12" products are typically rack mounted, as are the 8" units now on the market. 8" have not been successful to date, being used only in a few document storage systems, and interest in the 8" form factor seems to be concentrated among a few producers of stand-alone document storage systems or industrial systems. Suppliers of larger data systems and subsystems will prefer to remain with the 12" size because of its larger capacity per media unit. This leaves a relatively narrow niche for the 8" form factor at present, but if 5.25" designs top out in terms of available capacity per disk, 8" designs may look more appealing.

  Several firms are working on write-once and rewritable drives using the 4.72" CD-ROM format. The 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. Nevertheless, drive manufacturers will continue to investigate the CD format and other manufacturers are expected to provide write-once media for the CD format. Yamaha introduced a CD format write-once system in 1989 using media supplied by Fuji Photo Film and Sony and Fujitsu demonstrated CD format write-once systems at the 1990 Microsoft CD-ROM conference.

* 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 multi-user or document storage systems, and there has been some work done on a modification of the ESDI interface to support optical drives. 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.

  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 of the CD-ROM drives shipped today.

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

  Software for CD-ROM preparation and retrieval is becoming less difficult to locate. In many cases, software is supplied on the CD-ROM, with the published material. As most CD-ROM published works are of a textual or data base nature, publishers must obtain efficient text search or database search software. Over 50 software specialty houses make such programs available. Software for optical libraries requires creation of drivers for control of the library mechanism and systems software for integrating the library seamlessly into the overall system. System integration becomes increasingly complex as system complexity grows. Several man-years of software development are required to add optical libraries to mainframes.

* Standards: Physical standards for CD and CD-ROM were initially jointly set by Sony and Philips. The initial joint design was for an audio consumer product and this effort by two major firms

was sufficient to establish a de facto standard. The subsequent definition of the CD-ROM specification drew heavily upon the earlier design, and also became a de facto standard. In early 1986, Sony and Philips released an additional specification called CD-I (CD-Interactive) which defines a free-standing appliance rather than a computer peripheral. Limited hardware availability is expected in 1989. 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.

The announcement of the CD-I specification confused the market, especially the publishing segment, and delayed the release of published materials in the CD-ROM format. CD-I is more likely to appeal to the consumer marketplace than achieve success in the computer peripheral market, and major firms, such as Lotus, IBM, Intel and Microsoft have tended to ignore CD-I in favor of a competing format, DVI (Digital Video Interactive), now sponsored by Intel. CD-I has attracted considerable support, however, in the last year from firms preparing titles for the consumer and education markets.

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

Despite the availability of the ISO 9660 standard, some publishers of CD-ROM data have been reluctant to abandon previously used proprietary formats or the earlier High Sierra proposal, much to the inconvenience of end users who are trying to use multiple CD-ROM titles on their systems. The UNIX community is also displeased with aspects of the standard concerning file names and directory structures and is considering endorsing a modified version of the ISO 9660 standard named POSIX, which would allow the co-existence of UNIX-com patible 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, for operation in UNIX and UNIX-like environments.

Physical standards for other types of 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 agree ment to also submit the sampled servo approach for inclusion in a "dual stan dard". X3B11 finally embraced both approaches as well as a third approach, sampled servo with RZ modulation, suggested by ISI. As a result, there is no real write-once standard and many manufacturers, recognizing that the market is small anyway, have elected to go their own way and ignore the formatting aspects of standards efforts in favor of proprietary approaches to improved capacity or performance. 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.

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 confu- sion 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.

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. Standards for 5.25" and 3.5" families of drives and media should become avail- able in the 1990-1991 period. The 5.25" rewritable standard effort has been bedeviled by the same servo format arguments that hampered the write-once standard but has produced a worka- ble standard using the continuous composite servo (CCS) format (OSI draft standard 10089) which is close to final approval. The 3.5" standards have progressed toward a standard based on CCS, but disputes about disk cartridge issues such as shutter design and gripper holes for jukebox pickers must be finally resolved. Alternate formats, such as the discrete block format (DBF) proposed by some Japanese firms, remain to be addressed. The outlook is for eventual co-existence of multiple formats, with the marketplace deciding the winner.

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

At present, there is no standardization in larger sizes. There are already so many 12" drive designs in the field that stand- ardization of this size is unlikely in the near future, although

a standards project 12" media exists. The diversity of existing designs makes it difficult for most manufacturers to agree to changes because of the major costs of product redesign. New generations of 12" drives may be standardized to a greater degree, as working groups have been set up within the American X3B11 subcommittee and the Japanese SC23 standards subcommittees to consider standards for newer products. Progress has been slow, and many manufacturers don't express much enthusiasm for a 12" standard.

While Eastman Kodak is the only commercial supplier of 14" drives at present, there is also a nearly completed standards effort under way to define a standard for 14" write-once media.

* 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 free standing 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 deal 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. 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.

  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. lean towards endorsing the use of long distance Reed-Solomon codes for the

purpose of error detection and correction in read/write drives. Some Japanese firms have favored product codes, a method of performing error correction on a multi-dimensional data array, and the issue is still unresolved.

At least two firms in the U.S., Cyclotomics (an Eastman Kodak subsidiary) and Data Systems Technology (now a Cirrus Logic subsidiary), have developed algorithms and chips that will perform the bulk of the error detection and correction process, so the implementation of these functions should not be onerously expensive. Both of these firms are using Reed-Solomon codes.

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

Competing technologies

In making technology comparisons, it is important to remember that all technologies evolve and must be considered as "moving targets." Almost all forms of data storage have shown consistently improving bit storage density, track density, lower power requirements, faster access times, more intelligence and smaller size. Much of the experience gained in developing magnetic disk drives is applicable to the design of optical disk drives, and it appears that some techniques used by optical drive designers may be applicable to the design of magnetic disk drives. This type of cross-fertilization hastens the development of both technologies.

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

Magnetic disk drives

* Rigid disk drives: Rigid magnetic disk drives are the mainstay of today's auxiliary storage devices. Except on the lower end of the capacity and performance range, they appear relatively 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 300 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. It is unlikely, therefore, that the magnetic drive will be seriously threatened for the next few years in its role as a high performance system disk.

  Where removability is important, using 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 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 improbable.

* High capacity flexible disk drives: It is within the capabilities of today's technology to fabricate a floppy disk drive offering over 40 megabytes of storage capacity, and 20 megabyte devices are expected to be in high volume production in 1991. These high capacity floppy drives could compete with the very low-end of potential optical disk drive products. The market for personal computers has grown at a rapid rate, and shipments of small disk drives are keeping pace, creating a market for backup devices large enough to attract new product types.

  Although the 10 and 20 megabyte 5.25" flexible disk drives available in recent years have had nominal impact in the industry, three firms, Citizen, Insite Peripherals and Brier Technology, plan to ship 3.5" floppy drives with capacities of 20 megabytes in 1991. Brier has announced a 43 megabyte drive using a 26,000 BPI and 1,021 TPI format. But capacities in this range are only the beginning of the potential expansion of

floppy drive capabilities. A major problem 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 interchangability.

An interesting development is the proposal of flexible media drives that combine optical and magnetic technologies, such as the drive developed by Bernoulli Optical Systems (BOSCO) and now available for license. Such drives might offer significant competition in various applications due to favorable drive and media costs. BOSCO is a joint venture between Iomega and ICI, and developed an optical disk drive using flexible media. The 5.25" write-once drive uses the Bernoulli principle, as do other Iomega products, to position and stabilize the disk relative to the head. The drive is unusual in another way: It has two independent single stage rotary actuators and heads on both sides of the media. However, BOSCO does not intend to produce the drive and has made its technology available for licensing.

* Stretched surface recording: SSR, as this technique is commonly known, was devised by the 3M Corporation. It employs a disk composed of magnetically coated plastic film stretched across concentric cylindrical rings. The chief characteristic of this technology is that it allows a head to fly on an air cushion backed by a deformable surface that bulges slightly in the region under the head. This provides close head-media separation needed for high capacity but also makes the product head crash proof. Disk drives using this design technique could be produced in either fixed or removable format and might offer the same capacity as a low-end Winchester or optical drive. 3M has had various arrangements with other firms interested in developing drives for SSR disks for several years, most of which are no longer active, but no commitment for SSR drive or media manufacturing has been announced. As form factors continue to shrink, the viability of SSR has come into question by potential manufacturers.

Alternative optical devices: Cards and tape

* Optical cards: Two companies have announced optical cards: Drexler Technology Corporation and Optical Recording Corporation. The optical card announced in 1981 by Drexler Technology Corporation offers up to 4.11 megabytes of read-only or write-once storage contained on a credit card sized plastic substrate. 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.

  Production of drives and controllers suitable for use with the

card media is yet to be done on a commercial scale. Other optical card formats have been proposed by Sony, Canon, Dai Nippon Printing and Toppan Printing Company, all Japanese firms.

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 and other industrial automatic equipment. Twenty six companies have purchased licenses permitting them to manufacture optical card drives using Drexler patents.

An early program using a Drexler optical card with 2 megabyte capacity was established at Health Management Services, a subsidiary of Maryland Blue Cross/Blue Shield, but concerns about media multiple sourcing have caused delays and the program is not expected to resume. Drives for this program were to be made by Canon. Canon has also taken a media license from Drexler. Italy is experimenting with a national health card program using the Drexler card for patient data.

Nippon Conlux, Omron Tateisi, Olympus Optical and Kyocera are also prospective sources for Drexler-compatible optical card readers. Kyocera will be the supplier for CSK, a Japanese software company that holds a Drexler license. In March, 1989, a European standard for 2.6 megabyte optical cards and drives was published by the Drexler European Licensees Association, 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 write-once format and limited capacity of the Drexler card will limit it to specialized applications. The cost of the drive is unlikely to decrease below the cost of a floppy disk drive, so the optical card is unlikely to displace the large number of floppy disk drives widely used for software distribution. Because of its relatively limited capacity and/or performance, the optical card is not a competitor to the optical disk drive. The optical card will make its mark in the development of new applications rather than in the penetration of existing uses of storage devices, and will compete in such markets as the POS and security access markets against other portable storage devices such as smart cards.

* Optical tape: Optical tape drives, just leaving the developmental stage, represent another potential solution for those needing a way to store large amounts of archival data. So far, only write-once technology has been shown to be feasible for these

devices. While optical tape devices are inherently less capable of fast access to data than are disks, they do provide substantially greater capacity than magnetic tape in a single media unit, eliminating the need to handle as many media units per volume of data accessed. So far, only a few firms have been active in the optical tape field. The earliest were Docdata N.V., which has been developing a 6.2 gigabyte tape drive for use with IBM compatible tape controllers, and Laserstore, which has been working on a 2.5 gigabyte product. The Laserstore product will have a SCSI interface and be packaged in an 8" form factor. LaserTape Systems, a startup company, is developing an optical tape drive that will use a 50 gigabyte tape cartridge similar in dimensions to the IBM 3480 tape cartridge.

CREO Products, a Canadian firm, has been working with ICI on a write-once optical tape drive. The optical media, slit instead of punched, is similar to the media being supplied by ICI to BOSCO for its optical flexible disk drive development program. CREO delivered its first shipped product to the Canadian Government in 1990.

Magnetic tape drives

* High performance tape drives: Magnetic tape drives are shifting away from the reel-to-reel format in favor of cartridge formats. The IBM 3480 is setting a new 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. However, as rewritable optical disk drives become available, they have the potential to displace a significant fraction of the magnetic tape drives used for save/restore applications.

  Storage Technology Corporation has introduced an automated tape cartridge library that uses standard IBM 3480 tape cartridges and can hold up to 6,000 tapes in each modular unit. It will not be seriously challenged by optical drive based systems until IBM introduces an anticipated rewritable disk based library storage system, possibly in the mid 1990s.

  Helical scan tape drives offer some prospect of competition 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 are currently offering helical scan recorders. All of these products offer large capacities 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 150 to 300 kilobyte per second range. Because all of these technologies are based upon consumer electronics designs, media is widely available. The availability of existing consumer

products can reduce the cost of developing and manufacturing derivative pro ducts as computer peripherals. Nevertheless, significant rede sign 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 commercial success for its 8 millimeter format drives. However, lack of standardization and second sources inhibit sales of all the helical scan competitors. Much as CD-ROM has benefited from the sales and technology of CD audio players, the data version of 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". Capacities range from 4 to 100 megabytes in the .25" and smaller formats, and new drives are available in higher capacities in 5.25" form factors. The .5" tape cartridge drives will offer 240 megabytes in a 5.25" form factor. Some manufacturers are adopting the physical for mat of the 3480 cartridge in their drives but not the recording format; such products will be less expensive than the 3480 but will not offer media interchangeability with IBM systems.

  These products are threatened to some degree by write-once tech nology, 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 early 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 multi-user 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 be retarded until media costs are approximately equivalent. Since software distribution tasks rarely require the entire capacity of the media unit, the extra capacity of optical disks is not necessarily an advantage. 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.

  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 multi-user microcomputers. These products are relatively expensive and bulky, and are

vulnerable to gradual displacement as optical storage devices and high capacity tape cartridge devices come into wide use.

Other technologies

* Bubble memories: Bubble memories today are not serious competition to optical memories. 4 megabit chips are available today, with 16 megabit chips expected by 1991. 64 megabit chips are expected to be the next step, but are unlikely to be available until after 1995. 64 megabit chips might be used in arrays that might eventually be capacity competitive with low-end optical and magnetic disk memories, although it is highly unlikely that bubbles can compete on a cost per bit basis.

  Bubble technology density theoretically can be extended beyond that achievable with optical or magnetic disk technology if VBL (vertical Bloch line) storage proves to be feasible as a manufacturable technology. Much of the fundamental exploratory work on VBL is being performed at Carnegie Mellon University and Kyushu University, but some industrial exploration is happening at NEC, Hitachi, Magnesys and Sony. It will be at least 5 years -- and probably 10 -- before this technology is used in very large capacity arrays. If feasible, however, the inherently parallel organization of bubble memories promises to bring the equivalent of head per track performance to very large capacity storage devices. Such devices would be formidable competition to low-end optical and magnetic disk storage.

  At the present time, bubble memory is used almost entirely in military, aerospace, and harsh environment industrial applications. While most typical modular capacities are in the 720 kilobyte to 1.2 megabyte range, customized packages of up to 40 megabytes can be purchased at a cost of $5,000 per megabyte.

* 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. However, several firms are co-sponsoring 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 on the market 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.

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

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

Example:

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

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

to be connected to systems of all types, including personal computers, 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.

Examples:

* Maxoptix is considered a U.S. manufacturer, even though the firm plans to eventually manufacture 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.

Elevators: The basic unit used in counting optical libraries. One elevator 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 elevator unit in a physical system.

Revenue: Based on sales of disk drives or libraries alone, as normally sold by individual manufacturers. Controllers and library units sold as separate units are not included in disk drive revenue, nor are spare parts or service. When individual disk drive models include integral control functions, such as may be required for the first drive on a string of drives, the actual value of the complete unit is used. Library revenue is reported without the value of installed drives unless the sale is always made on a 'drives included' basis. Sale prices are estimated public sale transaction prices, whether at captive end user, PCM/Reseller or OEM/Integrator levels. All prices are in 1990 constant dollars.

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

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

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

APPLICATION CLASSIFICATION

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

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

Minicomputers/multiple user microcomputers: Drives and libraries attached to smaller general purpose processors typically serving multiple users, including network file servers. Examples: IBM System AS/400, AT&T 3B2, Hewlett-Packard 3000

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

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: Wang OIS series, Toshiba TOSFILE.

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

Consumer and hobby computers: Systems sold primarily to consumers for non-business applications. Examples: Commodore 64, MSX systems, most Atari models (Apple II is considered to be a professional/business microcomputer).

Other applications: Any application not included above.

READ-ONLY OPTICAL DISK DRIVES

1990 DISK/TREND REPORT

READ-ONLY OPTICAL DISK DRIVES

Coverage

Examples of disk drives in this group include:

4.72" disk diameter (CD-ROM)

Chinon	CDS-430, CDS 431
Goldstar Telecommunication	GCDR-200
Hitachi	CDR-1503S, CDR-1600S, CDR-3600
JVC	XR-R1001, XR-R100
Laser Magnetic Storage	CM131, CM201, CM210, CM212
Matsushita Electric	CR-501-B
Matsushita Electronic Comp.	EMO-103, SQ-D1, SQ-D101
Mitsumi Electric	CRMC-SR001N
NEC	PC-CD102, CDR-30, CDR 82, N5267-31
Nippon Columbia (Denon)	DRD-250, DRD-251, DRD-550, DRD-551
Pioneer	DRM-600/610
Sanyo	ROM-3000, ROM-3001, ROM-4005
Shinano Kenshi	DM-3020, DM-3120, DM-5000
Sony	CDU-510, CDU-541, CDU-6100, CDU-7101
Toshiba	XM-2200A, XM-3201B, XM-5100A

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

The CD-ROM is the dominant product type in this group because manufacturers leveraged the design, manufacturing and standards infrastructure developed for CD audio players, but CD-ROM performance is slow because of its strong design similarity to audio CD players. For purposes of this report, CD audio players that have been equipped with electronics to read CD-ROM formatted disks are considered as CD-ROM drives.

Market status

Growth of the read-only drive market continued in 1989. Automotive applications joined games as leading growth areas, while increasing use of the CD-ROM drive for distribution of documentation and data bases is also spurring demand.

Unit shipments surged to 602,500 units in 1989, up from 232,800 units in 1988. This 158% gain was driven in large part be the automotive and games segments, although all portions of the market grew. Revenues reached $293.9 million, actually increasing somewhat faster than shipments due to distribution mix changes. The number of participants increased to fifteen, as Shinano Kenshi began shipments under its own name. All read-only drives are made by non-U.S. companies, and all but LMSI are Asian firms, mostly Japanese. In general, the firms that started the CD-audio market have been the pioneers in CD-ROM.

In 1990, Sony introduced the Data Discman, the first product to incorporate a 3.15" (8 centimeter) drive. Aside from the diameter, the format is otherwise that of the larger CD-ROM. IBM has embraced the CD-ROM as a peripheral device on the system RS/6000 and certain high-end personal computers. Hewlett-Packard, DEC, IBM and other firms offer the CD-ROM as a means of distributing system documentation.

Because of its success in penetrating the automotive market, Toshiba was the largest shipper of non-captive CD-ROM drives in 1989, followed by Sony and Hitachi. NEC was the leading captive producer on the strength of sales for its game products. The percentage of CD-ROM drives used in consumer applications is expected to steadily increase from 19.6% of the market in 1989 to 31.8% in 1993.

Marketing trends

3,137,000 CD-ROM drives are forecasted for 1993 shipments, with revenues expected to rise to $822.4 million. Prices are expected to decrease from an average $375 in 1989 to $193 in 1993, under the stimulus of increased competition, larger quantities and an increasingly consumer oriented share of the applications mix. All production will continue to be by non-U.S. firms, but Asian countries other than Japan are expected to gradually improve their market share. Shipments of the 3.15" form factor CD-ROM are expected to be nominal until companies design more products that use it as a data oriented device.

62.2% of 1993 shipments are projected to be through OEM channels, up from 1989's 50.5% figure. Increasing sales to system manufacturers and integrators, plus the automotive segment, account for the change. 20.9% of shipments will be through PCM/Reseller channels, while 16.9% is forecast for captive shipments. Both captive and reseller unit shipments are increasing, but will decline as a percentage of the total, due to stronger anticipated OEM sales.

The introduction of multimedia (combined and interleaved data, audio, and video) on CD-ROM is expected to increase the size of the market for CD-ROM, especially in the education, industrial training, and point-of-sale markets. Shipments should begin in 1991 and reach substantial volume in 1993. There are two major multimedia formats: CD-I, sponsored by Sony and Philips, and DVI, which has been embraced by Intel, IBM, Lotus and other major companies. DVI chips and boards are available for developers currently, and this format appears most likely to succeed in the business oriented marketplace. CD-I has attracted most of its followers in the education, point-of-sale and consumer camps. CDTV, a stand-alone CD-ROM

reader with an alternate format, will be provided on Commodore CD-ROMs prepared with Amiga-based authoring systems starting in late 1990.

Finally, the demand for read-only storage is driven by the information that publishers provide for it. In addition to the estimated 1,500 titles now sold by CD-ROM publishers, there are an approximately equal number of "titles" published by companies for internal use. These 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 is growing as the price of authoring tools comes down and they become easier to use.

Applications

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

CD-ROM also 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.

Currently, read-only drives appear primarily on micro-based systems, including individual personal computers and workstations, which accounted for 37.4% of drive unit shipments in 1989. Consumer applications, notably the NEC PC Engine, accounted for 30.7%. In 1993, consumer applications, led by games and automotive uses, are expected to be the largest application area, with 36.9% of the units sold, followed closely by single user computers, with 29.1%. In the future, CD-ROM drives will increasingly be attached 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 use. In 1993, larger systems are expected to absorb 5.8% of the units sold, up from 3.5% in 1989.

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

Technical trends

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

Multi-media: 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 elec-

tronics. Older CD-ROM drives are not able to operate with the XA format and will require modification or special adapters.

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

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

Standards for motion video compression being worked out by MPEG (Motion Picture Experts Group) are likely to be adopted in 1990 for CD-I. A similar group, JPEG, is concentrating on compression standards for still video images. The Commodore CDTV player is ISO 9660 compatible but not MPEG compatible.

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

Performance: Average access times, which decreased below the .5 second range in 1986 have dipped well under 400 milliseconds since 1989. Further gains without raising cost significantly are difficult. Users would like faster data transfer rates also, especially where multimedia is used, but since the data format is fixed, this may require faster rotation rates.

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

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

Packaging: The packaging of CD-ROM drives has changed rapidly. In 1986, most of the drives shipped were not compatible with the full

height and half high form factors that have been adopted for 5.25" magnetic disk drive products. Today, most CD-ROM drive models in production are half high models. However, since the computer industry has moved to the 3.5" packaging profile, CD-ROM drives are usually mounted externally to the desktop computers and internally in tower configurations.

Sony, as noted previously, has already used the 3.15" format in its Data Discman, but it is too early to tell whether this will be a highly successful product or encourage other use of the 3.15" CD-ROM format. Data Discman went on sale in Japan July 1.

Authoring systems: Publishers of CD-ROMs require tools to help them prepare various types of content including text, databases, audio and video for mastering and replication.

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 around multiple drive configurations. Three firms (Kubik, Pioneer, and Next Technology) have announced autochangers for CD-ROM. The relatively slow bandwidths and throughput obtained from heavily loaded networks may make it impractical for servers containing multimedia formatted disks to adequately respond to user expectations for image motion and audio continuity. Fiber optic based networks may be needed to use multimedia in a network environment efficiently.

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

Writable CD: Except for mastering systems, writable CD-format media and systems are still not readily available, and the early enthusiasm of Philips and other potential producers seems to have cooled as a result of concerns about piracy and uncertainty as to whether development should be aimed at write-once or erasable media. The prospects for writable CD-format drives are reviewed in the discussion of read/write drives with under 1 gigabyte capacity.

Forecasting assumptions

1. CD-ROM players will be in production status in at least twelve companies in 1990. The form factor will fit within the 5.25" half high standard, but there are no immediate expectations for broad acceptance of the 3.15" drive.

2. The ISO formatted disk interchange standard for CD-ROM will be accepted almost universally by drive manufacturers and publish-

ers, and the Japanese cartridge format will become the dominant form, even in the absence of a formal standard.

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

4. The automotive segment and games segment will continue strong growth.

5. There will be a significant demand for CD-ROMs by system and subsystem integrators who will add them to specialized workstations, file servers, and memory subsystems.

6. CD-ROMs will appear on approximately 4% of the installed business oriented PC base and on about 5% of the installed base of home and educational systems, excluding games, by the end of 1993.

7. CD form factor write-once or rewritable drives will appear only in professional mastering systems and will have no negative impact on CD-ROM sales. No other form of read-only optical memory will seriously challenge CD-ROM before 1992.

8. The CD-I format will impact primarily the home and education markets. Final hardware will not appear until the latter part of 1991 and there will be additional shipment delays while programs and published materials are prepared. CD-I will have relatively minor impact on the CD-ROM in the business market. DVI will have no significant impact until 1991.

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

9. Automated libraries for CD-ROMs will be available to make CD-ROMs practical peripheral devices for mainframe and minicomputer systems.

1990 DISK/TREND REPORT

TABLE 17

READ-ONLY OPTICAL DISK DRIVES, ALL CAPACITIES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1989		Forecast							
	Revenues		1990		1991		1992		1993	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	--	--	--	--	--	--	--	--	--	--
TOTAL U.S. CAPTIVE	--	--	--	--	--	--	--	--	--	--
PCM/Reseller	--	--	--	--	--	--	--	--	--	--
OEM/Integrator	--	--	--	--	--	--	--	--	--	--
TOTAL U.S. NON-CAPTIVE	--	--	--	--	--	--	--	--	--	--
TOTAL U.S. REVENUES	--	--	--	--	--	--	--	--	--	--
Non-U.S. Manufacturers										
Captive	1.8	91.1	25.1	114.5	52.8	147.1	64.4	166.2	98.6	209.9
PCM/Reseller	55.8	78.1	83.9	119.6	115.3	162.8	141.6	200.4	166.3	236.1
OEM/Integrator	53.5	94.4	89.9	160.9	104.4	227.3	130.5	280.3	185.3	376.4
TOTAL NON-U.S. REVENUES	111.1	263.6	198.9	395.0	272.5	537.2	336.5	646.9	450.2	822.4
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	111.1	263.6	198.9	395.0	272.5	537.2	336.5	646.9	450.2	822.4
OEM Average Price ($000)	.375	.310	.330	.272	.240	.240	.214	.214	.193	.193

TABLE 18

READ-ONLY OPTICAL DISK DRIVES, ALL CAPACITIES

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1989		Forecast							
	Shipments		1990		1991		1992		1993	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	--	--	--	--	--	--	--	--	--	--
TOTAL U.S. CAPTIVE	--	--	--	--	--	--	--	--	--	--
PCM/Reseller	--	--	--	--	--	--	--	--	--	--
OEM/Integrator	--	--	--	--	--	--	--	--	--	--
TOTAL U.S. NON-CAPTIVE	--	--	--	--	--	--	--	--	--	--
TOTAL U.S. SHIPMENTS	--	--	--	--	--	--	--	--	--	--
Non-U.S. Manufacturers										
Captive	3.0	150.2	50.1	238.1	110.0	334.1	140.0	401.3	224.0	530.7
PCM/Reseller	106.3	147.5	174.0	245.1	262.0	370.0	354.0	501.0	462.0	656.0
OEM/Integrator	142.7	304.8	272.5	591.0	435.0	947.0	610.0	1,310.0	960.0	1,950.0
TOTAL NON-U.S. SHIPMENTS	252.0	602.5	496.6	1,074.2	807.0	1,651.1	1,104.0	2,212.3	1,646.0	3,136.7
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	252.0	602.5	496.6	1,074.2	807.0	1,651.1	1,104.0	2,212.3	1,646.0	3,136.7
Cumulative Shipments (000)										
IBM	--	--	--	--	--	--	--	--	--	--
Non-IBM	431.0	936.4	927.6	2,010.6	1,734.6	3,661.7	2,838.6	5,874.0	4,484.6	9,010.7
WORLDWIDE TOTAL	431.0	936.4	927.6	2,010.6	1,734.6	3,661.7	2,838.6	5,874.0	4,484.6	9,010.7

TABLE 19

READ-ONLY OPTICAL DISK DRIVES, ALL CAPACITIES

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1989 Revenues	FORECAST							
		1990		1991		1992		1993	
	4.72"	4.72"	3.15"	4.72"	3.15"	4.72"	3.15"	4.72"	3.15"
U.S. MANUFACTURERS									
TOTAL U.S. REVENUES	--	--	--	--	--	--	--	--	--
NON-U.S. MANUFACTURERS									
Captive	91.1	110.3	4.2	139.2	7.9	156.4	9.8	198.9	11.0
PCM/Reseller	78.1	119.6	--	162.8	--	200.4	--	236.1	--
OEM/Integrator	94.4	160.9	--	227.3	--	280.3	--	376.4	--
TOTAL NON-U.S. REVENUES	263.6	390.8	4.2	529.3	7.9	637.1	9.8	811.4	11.0
WORLDWIDE RECAP									
Captive	91.1 +384.6%	110.3 +21.1%	4.2 --	139.2 +26.2%	7.9 +88.1%	156.4 +12.4%	9.8 +24.1%	198.9 +27.2%	11.0 +12.2%
PCM/Reseller	78.1 +63.4%	119.6 +53.1%	-- --	162.8 +36.1%	-- --	200.4 +23.1%	-- --	236.1 +17.8%	-- --
OEM/Integrator	94.4 +227.8%	160.9 +70.4%	-- --	227.3 +41.3%	-- --	280.3 +23.3%	-- --	376.4 +34.3%	-- --
Total Revenues	263.6 +176.3%	390.8 +48.3%	4.2 --	529.3 +35.4%	7.9 +88.1%	637.1 +20.4%	9.8 +24.1%	811.4 +27.4%	11.0 +12.2%
ANNUAL SHARE, BY DIAMETER	100.0%	99.0%	1.0%	98.6%	1.4%	98.6%	1.4%	98.8%	1.2%

TABLE 20

READ-ONLY OPTICAL DISK DRIVES, ALL CAPACITIES

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DISK DIAMETER

	1989 Shipments	FORECAST							
		1990		1991		1992		1993	
	4.72"	4.72"	3.15"	4.72"	3.15"	4.72"	3.15"	4.72"	3.15"
U.S. MANUFACTURERS									
TOTAL U.S. SHIPMENTS	--	--	--	--	--	--	--	--	--
NON-U.S. MANUFACTURERS									
Captive	150.2	218.1	20.0	290.0	44.1	340.0	61.3	452.0	78.7
PCM/Reseller	147.5	245.1	--	370.0	--	501.0	--	656.0	--
OEM/Integrator	304.8	591.0	--	947.0	--	1,310.0	--	1,950.0	--
TOTAL NON-U.S. SHIPMENTS	602.5	1,054.2	20.0	1,607.0	44.1	2,151.0	61.3	3,058.0	78.7
WORLDWIDE RECAP									
Captive	150.2	218.1	20.0	290.0	44.1	340.0	61.3	452.0	78.7
	+129.3%	+45.2%	--	+33.0%	+120.5%	+17.2%	+39.0%	+32.9%	+28.4%
PCM/Reseller	147.5	245.1	--	370.0	--	501.0	--	656.0	--
	+45.5%	+66.2%	--	+51.0%	--	+35.4%	--	+30.9%	--
OEM/Integrator	304.8	591.0	--	947.0	--	1,310.0	--	1,950.0	--
	+362.5%	+93.9%	--	+60.2%	--	+38.3%	--	+48.9%	--
Total Shipments	602.5	1,054.2	20.0	1,607.0	44.1	2,151.0	61.3	3,058.0	78.7
	+158.8%	+75.0%	--	+52.4%	+120.5%	+33.9%	+39.0%	+42.2%	+28.4%
ANNUAL SHARE, BY DIAMETER	100.0%	98.2%	1.8%	97.4%	2.6%	97.3%	2.7%	97.6%	2.4%

TABLE 21

READ-ONLY OPTICAL DISK DRIVES, ALL CAPACITIES

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1989 Estimate Units (000)	1989 Estimate %	1993 Projection Units (000)	1993 Projection %
MAINFRAME/SUPERMINI General purpose	--	--	18.8	.6
MINICOMPUTERS AND MULTI-USER MICROS Business and professional, including networks	21.0	3.5	163.1	5.2
PERSONAL COMPUTERS Business and professional, single user	225.2	37.4	912.8	29.1
OFFICE SYSTEMS AND WORKSTATIONS Dedicated application	113.1	18.8	304.3	9.7
NON-OFFICE SYSTEMS AND WORKSTATIONS Technical, distribution, medical, other specialized	57.8	9.6	580.3	18.5
CONSUMER AND HOBBY COMPUTERS	118.1	19.6	997.4	31.8
OTHER APPLICATIONS	67.2	11.1	160.0	5.1
Total	602.5	100.0	3,136.7	100.0

TABLE 22

READ-ONLY OPTICAL DISK DRIVES, ALL CAPACITIES

MARKET SHARE SUMMARY
Worldwide Shipments of Non-Captive Disk Drives

	1989 Net Shipments					
	To United States Destinations			Worldwide		
	Units (000)		%	Units (000)		%
Drive Manufacturers	4.72"	Total		4.72"	Total	
Toshiba	72.0	72.0	28.9	116.0	116.0	25.6
Sony	96.0	96.0	38.6	113.0	113.0	25.0
Hitachi	53.0	53.0	21.3	84.0	84.0	18.6
Matsushita Electric	--	--	--	80.0	80.0	17.7
LMSI	23.0	23.0	9.2	45.0	45.0	9.9
Other U.S.	--	--	--	--	--	--
Other Non-U.S.	--	5.0	5.7	14.3	14.3	3.2
TOTAL	249.0	249.0	100.0	452.3	452.3	100.0

READ/WRITE OPTICAL DRIVES LESS THAN 1 GIGABYTE

1990 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

MOST	RMD 5128-S (E)

4.72" disk diameter

Sony	CDW-W1
Yamaha	YPR-1

5.25" disk diameter

Canon	MO-5001S (E), OM-500D (E)
Cherokee Data Systems	Tracker, M600, M610
Fujitsu	M2505B
Goldstar Telecommunication	GSO-5560 (E), GSO-5650WS
Hitachi	M-301S,OD 101-1, OD-112-1 (E)
Honeywell	AN/MU-928
IBM	3363
Kawasaki Steel	KL200S, KL1200S
Laser Magnetic Storage	510
Literal	525 WC, 525 GB, M810
Matsushita Electric Industrial	LF-5010, LF-7010 (E), LF-9000(E)
Maximum Storage	APX-3200, APX-4000
Maxtoptix	Tahiti (E)
Mitsubishi Electric	MW-5D1-11, ME-5E1 (E)
Mountain Optech	CS-400, SEL-2C, SE-400M
NEC	PC-OD101, N7915 (E)
Pentax Teknologies	LW-S501
Pioneer	DDU-5001, DE-U7001 (E)
Ricoh	RO-5041, RO-5042 (E), RO-5030E (E)
Sharp	JY-500 (E), JY-700 (E)
Sony	SMO-D510 (E)
Toshiba	WM-DO50, WM-DO70

8" disk diameter

Matsushita Graphic Commun.	PF-10, PF-3000

(E) indicates erasable or multifunction drive.

Two types of drives are included in this group: Write Once Read Many, (WORM) and Erasable (Rewritable). Provided that a drive is capable of writing and reading, it is classified in this group even if it can also

be used with read-only media. CD-Write-Once (CD-WO) also fits into this category. Multifunction drives capable of using either rewritable or write-once media are considered rewritable drives for purposes of this report. Multifunction drives first appeared on the market in 1990.

The read/write drives discussed in this section are typically used with small computer systems of the mini and micro class and with intelligent workstations. Small automated libraries (jukeboxes, in industry parlance) used in departmental level mass storage subsystems are usually equipped with 5.25" read/write drives and small diameter drives are increasingly being used in larger libraries as well.

Market status

The market for optical drives in this product group remained just as hectic in 1989 as it was previously. Since last year, 8" drives have practically disappeared, the first 3.5" rewritable drives with 128 megabyte capacity have been announced, three multifunction drives arrived in the marketplace, and the first phase change rewritable optical drive was announced. In addition to all of the product changes, some manufacturers even shipped significant numbers of drives.

1989 unit shipments, bolstered by the first deliveries in volume of rewritable drives, reached 91,500 units, up 114.8% from 1988. Ricoh, Sony, Pioneer, Canon and Matsushita Electric, were the leading shippers. Worldwide revenues grew 144.5% to $293.9 million. 1989 shipments from IBM were minor. Ricoh remained the leading shipper of write-once drives, while Sony was the leading shipper of rewritable drives. 50.5% of 1989 unit shipments were rewritable drives, just edging out write-once drives. Just about all drives shipped in this product group were 5.25" drives,

although significant quantities of 3.5" drives will appear in the last three years of the forecast period. Due to media shortages, some reliability problems, and shortfalls in the sales of systems, 1989 shipments of rewritable drives disappointed most manufacturers.

8" drives, mostly used in Japan for stand-alone document storage systems are phasing out, replaced by 5.25" drives. While they offered more capacity than the 5.25" drives, their larger form factor and higher price limited their attractiveness.

The most successful penetration of the system integrator market to date has been achieved through the combined efforts of Ricoh and Maxtor, which has exclusive rights to market Ricoh WORM optical drives in the U.S. OEM market. Maxtor's reach into the OEM arena put Ricoh far in the lead for shipments to OEMs through 1989. In the process, Maxtor received an education in the vagaries of the optical drive marketplace that serves it and its Maxoptix subsidiary well, as Maxoptix ramps up volume production of the "Tahiti" 5.25" rewritable drive.

Sony, Ricoh, and Canon have shipped substantial numbers of 5.25" magneto-optic drives and were joined in mid-1990 by Matsushita Electric, which announced the first phase-change rewritable drive in June. However, 3.5" rewritable drive development efforts have slipped badly. The Maxtor 3.5" erasable drive to be built by Seiko Epson was withdrawn, and the 3.5" drive being developed by Verbatim was cancelled after the development program was transferred to Laserdrive by Eastman Kodak. (Laserdrive was subsequently merged with ISI to form Literal Corporation.) More 3.5" drives are expected: The first has been announced by MOST, which anticipates being in full production in late 1990. Other 3.5" drive announcements are expected in 1990 and 1991.

Write-once media appears to be available in more than adequate quantity. Any of the major optical media producers have the capability to supply several times the current needs of the industry. The modest size of the industry to date was instrumental in causing the combining of Daicel's and Sumitomo Chemical's optical media production facilities to create a new joint venture, Optical Storage Corporation. 5.25" rewritable media remains in short supply, but should be available in adequate quantities by late 1990 as media suppliers ramp up production and improve yields.

Marketing trends

Strong growth of 5.25" rewritable drive shipments is anticipated, but growth in shipments of 5.25" write-once drives is expected to peak in 1992 as multifunction drives become available in quantity. Demand for 128 megabyte 3.5" rewritable drives is muted, as most system producers prefer at least double the capacity at the price level currently in effect. IBM is expected to announce its own version of the 128 megabyte 3.5" drive, and this should help shipments generally if the announcement materializes as expected.

For the total product group, 222,900 units are expected to ship in 1990, and 967,900 units are expected in 1993. Rewritable drives will account for 89.5% of shipments in 1993, of which 72% will be 5.25" and 28% will be 3.5" units. Only 10.5% of the 1993 total will be write-once units, almost all 5.25", but including a small number of 4.72" drives.

Some major Japanese disk drive firms, while developing and announcing 5.25" optical disk drive products, have made relatively small efforts to develop the U.S. market, preferring to wait until demand is stronger and

standards issues are resolved to the point where production equipment can be designed with little risk of a need to retool in the short term. Others, such as Ricoh, Canon, and Sony, are relying upon sales arrangements with strong U.S. storage products and systems producers. Eventually, 12 to 15 competitors are anticipated.

Manufacturers in this group that have announced new, higher capacity, but unstandardized write-once drives indicate a belief that the advantage gained from selling an improved product will outweigh the advantages of waiting for a standard in a market of limited size and growth prospects.

Disk drives using rewritable media are diverting growth from write-once disk drives. Commitments for existing 5.25" write-once drives, mostly in government markets, may result in some further upward movement, but the multiple onslaught of rewritable and multifunction drives will prove irresistible.

Small quantities of 4.72" (CD-WO) write-once drives began shipping in 1989, but the outlook for erasable 4.72" drive shipments is unclear and shipments are unlikely before late 1992. Shipments of mastering systems using CD-WO will decline after 1991, partly because initial demand will be fulfilled and partially because of anticipated announcements of rewritable CD format drives.

Projected Growth: Write-Once vs. Erasable Drives, 5.25" and Smaller

Worldwide captive & OEM unit shipments (In thousands)	1991			1992			1993		
	5.25"	4.72"	3.5"	5.25"	4.72"	3.5"	5.25"	4.72"	3.5"
Write-once	97.3	1.5	--	110.8	.8	--	101.0	.4	--
Erasable	262.9	--	56.5	413.1	--	132.0	599.4	--	267.0
Total	360.2	1.5	56.5	523.9	.8	132.0	700.4	.4	267.0

The forecasted growth in 3.5" erasable drive shipments will result from IBM's expected announcement in 1990, plus an expected displacement of cartridge tape drives used with small systems for backup or save/restore applications. Growth could be even larger if prices, which are initially expected to exceed the $1,000 level, are set to compete better with small tape drives. In 1991, 5.25" write-once drive growth will start to flatten as a result of competition from both 5.25" and 3.5" erasable drives, but existing manufacturing commitments should result in growth until then.

The CD-WO is a read/write drive in the CD-ROM physical format. The first such products, based on present CD-ROM mechanisms, have modest performance, and are available only as part of mastering systems produced by Yamaha and Sony, which do not intend to produce the drive for OEM sale. Sony and Philips have also proposed rewritable CD format drives, but have not published detailed specifications, price or delivery data.

While writable CD format data drives offered at a price under $500 could generate large sales, publishers of CD-ROM disks, fearing a recurrence of the piracy that has plagued personal computer software publishers, discourage the development and marketing of a read/write drive in CD-ROM format. Some companies expect to sidestep the limitation by using 3.5" rewritable drives and media with a portion of the media allocated to read-only data.

Applications

In 1989, non-office dedicated systems accounted for 31.1% of usage of drives in this product group, followed by dedicated office systems and personal computers at 27.3% and 26.9%, respectively. In 1993, these three

applications, plus attachments to multiuser systems are each expected to account for between 20 and 30 percent of usage.

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

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

The faster erasable drives such as the Maxoptix "Tahiti" are finding additional uses as system disks in high security applications requiring vault storage of recorded media when the equipment is unattended. When optical drive performance begins to compete with the performance of small form factor Winchester disk drives, optical drives are expected to displace some rigid disk drives in other situations where removability is an advantage.

For most backup purposes, media with a 10,000 write/erase cycle capability would be more than adequate. With annual small rigid disk drive shipments surpassing the fifteen million unit mark and cartridge tape drive shipments near two million units, a low cost, functionally superior backup device should have good sales prospects. This proposition is now being tested through the introduction of Matsushita Electric's multifunction phase change 5.25" drive in June of 1990.

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 storage or image storage will use the lower capacity, higher performance read/write drives. Entry level departmental applications will 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, defense contractors and aerospace firms.

Erasable optical storage is expected to significantly displace tape storage devices for backup when drive prices decline below $500. However, the high user price of the media ($100 to $200, compared to $15 to $20 for a tape reel or cartridge) is limiting initial acceptance.

Specific applications for drives in this product group include:

Save/restore operations

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

Reference level storage

* Storage of programs, freeing up fixed magnetic disk drives for data.

* Storage of data bases frequently used but infrequently changed.

Document storage

* Storage of images for use in departmental or small organizational CAD/CAM, medical, law enforcement, and financial record systems.

* Office automation systems at the departmental level.

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 is needed.

Technical trends

Drive technology has continued to advance and the pace of product change is rapid. Some of the key areas are discussed below. These comments apply to high capacity drives as well, unless otherwise noted.

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

The capacity of 3.5" drives will start at 128 megabytes, but there is substantial interest from users in higher capacity, so there is pressure on drive producers 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.

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 Eastman Kodak, 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.

The flexible write-once optical drive and media development by BOSCO has been halted, but the technology is available for licensing by other firms.

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

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

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

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

Substrates: Plastic is the currently preferred material, in order to reduce media cost and improve manufacturability. At present, Polycarbonate appears to be the future material of choice, displacing PMMA. PMMA is permeable to water vapor which, in turn, can cause corrosion of the active layer. Epoxy casting, which offers low optical distortion, is also being evaluated as a substrate fabrication technique.

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

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

Average access times: One of the major limitations of optical drives is average access time (seek time plus latency), which exceeds 50 milliseconds on all products yet announced except for the Maxtor 'Tahiti' 5.25" erasable drive, certain Mitsubishi drives, and MOST's 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. File fragmentation caused by the need to rewrite sectors due to media degradation also is a factor on write-once drives. Some drives, such as the Literal 810 series, incorporate sophisticated firmware and buffering to keep throughput high and

offer throughput advantage over less sophisticated designs.

The long access times of today's optical disk drives are less significant when the optical drive is used in an automated library, because the disk exchange and drive spin-up times are long in comparison to the drive access time. Reduction of drive spin-up time is important when the drive is used in a library based system in order to minimize the length of the waiting-for-access queue. Spin-up times of 2 seconds or less are desirable. Plastic substrates usually have less mass than do glass substrates, so are preferable to minimize spin-up time.

Some 5.25" drives are now achieving total average access times well under 50 milliseconds, and times in the 30 millisecond range seem achievable using improved head designs. 3.5" drives should be capable of total average access times in the 35 to 40 millisecond range initially, improving 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, an Optimem drive can access a band of tracks from the fine positioner's nominal center position. About 8.3 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.

Even when head positioning times improve, the amount of data quickly accessible from an optical disk drive will not match that quickly accessible on magnetic disks. Magnetic disks have multiple surfaces and make a cylinder of data available (with a short delay for head switching) from which data can be accessed. Optical drives, which today typically can access a single surface, must always move the head to reach additional tracks -- a more time-consuming operation. As heads shrink in mass and cost, optical drives will appear that offer on-line access to both sides of the disk.

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. Improvements in media materials, laser power, and tracking and focusing servos should eventually enable optical disk latency to approach magnetic disk latency. Canon's rewritable drive operates at 3,000 RPM, approaching the 3,600 RPM commonly used in the current generation of small rigid disk drives. Erasable media requires slightly less write power than write-once media, an advantage which can be translated into higher rotation speeds for erasable drives.

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

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

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

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

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

Standards: ANSI X3B11, ECMA TC31, ISO TC91/SC23 are all involved in standardization programs for unrecorded 5.25" and 3.5" media. ISO standards 9171-1 and 9171-2 cover write-once media in CCS and sampled servo formats.

Drafts of standards for 5.25" and 3.5" erasable media are currently in preparation and should be completed by ISO and ANSI in 1990 for 5.25" and in the 1991-1992 period for 3.5". The 5.25" physical 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 have caused enough conflict to delay the appearance of erasable 5.25" and 3.5" drive standards. Most rewritable drives adhere to the CCS format.

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

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

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

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

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

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

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

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

System software suppliers will probably have to face the choice of distributing source code to system integrators and OEMs, or remastering (for CD-ROM), or maintaining a significant ongoing effort to provide support for a complete range of systems. Many will choose to let other organizations bear support costs.

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

Forecasting assumptions

1. IBM is working on an internally manufactured rewritable 5.25" drive and a 3.5" rewritable drive. The timing and product form are uncertain, but a 3.5" drive announcement is expected in late 1990. IBM write-once drive shipments beginning in late 1987 will decline through 1990 and then cease.

2. Rewritable media will be available in adequate production quantities by late 1990.

3. Low-end rewritable drives will have competition from high capacity floppy disk drives targeted at the tape replacement market after 1990.

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

5. 4.72" write-once drives will remain in limited production through 1992. Rewritable 4.72" drives and media are not anticipated until late 1992.

TABLE 23

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 1 GIGABYTE

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1989		Forecast							
	Revenues		1990		1991		1992		1993	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	.3	.6	2.2	3.0	21.7	30.3	35.0	50.0	55.2	77.0
Other U.S. Captive	--	--	--	--	--	--	--	--	--	--
TOTAL U.S. CAPTIVE	.3	.6	2.2	3.0	21.7	30.3	35.0	50.0	55.2	77.0
PCM/Reseller	6.0	7.1	38.3	48.9	71.4	94.0	99.6	127.4	120.7	164.4
OEM/Integrator	8.3	10.7	28.6	40.0	62.2	83.4	96.7	133.5	114.7	168.2
TOTAL U.S. NON-CAPTIVE	14.3	17.8	66.9	88.9	133.6	177.4	196.3	260.9	235.4	332.6
TOTAL U.S. REVENUES	14.6	18.4	69.1	91.9	155.3	207.7	231.3	310.9	290.6	409.6
Non-U.S. Manufacturers										
Captive	4.5	143.1	24.7	242.3	39.0	326.8	28.7	356.5	24.5	416.3
PCM/Reseller	10.5	22.5	41.8	70.9	85.1	134.1	120.4	187.7	160.4	248.1
OEM/Integrator	73.1	109.9	165.2	249.2	242.6	333.3	329.7	445.2	372.5	528.7
TOTAL NON-U.S. REVENUES	88.1	275.5	231.7	562.4	366.7	794.2	478.8	989.4	557.4	1,193.1
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	102.7	293.9	300.8	654.3	522.0	1,001.9	710.1	1,300.3	848.0	1,602.7
OEM Average Price ($000)	1.9	2.1	1.9	2.0	1.7	1.7	1.5	1.5	1.3	1.3

TABLE 24

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 1 GIGABYTE

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1989		Forecast							
	Shipments		1990		1991		1992		1993	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	.1	.2	1.6	2.1	16.1	22.5	28.0	40.0	48.0	67.0
Other U.S. Captive	--	--	--	--	--	--	--	--	--	--
TOTAL U.S. CAPTIVE	.1	.2	1.6	2.1	16.1	22.5	28.0	40.0	48.0	67.0
PCM/Reseller	1.7	2.0	9.7	12.3	18.4	24.1	26.9	34.3	35.0	47.6
OEM/Integrator	2.8	3.8	7.1	10.1	18.8	24.9	34.2	46.8	45.9	67.0
TOTAL U.S. NON-CAPTIVE	4.5	5.8	16.8	22.4	37.2	49.0	61.1	81.1	80.9	114.6
TOTAL U.S. SHIPMENTS	4.6	6.0	18.4	24.5	53.3	71.5	89.1	121.1	128.9	181.6
Non-U.S. Manufacturers										
Captive	.6	23.7	1.9	40.0	4.4	65.8	4.9	86.9	5.3	127.5
PCM/Reseller	4.6	8.1	16.5	26.4	43.2	65.5	80.1	121.1	131.7	198.9
OEM/Integrator	38.9	53.7	91.6	132.0	157.0	215.6	241.8	327.7	322.5	459.9
TOTAL NON-U.S. SHIPMENTS	44.1	85.5	110.0	198.4	204.6	346.9	326.8	535.7	459.5	786.3
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	48.7	91.5	128.4	222.9	257.9	418.4	415.9	656.8	588.4	967.9
Cumulative Shipments (000)										
IBM	2.0	2.7	3.6	4.8	19.7	27.3	47.7	67.3	95.7	134.3
Non-IBM	86.2	154.5	213.0	375.3	454.8	771.2	842.7	1,388.0	1,383.1	2,288.9
WORLDWIDE TOTAL	88.2	157.2	216.6	380.1	474.5	798.5	890.4	1,455.3	1,478.8	2,423.2

TABLE 25

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 1 GIGABYTE

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1989 Revenues			FORECAST 1990				1991				1992				1993			
	8"	5.25"	4.72"	8"	5.25"	4.72"	3.5"	8"	5.25"	4.72"	3.5"	8"	5.25"	4.72"	3.5"	8"	5.25"	4.72"	3.5"
U.S. MANUFACTURERS																			
IBM Captive	--	.6	--	--	.3	--	2.7	--	--	--	30.3	--	--	--	50.0	--	--	--	77.0
PCM/Reseller	--	7.1	--	--	48.9	--	--	--	94.0	--	--	--	127.4	--	--	--	164.4	--	--
OEM/Integrator	--	10.7	--	--	40.0	--	--	--	83.4	--	--	--	133.5	--	--	--	168.2	--	--
TOTAL U.S. REVENUES	--	18.4	--	--	89.2	--	2.7	--	177.4	--	30.3	--	260.9	--	50.0	--	332.6	--	77.0
NON-U.S. MANUFACTURERS																			
Captive	5.3	135.3	2.5	3.5	206.2	32.6	--	2.3	265.0	34.5	25.0	1.1	291.0	18.4	46.0	1.1	301.0	9.2	105.0
PCM/Reseller	--	22.5	--	--	70.5	--	.4	--	119.7	--	14.4	--	145.9	--	41.8	--	172.1	--	76.0
OEM/Integrator	.7	109.2	--	--	245.9	--	3.3	--	320.1	--	13.2	--	411.2	--	34.0	--	468.7	--	60.0
TOTAL NON-U.S. REVENUES	6.0	267.0	2.5	3.5	522.6	32.6	3.7	2.3	704.8	34.5	52.6	1.1	848.1	18.4	121.8	1.1	941.8	9.2	241.0
WORLDWIDE RECAP																			
Captive	5.3	135.9	2.5	3.5	206.5	32.6	2.7	2.3	265.0	34.5	55.3	1.1	291.0	18.4	96.0	1.1	301.0	9.2	182.0
	-56.6%	+316.9%	--	-34.0%	+51.9%	--	--	-34.3%	+28.3%	+5.8%	--	-52.2%	+9.8%	-46.7%	+73.6%	--	+3.4%	-50.0%	+89.6%
PCM/Reseller	--	29.6	--	--	119.4	--	.4	--	213.7	--	14.4	--	273.3	--	41.8	--	336.5	--	76.0
	--	+659.0%	--	--	+303.4%	--	--	--	+79.0%	--	--	--	+27.9%	--	+190.3%	--	+23.1%	--	+81.8%
OEM/Integrator	.7	119.9	--	--	285.9	--	3.3	--	403.5	--	13.2	--	544.7	--	34.0	--	636.9	--	60.0
	-73.1%	+74.0%	--	-100.0%	+138.4%	--	--	--	+41.1%	--	+300.0%	--	+35.0%	--	+157.6%	--	+16.9%	--	+76.5%
Total Revenues	6.0	285.4	2.5	3.5	611.8	32.6	6.4	2.3	882.2	34.5	82.9	1.1	1,109.0	18.4	171.8	1.1	1,274.4	9.2	318.0
	-59.5%	+170.8%	--	-41.7%	+114.4%	--	--	-34.3%	+44.2%	+5.8%	--	-52.2%	+25.7%	-46.7%	+107.2%	--	+14.9%	-50.0%	+85.1%
ANNUAL SHARE, BY DIAMETER	2.0%	97.2%	.8%	.5%	93.6%	5.0%	.9%	.2%	88.2%	3.4%	8.2%	.1%	85.4%	1.4%	13.1%	.1%	79.6%	.6%	19.7%

TABLE 26

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 1 GIGABYTE

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DISK DIAMETER

	1989 Shipments			FORECAST															
				1990				1991				1992				1993			
	8"	5.25"	4.72"	8"	5.25"	4.72"	3.5"	8"	5.25"	4.72"	3.5"	8"	5.25"	4.72"	3.5"	8"	5.25"	4.72"	3.5"
U.S. MANUFACTURERS																			
IBM Captive	--	.2	--	--	.1	--	2.0	--	--	--	22.5	--	--	--	40.0	--	--	--	67.0
PCM/Reseller	--	2.0	--	--	12.3	--	--	--	24.1	--	--	--	34.3	--	--	--	47.6	--	--
OEM/Integrator	--	3.8	--	--	10.1	--	--	--	24.9	--	--	--	46.8	--	--	--	67.0	--	--
TOTAL U.S. SHIPMENTS	--	6.0	--	--	22.5	--	2.0	--	49.0	--	22.5	--	81.1	--	40.0	--	114.6	--	67.0
NON-U.S. MANUFACTURERS																			
Captive	.4	23.2	.1	.3	38.3	1.4	--	.2	54.1	1.5	10.0	.1	66.0	.8	20.0	.1	77.0	.4	50.0
PCM/Reseller	--	8.1	--	--	26.1	--	.3	--	53.5	--	12.0	--	83.1	--	38.0	--	122.9	--	76.0
OEM/Integrator	.1	53.6	--	--	129.5	--	2.5	--	203.6	--	12.0	--	293.7	--	34.0	--	385.9	--	74.0
TOTAL NON-U.S. SHIPMENTS	.5	84.9	.1	.3	193.9	1.4	2.8	.2	311.2	1.5	34.0	.1	442.8	.8	92.0	.1	585.8	.4	200.0
WORLDWIDE RECAP																			
Captive	.4	23.4	.1	.3	38.4	1.4	2.0	.2	54.1	1.5	32.5	.1	66.0	.8	60.0	.1	77.0	.4	117.0
	-50.0%	+207.9%	--	-25.0%	+64.1%	--	--	-33.3%	+40.9%	+7.1%	--	-50.0%	+22.0%	-46.7%	+84.6%	--	+16.7%	-50.0%	+95.0%
PCM/Reseller	--	10.1	--	--	38.4	--	.3	--	77.6	--	12.0	--	117.4	--	38.0	--	170.5	--	76.0
	--	+621.4%	--	--	+280.2%	--	--	--	+102.1%	--	--	--	+51.3%	--	+216.7%	--	+45.2%	--	+100.0%
OEM/Integrator	.1	57.4	--	--	139.6	--	2.5	--	228.5	--	12.0	--	340.5	--	34.0	--	452.9	--	74.0
	-75.0%	+77.2%	--	-100.0%	+143.2%	--	--	--	+63.7%	--	+380.0%	--	+49.0%	--	+183.3%	--	+33.0%	--	+117.6%
Total Shipments	.5	90.9	.1	.3	216.4	1.4	4.8	.2	360.2	1.5	56.5	.1	523.9	.8	132.0	.1	700.4	.4	267.0
	-58.3%	+119.6%	--	-40.0%	+138.1%	--	--	-33.3%	+66.5%	+7.1%	--	-50.0%	+45.4%	-46.7%	+133.6%	--	+33.7%	-50.0%	+102.3%
ANNUAL SHARE, BY DIAMETER	.5%	99.4%	.1%	.1%	97.2%	.6%	2.1%	--	86.2%	.4%	13.4%	--	79.9%	.1%	20.0%	--	72.5%	--	27.5%

TABLE 27

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 1 GIGABYTE

WORLDWIDE SHIPMENTS (000)

ERASABLE/WRITE-ONCE DRIVE ANALYSIS

	1989		Forecast							
	--Shipments--		-----1990----		-----1991----		-----1992----		-----1993----	
	Units	%	Units	%	Units	%	Units	%	Units	%
U.S. MANUFACTURERS										
Captive Total	.2		2.1		22.5		40.0		67.0	
Write-Once	.2	100.0	.1	4.8	--	--	--	--	--	--
Erasable	--	--	2.0	95.2	22.5	100.0	40.0	100.0	67.0	100.0
OEM/PCM Total	5.8		22.4		49.0		81.1		114.6	
Write-Once	5.1	88.0	8.7	38.8	13.1	26.7	15.0	18.5	15.9	13.9
Erasable	.7	12.0	13.7	61.2	35.9	73.3	66.1	81.5	98.7	86.1
Total U.S.	6.0		24.5		71.5		121.1		181.6	
Write-Once	5.3	88.4	8.8	35.9	13.1	18.3	15.0	12.4	15.9	8.8
Erasable	.7	11.6	15.7	64.1	58.4	81.7	106.1	87.6	165.7	91.2
NON-U.S. MANUFACTURERS										
Captive Total	23.7		40.0		65.8		86.9		127.5	
Write-Once	7.0	29.5	11.3	28.3	14.2	21.6	14.8	17.0	14.5	11.4
Erasable	16.7	70.5	28.7	71.7	51.6	78.4	72.1	83.0	113.0	88.6
OEM/PCM Total	61.8		158.4		281.1		448.8		658.8	
Write-Once	33.0	53.5	53.0	33.5	71.6	25.5	81.8	18.2	71.0	10.8
Erasable	28.8	46.5	105.4	66.5	209.5	74.5	367.0	81.8	587.8	89.2
Total Non-U.S.	85.5		198.4		346.9		535.7		786.3	
Write-Once	40.0	46.8	64.3	32.4	85.8	24.7	96.6	18.0	85.5	10.9
Erasable	45.5	53.2	134.1	67.6	261.1	75.3	439.1	82.0	700.8	89.1
WORLDWIDE RECAP										
Total Worldwide Shipments	91.5		222.9		418.4		656.8		967.9	
	+114.7%		+143.6%		+87.7%		+56.9%		+47.3%	
Write-Once	45.3	49.5	73.1	32.8	98.9	23.6	111.6	17.0	101.4	10.5
	+28.3%		+61.3%		+35.2%		+12.8%		-9.1%	
Erasable	46.2	50.5	149.8	67.2	319.5	76.4	545.2	83.0	866.5	89.5
	+532.8%		+224.2%		+113.2%		+70.6%		+58.9%	

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

TABLE 28

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 1 GIGABYTE

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

	1989 Estimate		1993 Projection	
APPLICATION	Units (000)	%	Units (000)	%
MAINFRAME/SUPERMINI				
General purpose	1.1	1.2	20.3	2.1
MINICOMPUTERS AND MULTI-USER MICROS				
Business and professional, including networks	12.1	13.2	214.9	22.2
PERSONAL COMPUTERS				
Business and professional, single user	24.6	26.9	200.4	20.7
OFFICE SYSTEMS AND WORKSTATIONS				
Dedicated application	25.0	27.3	268.1	27.7
NON-OFFICE SYSTEMS AND WORKSTATIONS				
Technical, distribution, medical, other specialized	28.5	31.1	236.2	24.4
CONSUMER AND HOBBY COMPUTERS	--	--	9.7	1.0
OTHER APPLICATIONS	.2	.3	18.3	1.9
Total	91.5	100.0	968.0	100.0

READ/WRITE OPTICAL DRIVES MORE THAN 1 GIGABYTE

1990 DISK/TREND REPORT

READ/WRITE OPTICAL DISK DRIVES, MORE THAN 1 GIGABYTE

Coverage

Examples of disk drives in this group include:

14" disk diameter

Eastman Kodak	6800

12" disk diameter

ATG Gigadisc	GD1002, GD6000, GD6001
Fujitsu	F6441B1, M2502A/B
Hitachi	OD 301A-1
Laser Magnetic Storage	1200E, 1250E
NEC	N7911/N6329-21, N6513
Nikon	MO-DD120C (Erasable)
Optimem	1000, 2400, 4400
Sony	WDD 600, WDD 3000
Toshiba	WM-S500

8" diameter

Fujitsu	F6443 (Erasable)

High capacity optical disk drives are read/write drives, either write-once or erasable. At present, only write-once drives are available in this capacity range, although Nikon has announced a 12" erasable drive for possible late 1990 delivery. 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. At present, all but one of the available drives in this group use 12" media, and all but one access a single side of a single disk. Fujitsu is making an 8" non-removable rewritable drive in small quantities, and LMSI has announced a dual headed 12" drive with 5.6 megabyte total capacity.

Market status

In 1989, 10,400 drives were shipped worldwide, down 1.9% from 1988, due largely to a decline in shipments from U.S. producers and captive shipments by non-U.S. firms. 1989 non-U.S. OEM drive shipments increased modestly but the increase was cancelled by a similar decline in U.S. OEM shipments. 1989 revenues rose to $119.6 million, a strong 50.3% gain over 1988 that was achieved through selective price increases on older drives and the introduction of new products commanding higher prices. 58% of revenues came from OEM sales, about the same as 1987, but up from 49.2% in 1988.

Over 94% of units shipped were produced by non-U.S. firms, a slightly higher share than in 1988. 1989's leading producers were Laser Magnetic Storage, Hitachi, Toshiba and Sony, with Toshiba the leading captive supplier and LMSI the leading OEM supplier on a worldwide basis.

Japanese firms have historically led this drive group because of early emphasis for use in systems capable of storing documents produced in Asian character sets. In 1988, non-Japanese producers narrowed the lead of Japanese producers and were responsible for half of the unit shipments in this product group. In 1989, the non-Japanese firms lost some ground and captured only 46% of the unit shipments.

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 has established a business unit to perform optical drive based system integration for specific customers. Eastman Kodak's willingness to sell optical drives to replace microfilm equipment for records management has also helped to expand the available market.

Marketing trends

Because high capacity optical disk drives are used mostly in large systems and 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 moderately from 10,400 units in 1989 to 27,400 units in 1993. Revenues in this same period are forecasted to expand from $119.6 million (17.7% of the worldwide optical disk drive market) to $373.3 million (a decline to 13.3% of the worldwide optical disk drive market).

Growth within the forecast period may be slowed by competition from smaller, yet higher capacity 5.25" optical disks, long lead times on software development for use with optical drives in large systems, and the generally higher price levels of storage subsystems based on the large capacity drives. Nevertheless, acceleration of growth will occur in 1991 and 1992 as the customers react to the dual head drives now entering the marketplace. Growth will decline subsequently under pressures from higher capacity 5.25" drives.

While IBM has an optical disk drive development program underway, no early introduction of internally produced high capacity drives from IBM is anticipated. IBM's current policy is to purchase appropriate 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. DEC has taken similar action, offering the LMSI 12" drives as the DEC model RV20, and Unisys has been purchasing 12" drives from Hitachi to run on its 1100 mainframe.

Third parties, including Data/Ware Development and Comparex, also

offer optical drive subsystems for attachment to IBM mainframes, and it is likely that other firms will also provide such attachments.

Applications

In 1989, the largest application areas for high capacity optical drives were again office systems, and non-office workstations. Together, these categories accounted for 58.2% of unit shipments, down from 64% in 1988. In 1993, 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. Major applications for optical disk drives over 1 gigabyte capacity include records management, medical, geophysical, military or industrial imaging, storage of transaction documents that must be kept for future reference. Almost all of these are archival in nature.

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. A few financial institutions use them for accumulating various types of transaction data in other than image form.

Typical usage will include:

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 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 attracting the attention of insurance companies, banks, and other large organizations that must have ready recall of large amounts of account related data.

Approximately 15% of the drives in this group were shipped in automated library subsystems in 1989, and this percentage is increasing at a

rate of 1% to 2% annually, so that in 1993, 20 to 22% of the units in this group are expected to be installed in jukeboxes upon shipment to the ultimate end user. An automated library system using large capacity drives usually has two or more drives to improve overall response time, but the single drive, five cartridge LMSI library is a notable exception.

While the records management market will eventually be a major consumer of high capacity optical disk drives, this market is likely 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.

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

Mainframes and minicomputers have become hosts for large optical drives, as they have the capability needed to process or distribute the large amounts of data stored. Tape subsystems currently used in mainframe environments will eventually be supplemented by large capacity optical drives operating with automated libraries, including an optical disk based replacement for the IBM 3850 mass storage system expected around the middle of the decade. However, the 3850 replacement is expected to use 3.5" drives and media of 200 megabyte or greater capacity.

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 and

this segment of the market will attract smaller diameter drives used with library units of 10-20 disk capacity. The LMSI drive and library announced this year are an attempt to preempt competition from the smaller diameter drives in the departmental system market segment.

Technical trends

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

* Performance: Almost all of the released products in this group currently use complex optical head assemblies, resulting in excessive head positioning times. This is of less consequence when the drive is used in a library subsystem, because of the long time required to locate, mount, and spin-up the disk to operating speed. Considerable work is being done by manufacturers to reduce drive complexity and to improve access time. Even so, it will probably be several years before typical head positioning times are below 100 milliseconds for these drives.

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

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

* System design: Many large capacity optical disk storage systems will incorporate an automated library. Several firms, including Cygnet, Filenet, Laser Magnetic Storage, Hitachi and others have

designed libraries, discovering in the process that it is a major project, requiring substantial time and investment. To be a generally applicable product, the library may have to accommodate several brands of disk drives, an awkward consideration given the lack of product standardization in the industry. The library unit also has to be interfaced to the computer system with which it is to be used, requiring significant development time. The drives themselves must be designed to withstand thousands of cartridge insertions without failure and must accommodate library control and signaling functions.

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

* Capacity: Capacity per disk is increasing through the use of zoned recording and other compression techniques. Newer 12" drives offer over 3 gigabytes per side, improved from a typical 1 gigabyte per side in earlier models. Shorter wavelength lasers are expected to bring an additional 30% to 40% improvement by late 1992.

* Multiple heads: The larger form factor of the high capacity drive permits the eventual use of multiple, independent heads and actuators when economically feasible. Multiple head/actuator assemblies for both sides of the media were prototyped by BOSCO in its flexible 1.3 gigabyte 5.25" drive development effort and were introduced in a new 12" drive by LMSI in 1990. The use of multiple heads in a 5.25" drive with capacity of 500 megabytes per side or more will eventually create a 5.25" diameter category in this product group. BOSCO's drive development program was aimed at producing a 1.3 gigabyte, dual head 5.25" drive that, had it been produced, would have been the first 5.25" drive to offer over 1 gigabyte of on-line capacity.

* Rewritability: Nikon expects to have limited quantities of a rewritable 12" drive and media available in late 1990, but no other firms have yet indicated definite intentions to offer a production drive. When such drives do appear, shipments are likely to be modest until customers feel confident about the technology. Sony has discussed 5.25" rewritable magneto-optic media of over 1 gigabyte capacity as a future possibility, but has been non-committal on the availibility of a dual head drive.

* Non-removable multiple disks: A multidisk Winchester-like configuration has been considered by various system manufacturers, but probably won't be aggressively marketed until the characteristics of optical drive components have advanced to the point

where a drive could closely approach the costs and performance of high capacity magnetic disk drives. The disk diameters employed will probably be 5.25" or 8", and the media will, naturally, be rewritable. Fujitsu has made limited quantities of such a drive with 8" disks.

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

  For the next few years, the 12" form factor will remain the most frequently encountered size in this product group. As areal density improves and dual head drives are introduced, 8" and 5.25" drives are expected to fall into this class of optical drive. However, the 5.25" candidates for this group will most likely be equipped with dual heads.

  There is no expectation of any 3.5" drives in this group within the forseeable future. Major improvements in lasers and other components will be required before even a dual head 1 gigabyte drive is practical.

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

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

* Lasers: The larger form factors of the high capacity optical drive favor the use of head assemblies with multiple lasers. The use of multiple lasers can improve drive performance by permitting direct read during write, higher bit densities, use of unusual active layer material, and possibly other benefits. If

head designs that separate the laser from the head optics are adopted to reduce mass, it may also be possible to use non-semiconductor lasers and still achieve reasonable performance. Because non-semiconductor lasers can operate at higher frequencies and powers, very high performance may be possible by using them in optical storage systems. RCA, for instance, has produced a few specialized systems for the U.S. government using non-semiconductor lasers. However, cost and reliability will have to be traded for performance in such designs. The short wavelength semiconductor lasers being developed by IBM and others probably have more applicability.

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

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

* Substrates: Both plastic and glass are in use for 12" media substrates, and Eastman Kodak is using an aluminum substrate for its 14" drive. Because of the difficulty in molding large diameter plastic substrates with adequately low birefringence, it seems likely that glass will play an increasingly prominent role in attempts to fabricate readily producible erasable media for large diameter drives. Producers of glass substrates have demonstrated that glass hardened by ion bombardment has adequate mechanical strength to withstand routine use under projected conditions for future drive designs. However, there is still uncertainty 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 represent a longer term hazard.

Forecasting assumptions

1. No IBM-produced units in this product group will be shipped through 1992.

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

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

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

5. Rewritable 12" drives and media will arrive in the market in 1990, but will have only marginal impact through 1992.

TABLE 29

READ/WRITE OPTICAL DISK DRIVES, MORE THAN 1 GIGABYTE

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1989		Forecast							
	Revenues		1990		1991		1992		1993	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	--	--	--	--	1.8	1.8	1.8	1.8	3.6	5.4
TOTAL U.S. CAPTIVE	--	--	--	--	1.8	1.8	1.8	1.8	3.6	5.4
PCM/Reseller	--	--	--	--	--	--	--	--	--	--
OEM/Integrator	5.8	7.0	3.8	4.8	5.4	7.3	7.5	11.0	14.2	19.1
TOTAL U.S. NON-CAPTIVE	5.8	7.0	3.8	4.8	5.4	7.3	7.5	11.0	14.2	19.1
TOTAL U.S. REVENUES	5.8	7.0	3.8	4.8	7.2	9.1	9.3	12.8	17.8	24.5
Non-U.S. Manufacturers										
Captive	--	42.2	--	57.7	--	95.4	--	117.5	--	139.0
PCM/Reseller	3.2	7.9	5.1	14.5	24.2	41.9	32.4	51.8	38.2	64.8
OEM/Integrator	36.5	62.5	42.4	78.8	58.8	98.8	81.3	128.4	93.5	145.0
TOTAL NON-U.S. REVENUES	39.7	112.6	47.5	151.0	83.0	236.1	113.7	297.7	131.7	348.8
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	45.5	119.6	51.3	155.8	90.2	245.2	123.0	310.5	149.5	373.3
OEM Average Price ($000)	9.6	10.0	10.0	11.0	11.0	11.0	10.8	10.8	10.7	10.7

TABLE 30

READ/WRITE OPTICAL DISK DRIVES, MORE THAN 1 GIGABYTE

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1989 Shipments		Forecast 1990		1991		1992		1993	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	--	--	--	--	.1	.1	.1	.1	.2	.3
TOTAL U.S. CAPTIVE	--	--	--	--	.1	.1	.1	.1	.2	.3
PCM/Reseller	--	--	--	--	--	--	--	--	--	--
OEM/Integrator	.5	.6	.4	.5	.5	.7	.6	.9	1.1	1.5
TOTAL U.S. NON-CAPTIVE	.5	.6	.4	.5	.5	.7	.6	.9	1.1	1.5
TOTAL U.S. SHIPMENTS	.5	.6	.4	.5	.6	.8	.7	1.0	1.3	1.8
Non-U.S. Manufacturers										
Captive	--	2.9	--	3.4	--	5.3	--	6.6	--	7.9
PCM/Reseller	.3	.6	.4	1.0	1.5	2.6	2.0	3.2	2.3	3.9
OEM/Integrator	3.9	6.3	4.2	7.1	5.3	8.9	7.6	12.0	8.9	13.8
TOTAL NON-U.S. SHIPMENTS	4.2	9.8	4.6	11.5	6.8	16.8	9.6	21.8	11.2	25.6
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	4.7	10.4	5.0	12.0	7.4	17.6	10.3	22.8	12.5	27.4
Cumulative Shipments (000)										
IBM	--	--	--	--	--	--	--	--	--	--
Non-IBM	20.3	45.0	25.3	57.0	32.7	74.6	43.0	97.4	55.5	124.8
WORLDWIDE TOTAL	20.3	45.0	25.3	57.0	32.7	74.6	43.0	97.4	55.5	124.8

TABLE 31

READ/WRITE OPTICAL DISK DRIVES, MORE THAN 1 GIGABYTE

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1989 Estimate Units (000)	1989 Estimate %	1993 Projection Units (000)	1993 Projection %
MAINFRAME/SUPERMINI General purpose	1.1	10.8	1.6	5.9
MINICOMPUTERS AND MULTI-USER MICROS Business and professional, including networks	2.2	20.7	5.0	18.4
PERSONAL COMPUTERS Business and professional, single user	1.1	10.3	.6	2.1
OFFICE SYSTEMS AND WORKSTATIONS Dedicated application	3.5	34.1	12.5	45.6
NON-OFFICE SYSTEMS AND WORKSTATIONS Technical, distribution, medical, other specialized	2.5	24.1	7.6	27.8
CONSUMER AND HOBBY COMPUTERS	--	--	--	--
OTHER APPLICATIONS	--	--	.1	.2
Total	10.4	100.0	27.4	100.0

READ-ONLY OPTICAL LIBRARIES

1990 DISK/TREND REPORT

READ-ONLY OPTICAL LIBRARIES

Coverage

Examples of optical disk libraries in this group include:

4.72" disk diameter (CD-ROM)

Kubik Enterprises	DDC-240, Multi-Server
Next Technology	Voyager
Pioneer	DRM-600

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.

Market status

The market for read-only optical disk libraries is just getting started. Only three firms are in production and of these, only Pioneer has significant shipment volume. The products range in sophistication from the 270 disk library of Next Technology to the integrated drive and six unit capacity of Pioneer, which is derived from the design of a multi-disk CD audio player. The Kubik library, an unusual rotary mechanism that operates much like a carousel-type slide projector, is still in pilot line production status.

Marketing trends

Read-only optical library revenues were only $400,000 in 1989, but are expected to reach $14.2 million by 1993. The number of competitors is expected to increase in order to serve the increasing interest of network users 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. About 37% of the 1993 revenue will be derived from reseller sales, while almost 60% will come from OEM sales.

Unit shipments in 1989 were only 14 units. In 1993, shipments of over 11,000 units are projected, but the majority of these shipments are expected to be low-end, low performance devices holding no more than ten disks. Almost 75% of the unit shipments will be to U.S. companies, and of this amount, 61% will be sold to OEMs. 75% of reseller shipments will also be to U.S. companies.

Applications

The primary application for the read-only optical library is in file servers on networks. Buyer usage patterns will be generally similar to those for the free-standing CD-ROM drives as discussed in the section on read-only drives. High-end read-only libraries are likely to find applications in large institutional libraries and in organizations that must provide network access to large amounts of documentation for many users located at diverse sites. Low-end libraries, such as the Pioneer unit, will be used primarily with single-user computers and workstations or with servers in small networks with low transaction rates.

Certain users of CD-ROM data bases that span more than one disk will find the low-end read-only libraries particularly convenient. Legal case records, citations and regulatory material often fit this pattern, as do CD-ROM records of archival material such as patent records. Other beneficiaries of low-end libraries could include users of large clip art files, those concerned with large numbers of maps, and analysts wishing to keep large collections of historical financial data readily available.

Technical trends

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

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

As with all libraries, suitable software must be generated to integrate the library and its associated drives into the system. This software is not yet available to match all the available libraries to all of the commonly used computers and operating systems.

Forecasting assumptions

1. Read-only library sales will continue to be dominated by low cost, low performance devices.
2. Shipments of read-only libraries using formats other than the 4.72" CD-ROM format are not anticipated in the time frame of the forecast.
3. Non-U.S. suppliers will dominate the read-only library market. There will be no significant production by U.S. firms.
4. There will be no significant changes in technology affecting read-only libraries over the period of the forecast.
5. There will be a significant demand for read-only libraries by OEMs and subsystem integrators who will add them to specialized workstations, file servers, and memory subsystems.

TABLE 32

OPTICAL LIBRARIES, READ-ONLY

REVENUE SUMMARY

	LIBRARY REVENUES, BY SHIPMENT DESTINATION ($M)									
	1989		Forecast							
	Revenues		1990		1991		1992		1993	
	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	--	--	.1	.1	1.0	1.1	2.0	2.4	2.8	3.4
TOTAL U.S. NON-CAPTIVE	--	--	.1	.1	1.0	1.1	2.0	2.4	2.8	3.4
TOTAL U.S. REVENUES	--	--	.1	.1	1.0	1.1	2.0	2.4	2.8	3.4
Non-U.S. Manufacturers										
Captive	--	--	.1	.1	.2	.3	.2	.3	.3	.4
PCM/Reseller	--	--	1.3	1.8	1.8	2.4	2.2	3.0	3.0	4.0
OEM/Integrator	.3	.4	2.4	3.1	2.7	3.5	3.4	5.1	4.8	6.4
TOTAL NON-U.S. REVENUES	.3	.4	3.8	5.0	4.7	6.2	5.8	8.4	8.1	10.8
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	.3	.4	3.9	5.1	5.7	7.3	7.8	10.8	10.9	14.2
OEM Average Price ($000)	25.0	28.6	1.4	1.3	1.3	1.3	1.5	1.4	1.5	1.4

TABLE 33

OPTICAL LIBRARIES, READ-ONLY

UNIT SHIPMENT SUMMARY (SINGLE UNITS)

	LIBRARY UNIT SHIPMENTS, BY SHIPMENT DESTINATION									
	1989		Forecast							
	Shipments		1990		1991		1992		1993	
	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	2.0	2.0	5.0	5.0	80.0	85.0	200.0	240.0	350.0	430.0
TOTAL U.S. NON-CAPTIVE	2.0	2.0	5.0	5.0	80.0	85.0	200.0	240.0	350.0	430.0
TOTAL U.S. SHIPMENTS	2.0	2.0	5.0	5.0	80.0	85.0	200.0	240.0	350.0	430.0
Non-U.S. Manufacturers										
Captive	--	--	120.0	120.0	150.0	200.0	200.0	275.0	250.0	350.0
PCM/Reseller	--	--	1,300.0	1,750.0	1,800.0	2,400.0	2,200.0	3,000.0	3,000.0	4,000.0
OEM/Integrator	10.0	12.0	1,825.0	2,430.0	2,700.0	3,500.0	3,400.0	5,100.0	4,800.0	6,400.0
TOTAL NON-U.S. SHIPMENTS	10.0	12.0	3,245.0	4,300.0	4,650.0	6,100.0	5,800.0	8,375.0	8,050.0	10,750.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	12.0	14.0	3,250.0	4,305.0	4,730.0	6,185.0	6,000.0	8,615.0	8,400.0	11,180.0
Cumulative Shipments (000)										
IBM	--	--	--	--	--	--	--	--	--	--
Non-IBM	--	--	3.2	4.3	7.9	10.5	13.9	19.1	22.3	30.3
WORLDWIDE TOTAL	--	--	3.2	4.3	7.9	10.5	13.9	19.1	22.3	30.3

READ/WRITE OPTICAL LIBRARIES 1-39 CARTRIDGES

1990 DISK/TREND REPORT

READ/WRITE OPTICAL LIBRARIES, 1 - 39 CARTRIDGES

Coverage

Examples of optical disk libraries in this group include:

5.25" disk diameter

Aisin Seiki	JC2000
Cygnet Systems	5250/W
DSM	20, 27, 28, 30, 38
Fujitsu	F6442-B2
Hewlett-Packard	C1710A,20GB/A
Hitachi	OL101, OL112
International Data Engineering	Personal Library
Mitsubishi Electric	MW-5G2-Z
Ricoh	RJ5160

12" disk diameter

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

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

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

Market status

481 optical libraries were shipped in 1989 for this group, about equally split between U.S. and non-U.S. manufacturers. 1989 revenues were ten million dollars. Shipments were split equally between U.S. and non-U.S. destinations. Participants include firms which have been active for several years, such as Hitachi and Access (which originally sold through LMSI exclusively) and many newer entrants such as DSM, Hewlett-Packard and IDE, which have used mostly smaller form factor drives.

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 some cases, library producers (such as Cygnet, Hewlett-Packard and Hitachi) specify and buy drives and there is no other choice. This pattern recognizes the wide range of variation in drive performance, reliability and manufacturing tolerances: Not all drives operate equally well in a given library. Business reasons may also dictate the choice of a single drive supplier to reduce development and support costs for captive producers.

Marketing trends

By 1993, unit shipments are projected to reach 8,275 units worldwide, with about 60% of the total being sold in the U.S. Both the number of units and the U.S./non-U.S. ratio will be affected by shipment growth of inexpensive tabletop libraries sold for use with workstations and high-end personal computers. The increasing proportion of single-drive libraries will also cause a rapid decline in the average price within this group during the forecast period. However, viewed separately, high-end and low-end price declines will be more gradual.

Almost 90% of the 1993 shipments are projected to be made to OEMs and system integrators. 7% will be through PCM/Resellers, and 3% will be captive shipments. 5.25" shipments are forecasted to grow from 61% of the total to nearly 80% of the total, with the balance being in 12" libraries.

Revenue is forecasted to reach $83 million in 1993. U.S. firms are expected to retain slightly more than half of the revenue, and more than half of the revenue should be generated from sales in the U.S. market.

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

By far the largest proportion of shipments will be on an OEM basis, with nearly 90% of unit shipments (mostly low-end) made to OEM/Integrators. High-end libraries 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, system manufacturers will elect to be purchasers of libraries rather than manufacturers, 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 users. The LMSI library may occupy a middle ground: While inexpensive and having only one drive, the dual head drive design provides on-line capacity so large that throughput may frequently be better than that of multidrive 5.25" units. In cases where rewritable media is not required, the LMSI library may displace some 5.25" libraries in both single user and multiuser systems.

Technical trends

For the time being, this class of library will continue to use 5.25" or 12" drives and media. 3.5" libraries are being studied, but until drives with capacities in the 200-300 megabyte range appear, 3.5" libraries will offer so much less throughput than 5.25" libraries that they will be unattractive. In addition, 3.5" cartridges do not yet have a generally accepted method for engaging a picker mechanism, and until this ambiguity is clarified, the 3.5" library will not be brought to market.

System integration remains a major consideration. Libraries and drives must operate smoothly as a subsystem under control of standard operating systems. Substantial software development is required and becomes more complex as the sophistication of the host system increases, delaying market entry and acceptance. Furthermore, libraries need to be able to use more than one drive model in a given library model, requiring that drives have tighter manufacturing tolerances where they must interface the library. Libraries need to be designed to tolerate a range of drive inconsistency.

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 inexpensive, and its high data availability and throughput will be difficult targets for conventional 5.25" library designs to meet. Should direct overwrite rewritable 12" drives and media become readily available, small 12" libraries will become more important competitors in all but the most price sensitive situations.

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

Forecasting assumptions

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

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

3. Erasable drives will be used in more libraries than will write-once drives, and will eventually be supplanted 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.

6. No 12" direct overwrite rewritable drives are expected to be readily available in significant quantity in the forecast period. Sample units, if available, will not impact the library market.

TABLE 34

OPTICAL LIBRARIES, 1-39 DISKS

REVENUE SUMMARY

	LIBRARY REVENUES, BY SHIPMENT DESTINATION ($M)									
	1989 Revenues		Forecast 1990		1991		1992		1993	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	1.9	2.2	7.5	9.3	9.9	12.3	12.0	14.9	11.9	15.4
TOTAL U.S. CAPTIVE	1.9	2.2	7.5	9.3	9.9	12.3	12.0	14.9	11.9	15.4
PCM/Reseller	.2	.2	.9	1.1	1.3	1.7	1.7	2.2	2.0	2.6
OEM/Integrator	3.0	3.2	9.4	11.6	17.0	23.2	19.9	28.8	18.7	28.3
TOTAL U.S. NON-CAPTIVE	3.2	3.4	10.3	12.7	18.3	24.9	21.6	31.0	20.7	30.9
TOTAL U.S. REVENUES	5.1	5.6	17.8	22.0	28.2	37.2	33.6	45.9	32.6	46.3
Non-U.S. Manufacturers										
Captive	--	.4	--	.6	--	1.4	--	2.2	--	3.7
PCM/Reseller	--	--	--	--	--	--	--	--	--	--
OEM/Integrator	.4	4.0	3.2	7.7	7.3	14.6	12.4	24.3	16.9	33.4
TOTAL NON-U.S. REVENUES	.4	4.4	3.2	8.3	7.3	16.0	12.4	26.5	16.9	37.1
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	5.5	10.0	21.0	30.3	35.5	53.2	46.0	72.4	49.5	83.4
OEM Average Price ($000)	20.6	18.2	7.4	7.8	8.8	9.0	8.5	8.8	8.1	8.3

TABLE 35

OPTICAL LIBRARIES, 1-39 DISKS

UNIT SHIPMENT SUMMARY (SINGLE UNITS)

	LIBRARY UNIT SHIPMENTS, BY SHIPMENT DESTINATION									
	1989		Forecast							
	Shipments		1990		1991		1992		1993	
	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	62.0	216.0	268.0	322.0	401.0	418.0	522.0	459.0	596.0
TOTAL U.S. CAPTIVE	52.0	62.0	216.0	268.0	322.0	401.0	418.0	522.0	459.0	596.0
PCM/Reseller	10.0	10.0	40.0	50.0	60.0	80.0	80.0	105.0	100.0	130.0
OEM/Integrator	138.0	148.0	1,485.0	1,975.0	2,290.0	3,220.0	2,960.0	4,360.0	3,215.0	5,020.0
TOTAL U.S. NON-CAPTIVE	148.0	158.0	1,525.0	2,025.0	2,350.0	3,300.0	3,040.0	4,465.0	3,315.0	5,150.0
TOTAL U.S. SHIPMENTS	200.0	220.0	1,741.0	2,293.0	2,672.0	3,701.0	3,458.0	4,987.0	3,774.0	5,746.0
Non-U.S. Manufacturers										
Captive	--	13.0	--	16.0	--	39.0	--	65.0	--	109.0
PCM/Reseller	--	--	--	--	--	--	--	--	--	--
OEM/Integrator	27.0	248.0	220.0	510.0	480.0	990.0	855.0	1,704.0	1,205.0	2,420.0
TOTAL NON-U.S. SHIPMENTS	27.0	261.0	220.0	526.0	480.0	1,029.0	855.0	1,769.0	1,205.0	2,529.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	227.0	481.0	1,961.0	2,819.0	3,152.0	4,730.0	4,313.0	6,756.0	4,979.0	8,275.0
Cumulative Shipments (000)										
IBM	--	--	--	--	--	--	--	--	--	--
Non-IBM	.2	.4	2.1	3.3	5.3	8.0	9.6	14.7	14.6	23.0
WORLDWIDE TOTAL	.2	.4	2.1	3.3	5.3	8.0	9.6	14.7	14.6	23.0

TABLE 36

OPTICAL LIBRARIES, 1-39 DISKS

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1989 Revenues		FORECAST							
			1990		1991		1992		1993	
	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"
U.S. MANUFACTURERS										
U.S. Captive	1.7	.5	8.6	.7	11.4	.9	13.9	1.0	14.2	1.2
PCM/Reseller	.2	--	1.1	--	1.7	--	2.2	--	2.6	--
OEM/Integrator	.8	2.4	8.8	2.8	20.0	3.2	24.7	4.1	24.1	4.2
TOTAL U.S. REVENUES	2.7	2.9	18.5	3.5	33.1	4.1	40.8	5.1	40.9	5.4
NON-U.S. MANUFACTURERS										
Captive	.4	--	.5	.1	1.3	.1	2.0	.2	3.5	.2
OEM/Integrator	3.0	1.0	5.4	2.3	10.1	4.5	16.6	7.7	21.9	11.5
TOTAL NON-U.S. REVENUES	3.4	1.0	5.9	2.4	11.4	4.6	18.6	7.9	25.4	11.7
WORLDWIDE RECAP										
Captive	2.1	.5	9.1	.8	12.7	1.0	15.9	1.2	17.7	1.4
	--	--	+333.3%	+60.0%	+39.6%	+25.0%	+25.2%	+20.0%	+11.3%	+16.7%
PCM/Reseller	.2	--	1.1	--	1.7	--	2.2	--	2.6	--
	--	--	+450.0%	--	+54.5%	--	+29.4%	--	+18.2%	--
OEM/Integrator	3.8	3.4	14.2	5.1	30.1	7.7	41.3	11.8	46.0	15.7
	--	--	+273.7%	+50.0%	+112.0%	+51.0%	+37.2%	+53.2%	+11.4%	+33.1%
Total Revenues	6.1	3.9	24.4	5.9	44.5	8.7	59.4	13.0	66.3	17.1
	--	--	+300.0%	+51.3%	+82.4%	+47.5%	+33.5%	+49.4%	+11.6%	+31.5%
ANNUAL SHARE, BY DIAMETER	61.1%	38.9%	80.6%	19.4%	83.7%	16.3%	82.1%	17.9%	79.6%	20.4%

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

TABLE 37

OPTICAL LIBRARIES, 1-39 DISKS

WORLDWIDE SHIPMENTS (SINGLE UNITS)

BREAKDOWN BY DISK DIAMETER

	1989 Shipments		FORECAST							
			1990		1991		1992		1993	
	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"
U.S. MANUFACTURERS										
U.S. Captive	50.0	12.0	253.0	15.0	381.0	20.0	499.0	23.0	570.0	26.0
PCM/Reseller	10.0	--	50.0	--	80.0	--	105.0	--	130.0	--
OEM/Integrator	40.0	108.0	1,850.0	125.0	3,080.0	140.0	4,200.0	160.0	4,860.0	160.0
TOTAL U.S. SHIPMENTS	100.0	120.0	2,153.0	140.0	3,541.0	160.0	4,804.0	183.0	5,560.0	186.0
NON-U.S. MANUFACTURERS										
Captive	13.0	--	15.0	1.0	38.0	1.0	62.0	3.0	105.0	4.0
OEM/Integrator	216.0	32.0	380.0	130.0	710.0	280.0	1,194.0	510.0	1,600.0	820.0
TOTAL NON-U.S. SHIPMENTS	229.0	32.0	395.0	131.0	748.0	281.0	1,256.0	513.0	1,705.0	824.0
WORLDWIDE RECAP										
Captive	63.0	12.0	268.0	16.0	419.0	21.0	561.0	26.0	675.0	30.0
	--	--	+325.4%	+33.3%	+56.3%	+31.3%	+33.9%	+23.8%	+20.3%	+15.4%
PCM/Reseller	10.0	--	50.0	--	80.0	--	105.0	--	130.0	--
	--	--	+400.0%	--	+60.0%	--	+31.3%	--	+23.8%	--
OEM/Integrator	256.0	140.0	2,230.0	255.0	3,790.0	420.0	5,394.0	670.0	6,460.0	980.0
	--	--	+771.1%	+82.1%	+70.0%	+64.7%	+42.3%	+59.5%	+19.8%	+46.3%
Total Shipments	329.0	152.0	2,548.0	271.0	4,289.0	441.0	6,060.0	696.0	7,265.0	1,010.0
	--	--	+674.5%	+78.3%	+68.3%	+62.7%	+41.3%	+57.8%	+19.9%	+45.1%
ANNUAL SHARE, BY DIAMETER	68.5%	31.5%	90.5%	9.5%	90.8%	9.2%	89.8%	10.2%	87.9%	12.1%

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

TABLE 38

OPTICAL LIBRARIES, 1-39 DISKS

WORLDWIDE SHIPMENTS (SINGLE UNITS)

ERASABLE/WRITE-ONCE DRIVE ANALYSIS

	1989 --Shipments--		Forecast 1990		1991		1992		1993	
	Units	%	Units	%	Units	%	Units	%	Units	%
U.S. MANUFACTURERS										
Captive Total	62.0		268.0		401.0		522.0		596.0	
Write-Once	12.0	19.4	15.0	5.6	20.0	5.0	23.0	4.4	26.0	4.4
Erasable	50.0	80.6	253.0	94.4	381.0	95.0	499.0	95.6	570.0	95.6
OEM/PCM Total	158.0		2,025.0		3,300.0		4,465.0		5,150.0	
Write-Once	108.0	68.5	675.0	33.3	650.0	19.7	440.0	9.9	290.0	5.6
Erasable	50.0	31.5	1,350.0	66.7	2,650.0	80.3	4,025.0	90.1	4,860.0	94.4
Total U.S.	220.0		2,293.0		3,701.0		4,987.0		5,746.0	
Write-Once	120.0	54.6	690.0	30.1	670.0	18.1	463.0	9.3	316.0	5.5
Erasable	100.0	45.4	1,603.0	69.9	3,031.0	81.9	4,524.0	90.7	5,430.0	94.5
NON-U.S. MANUFACTURERS										
Captive Total	13.0		16.0		39.0		65.0		109.0	
Write-Once	13.0	100.0	16.0	100.0	19.0	48.7	23.0	35.4	26.0	23.9
Erasable	--	--	--	--	20.0	51.3	42.0	64.6	83.0	76.1
OEM/PCM Total	248.0		510.0		990.0		1,704.0		2,420.0	
Write-Once	238.0	96.1	420.0	82.5	780.0	78.9	1,115.0	65.5	1,520.0	62.9
Erasable	10.0	3.9	90.0	17.5	210.0	21.1	589.0	34.5	900.0	37.1
Total Non-U.S.	261.0		526.0		1,029.0		1,769.0		2,529.0	
Write-Once	251.0	96.3	436.0	83.0	799.0	77.7	1,138.0	64.4	1,546.0	61.2
Erasable	10.0	3.7	90.0	17.0	230.0	22.3	631.0	35.6	983.0	38.8
WORLDWIDE RECAP										
Total Worldwide Shipments	481.0		2,819.0		4,730.0		6,756.0		8,275.0	
	--		+486.0%		+67.7%		+42.8%		+22.4%	
Write-Once	371.0	77.2	1,126.0	39.9	1,469.0	31.1	1,601.0	23.7	1,862.0	22.5
	--		+203.5%		+30.4%		+8.9%		+16.3%	
Erasable	110.0	22.8	1,693.0	60.1	3,261.0	68.9	5,155.0	76.3	6,413.0	77.5
	--		+1439.1%		+92.6%		+58.0%		+24.4%	

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

READ/WRITE OPTICAL LIBRARIES 40-69 CARTRIDGES

1990 DISK/TREND REPORT

READ/WRITE OPTICAL LIBRARIES, 40 - 69 CARTRIDGES

Coverage

Examples of optical disk libraries in this group include:

5.35" disk diameter

Document Imaging Systems	Docustore, 600, 675
DSM	5100
Eastman Kodak	560
Hitachi	OL101, OL112
Matsushita Electric Industry	LF-J5000A, LF-J5080
Matsushita Graphic Commun.	LD-24, LD-48
Mitsubishi Electric	MW-5G2-A
NKK	N-556E, N-556W
Ricoh	RJ5330E

8" disk diameter

Matsushita Graphic Commun.	LD-30

12" disk diameter

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

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

Market status

In 1989, this group led in unit shipments of optical libraries, with 696 units worldwide. 55% of shipments were 12", with the rest 5.25". 5.25" libraries have now displaced 8" libraries completely. 1989 revenues reached $32.2 million, 78% of which was generated by 12" libraries. The

number of library manufacturers in this product group is increasing slowly, but not all competitors manufacture libraries internally. Some are made by contract manufacturers on an exclusive basis.

Marketing trends

In 1993, unit shipments of nearly 4,500 optical disk libraries in this product group are forecasted, falling behind the read-only and 1 - 39 cartridge library groups. The balance between 12" and 5.25" drive use will have shifted heavily in favor of 5.25", with nearly 80% of shipments in the smaller size. However, 12" will still hold 52% of the revenues. While an increasing number of manufacturers in the 5.25" segment is expected, the number of competitors in the 12" segment is expected to be relatively stable.

While nearly all of the 1989 shipments of libraries in this group involved write-once drives, in 1993 equality between write-once and rewritable drives is anticipated. The balance could shift more quickly if standardized multifunction drive availability is accelerated, 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 larger 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 micro and minicomputers will be the most frequently found host systems for the medium scale optical library, followed by non-office systems and workstations. Use with personal computers will be uncommon. Mainframe hosts will be a small, but increasing host attachment opportunity.

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. In addition, there will be a steady increase in the number of standard software and hardware systems for which standard integration procedures and tools are offered and supported.

Forecasting assumptions

1. Archival applications will continue to favor write-once drives and media.
2. There are no immediate expectations in this product group for libraries using formats other than 12" and 5.25" format.
3. IBM, DEC, and other major system manufacturers will be marketing libraries of this class during the forecast period.
4. There will be no fundamental changes in technology affecting this group of libraries over the period of the forecast.

TABLE 39

OPTICAL LIBRARIES, 40-69 DISKS

REVENUE SUMMARY

	LIBRARY REVENUES, BY SHIPMENT DESTINATION ($M)									
	1989 Revenues		Forecast 1990		1991		1992		1993	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	7.4	10.9	10.6	15.4	15.1	22.8	20.4	31.0	29.6	44.5
TOTAL U.S. CAPTIVE	7.4	10.9	10.6	15.4	15.1	22.8	20.4	31.0	29.6	44.5
PCM/Reseller	--	--	--	--	--	--	--	--	--	--
OEM/Integrator	6.7	8.5	9.6	12.1	14.5	21.1	18.8	28.2	21.6	35.0
TOTAL U.S. NON-CAPTIVE	6.7	8.5	9.6	12.1	14.5	21.1	18.8	28.2	21.6	35.0
TOTAL U.S. REVENUES	14.1	19.4	20.2	27.5	29.6	43.9	39.2	59.2	51.2	79.5
Non-U.S. Manufacturers										
Captive	--	6.3	.9	6.5	1.6	7.8	2.2	8.2	2.7	8.7
PCM/Reseller	--	--	.7	1.4	1.4	2.8	2.3	4.4	2.9	5.5
OEM/Integrator	3.7	6.5	8.2	12.8	14.6	23.1	18.4	28.8	21.5	33.9
TOTAL NON-U.S. REVENUES	3.7	12.8	9.8	20.7	17.6	33.7	22.9	41.4	27.1	48.1
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	17.8	32.2	30.0	48.2	47.2	77.6	62.1	100.6	78.3	127.6
OEM Average Price ($000)	33.9	31.4	26.8	25.9	23.9	24.0	22.7	22.4	21.4	20.9

TABLE 40

OPTICAL LIBRARIES, 40-69 DISKS

UNIT SHIPMENT SUMMARY (SINGLE UNITS)

	LIBRARY UNIT SHIPMENTS, BY SHIPMENT DESTINATION									
	1989 Shipments		Forecast 1990		1991		1992		1993	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	46.0	68.0	108.0	138.0	170.0	235.0	265.0	365.0	444.0	596.0
TOTAL U.S. CAPTIVE	46.0	68.0	108.0	138.0	170.0	235.0	265.0	365.0	444.0	596.0
PCM/Reseller	--	--	--	--	--	--	--	--	--	--
OEM/Integrator	197.0	242.0	315.0	384.0	531.0	712.0	706.0	1,030.0	842.0	1,396.0
TOTAL U.S. NON-CAPTIVE	197.0	242.0	315.0	384.0	531.0	712.0	706.0	1,030.0	842.0	1,396.0
TOTAL U.S. SHIPMENTS	243.0	310.0	423.0	522.0	701.0	947.0	971.0	1,395.0	1,286.0	1,992.0
Non-U.S. Manufacturers										
Captive	--	150.0	25.0	172.0	50.0	210.0	70.0	235.0	90.0	260.0
PCM/Reseller	--	--	40.0	80.0	80.0	160.0	130.0	250.0	180.0	340.0
OEM/Integrator	110.0	236.0	350.0	578.0	685.0	1,132.0	930.0	1,513.0	1,175.0	1,904.0
TOTAL NON-U.S. SHIPMENTS	110.0	386.0	415.0	830.0	815.0	1,502.0	1,130.0	1,998.0	1,445.0	2,504.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	353.0	696.0	838.0	1,352.0	1,516.0	2,449.0	2,101.0	3,393.0	2,731.0	4,496.0
Cumulative Shipments (000)										
IBM	--	--	--	--	--	--	--	--	--	--
Non-IBM	.3	.7	1.1	2.0	2.7	4.5	4.8	7.8	7.5	12.3
WORLDWIDE TOTAL	.3	.7	1.1	2.0	2.7	4.5	4.8	7.8	7.5	12.3

TABLE 41

OPTICAL LIBRARIES, 40-69 DISKS

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1989 Revenues		FORECAST							
			1990		1991		1992		1993	
	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"
U.S. MANUFACTURERS										
U.S. Captive	--	10.9	1.3	14.1	2.8	20.0	5.4	25.6	10.0	34.5
OEM/Integrator	1.8	6.7	3.2	8.9	6.2	14.9	10.3	17.9	13.5	21.5
TOTAL U.S. REVENUES	1.8	17.6	4.5	23.0	9.0	34.9	15.7	43.5	23.5	56.0
NON-U.S. MANUFACTURERS										
Captive	2.8	3.5	3.0	3.5	4.3	3.5	4.5	3.7	4.8	3.9
PCM/Reseller	--	--	1.4	--	2.8	--	4.4	--	5.5	--
OEM/Integrator	2.5	4.0	7.5	5.3	16.8	6.3	21.9	6.9	26.8	7.1
TOTAL NON-U.S. REVENUES	5.3	7.5	11.9	8.8	23.9	9.8	30.8	10.6	37.1	11.0
WORLDWIDE RECAP										
Captive	2.8	14.4	4.3	17.6	7.1	23.5	9.9	29.3	14.8	38.4
	--	--	+53.6%	+22.2%	+65.1%	+33.5%	+39.4%	+24.7%	+49.5%	+31.1%
PCM/Reseller	--	--	1.4	--	2.8	--	4.4	--	5.5	--
	--	--	--	--	+100.0%	--	+57.1%	--	+25.0%	--
OEM/Integrator	4.3	10.7	10.7	14.2	23.0	21.2	32.2	24.8	40.3	28.6
	--	--	+148.8%	+32.7%	+115.0%	+49.3%	+40.0%	+17.0%	+25.2%	+15.3%
Total Revenues	7.1	25.1	16.4	31.8	32.9	44.7	46.5	54.1	60.6	67.0
	--	--	+131.0%	+26.7%	+100.6%	+40.6%	+41.3%	+21.0%	+30.3%	+23.8%
ANNUAL SHARE, BY DIAMETER	22.0%	78.0%	34.1%	65.9%	42.5%	57.5%	46.3%	53.7%	47.6%	52.4%

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

TABLE 42

OPTICAL LIBRARIES, 40-69 DISKS

WORLDWIDE SHIPMENTS (SINGLE UNITS)

BREAKDOWN BY DISK DIAMETER

	1989 Shipments		FORECAST							
			1990		1991		1992		1993	
	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"
U.S. MANUFACTURERS										
U.S. Captive	--	68.0	50.0	88.0	110.0	125.0	205.0	160.0	380.0	216.0
OEM/Integrator	132.0	110.0	235.0	149.0	460.0	252.0	710.0	320.0	991.0	405.0
TOTAL U.S. SHIPMENTS	132.0	178.0	285.0	237.0	570.0	377.0	915.0	480.0	1,371.0	621.0
NON-U.S. MANUFACTURERS										
Captive	50.0	100.0	72.0	100.0	110.0	100.0	130.0	105.0	150.0	110.0
PCM/Reseller	--	--	80.0	--	160.0	--	250.0	--	340.0	--
OEM/Integrator	130.0	106.0	440.0	138.0	965.0	167.0	1,320.0	193.0	1,695.0	209.0
TOTAL NON-U.S. SHIPMENTS	180.0	206.0	592.0	238.0	1,235.0	267.0	1,700.0	298.0	2,185.0	319.0
WORLDWIDE RECAP										
Captive	50.0	168.0	122.0	188.0	220.0	225.0	335.0	265.0	530.0	326.0
	--	--	+144.0%	+11.9%	+80.3%	+19.7%	+52.3%	+17.8%	+58.2%	+23.0%
PCM/Reseller	--	--	80.0	--	160.0	--	250.0	--	340.0	--
	--	--	--	--	+100.0%	--	+56.3%	--	+36.0%	--
OEM/Integrator	262.0	216.0	675.0	287.0	1,425.0	419.0	2,030.0	513.0	2,686.0	614.0
	--	--	+157.6%	+32.9%	+111.1%	+46.0%	+42.5%	+22.4%	+32.3%	+19.7%
Total Shipments	312.0	384.0	877.0	475.0	1,805.0	644.0	2,615.0	778.0	3,556.0	940.0
	--	--	+181.1%	+23.7%	+105.8%	+35.6%	+44.9%	+20.8%	+36.0%	+20.8%
ANNUAL SHARE, BY DIAMETER	44.9%	55.1%	65.0%	35.0%	73.8%	26.2%	77.2%	22.8%	79.2%	20.8%

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

TABLE 43

OPTICAL LIBRARIES, 40-69 DISKS

WORLDWIDE SHIPMENTS (SINGLE UNITS)

ERASABLE/WRITE-ONCE DRIVE ANALYSIS

	1989 --Shipments--		Forecast							
			1990		1991		1992		1993	
	Units	%	Units	%	Units	%	Units	%	Units	%
U.S. MANUFACTURERS										
Captive Total	68.0		138.0		235.0		365.0		596.0	
Write-Once	68.0	100.0	138.0	100.0	235.0	100.0	340.0	93.3	556.0	93.4
Erasable	--	--	--	--	--	--	25.0	6.7	40.0	6.6
OEM/PCM Total	242.0		384.0		712.0		1,030.0		1,396.0	
Write-Once	216.0	89.4	384.0	100.0	600.0	84.4	430.0	41.7	545.0	39.0
Erasable	26.0	10.6	--	--	112.0	15.6	600.0	58.3	851.0	61.0
Total U.S.	310.0		522.0		947.0		1,395.0		1,992.0	
Write-Once	284.0	91.7	522.0	100.0	835.0	88.3	770.0	55.3	1,101.0	55.4
Erasable	26.0	8.3	--	--	112.0	11.7	625.0	44.7	891.0	44.6
NON-U.S. MANUFACTURERS										
Captive Total	150.0		172.0		210.0		235.0		260.0	
Write-Once	150.0	100.0	172.0	100.0	210.0	100.0	235.0	100.0	260.0	100.0
OEM/PCM Total	236.0		658.0		1,292.0		1,763.0		2,244.0	
Write-Once	236.0	100.0	553.0	84.1	872.0	67.6	933.0	53.0	734.0	32.7
Erasable	--	--	105.0	15.9	420.0	32.4	830.0	47.0	1,510.0	67.3
Total Non-U.S.	386.0		830.0		1,502.0		1,998.0		2,504.0	
Write-Once	386.0	100.0	725.0	87.4	1,082.0	72.1	1,168.0	58.6	994.0	39.7
Erasable	--	--	105.0	12.6	420.0	27.9	830.0	41.4	1,510.0	60.3
WORLDWIDE RECAP										
Total Worldwide Shipments	696.0		1,352.0		2,449.0		3,393.0		4,496.0	
	--		+94.2%		+81.1%		+38.5%		+32.5%	
Write-Once	670.0	96.4	1,247.0	92.3	1,917.0	78.4	1,938.0	57.2	2,095.0	46.6
	--		+86.1%		+53.7%		+1.1%		+8.1%	
Erasable	26.0	3.6	105.0	7.7	532.0	21.6	1,455.0	42.8	2,401.0	53.4
	--		+303.8%		+406.6%		+173.5%		+65.0%	

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

READ/WRITE OPTICAL LIBRARIES 70 OR MORE CARTRIDGES

1990 DISK/TREND REPORT

READ/WRITE OPTICAL LIBRARIES, 70 OR MORE CARTRIDGES

Coverage

Examples of optical disk libraries in this group include:

5.25" disk diameter

Document Imaging Systems	675, 900
DSM	300
Mitsubishi Electric	MW-5G2-B, MW-5G2-C

12" and 14" disk diameter

Cygnet Systems	1800
Eastman Kodak	6800 ADL
Filenet	OSAR models 79GT, 90, 90GT, 200, 288

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

Market status

253 units were shipped in 1990, and all but 30 units were 12" models. Worldwide revenues were almost $24 million, 83% of which was generated from sales in the U.S. American manufacturers heavily dominate the product group, with Filenet and Cygnet the major players. Nearly 85% of 1989 shipments were to the OEM/Integrator channel, with captive shipments providing the balance. U.S. firms shipped 78.6% of the worldwide unit total. There is no PCM/Reseller activity for the libraries in this group because the system integration and support requirements are too complex for other than the equipment manufacturer to deal with.

Marketing trends

In 1993, worldwide shipments are expected to grow to 1,047 units, with 76% expected in the U.S. Revenue will grow to $87.6 million, 79% of which will be generated in the U.S., reflecting a trend toward larger system configurations. 12" libraries should be able to retain 72% of the unit shipments in 1993, and about 81% of the 12" libraries are expected to use write-once drives and media. The 5.25" libraries are more likely to use erasable or multi-function drives. The emphasis on archival applications for this product group and the desire of the archivist to minimize the number of media units involved favor the continued use of the 12" write-once drive.

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% of the 1993 library sales.

Applications

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

Technical trends

The large libraries that have appeared so far have used X-Y elevators 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 as well as multiple elevator mechanisms. It is conceivable that some suppliers may attempt a silo design similar in concept to the tape cartridge library system developed by Storage Technology.

Forecasting assumptions

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

2. 12" will continue as the dominant format, but will be challenged by 5.25" libraries. Other formats are not expected to be significant in the forecast period.

3. U.S. suppliers will continue to dominate this segment of the library market due to their experience and strength in system integration skills.

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

TABLE 44

OPTICAL LIBRARIES, 70 OR MORE DISKS

REVENUE SUMMARY

	LIBRARY REVENUES, BY SHIPMENT DESTINATION ($M)									
	1989 Revenues		Forecast 1990		1991		1992		1993	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	7.3	8.4	12.4	13.8	16.3	19.4	22.1	27.0	27.9	34.6
TOTAL U.S. CAPTIVE	7.3	8.4	12.4	13.8	16.3	19.4	22.1	27.0	27.9	34.6
PCM/Reseller	--	--	--	--	--	--	--	--	--	--
OEM/Integrator	12.2	14.6	12.4	15.3	23.4	28.6	31.2	38.2	39.0	48.5
TOTAL U.S. NON-CAPTIVE	12.2	14.6	12.4	15.3	23.4	28.6	31.2	38.2	39.0	48.5
TOTAL U.S. REVENUES	19.5	23.0	24.8	29.1	39.7	48.0	53.3	65.2	66.9	83.1
Non-U.S. Manufacturers										
Captive	--	.3	--	.2	--	.3	--	.3	--	.4
PCM/Reseller	--	--	--	--	--	--	--	--	--	--
OEM/Integrator	.2	.4	.4	.7	1.2	2.1	2.3	3.4	2.6	4.1
TOTAL NON-U.S. REVENUES	.2	.7	.4	.9	1.2	2.4	2.3	3.7	2.6	4.5
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	19.7	23.7	25.2	30.0	40.9	50.4	55.6	68.9	69.5	87.6
OEM Average Price ($000)	77.5	75.4	72.3	70.5	70.7	67.5	65.8	64.1	64.7	62.8

TABLE 45

OPTICAL LIBRARIES, 70 OR MORE DISKS

UNIT SHIPMENT SUMMARY (SINGLE UNITS)

	LIBRARY UNIT SHIPMENTS, BY SHIPMENT DESTINATION									
	1989		Forecast							
	Shipments		1990		1991		1992		1993	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
IBM Captive	--	--	--	--	--	--	--	--	--	--
Other U.S. Captive	39.0	44.0	64.0	70.0	86.0	100.0	119.0	142.0	158.0	191.0
TOTAL U.S. CAPTIVE	39.0	44.0	64.0	70.0	86.0	100.0	119.0	142.0	158.0	191.0
PCM/Reseller	--	--	--	--	--	--	--	--	--	--
OEM/Integrator	150.0	179.0	157.0	192.0	298.0	365.0	409.0	499.0	521.0	641.0
TOTAL U.S. NON-CAPTIVE	150.0	179.0	157.0	192.0	298.0	365.0	409.0	499.0	521.0	641.0
TOTAL U.S. SHIPMENTS	189.0	223.0	221.0	262.0	384.0	465.0	528.0	641.0	679.0	832.0
Non-U.S. Manufacturers										
Captive	--	10.0	--	10.0	--	12.0	--	15.0	--	18.0
PCM/Reseller	--	--	--	--	--	--	--	--	--	--
OEM/Integrator	10.0	20.0	20.0	35.0	50.0	90.0	100.0	150.0	122.0	197.0
TOTAL NON-U.S. SHIPMENTS	10.0	30.0	20.0	45.0	50.0	102.0	100.0	165.0	122.0	215.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	199.0	253.0	241.0	307.0	434.0	567.0	628.0	806.0	801.0	1,047.0
Cumulative Shipments (000)										
IBM	--	--	--	--	--	--	--	--	--	--
Non-IBM	.2	.2	.4	.5	.8	1.1	1.5	1.9	2.3	2.9
WORLDWIDE TOTAL	.2	.2	.4	.5	.8	1.1	1.5	1.9	2.3	2.9

TABLE 46

OPTICAL LIBRARIES, 70 OR MORE DISKS

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1989 Revenues		FORECAST							
			1990		1991		1992		1993	
	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"
U.S. MANUFACTURERS										
U.S. Captive	--	8.4	--	13.8	.2	19.2	.5	26.5	.9	33.7
OEM/Integrator	--	14.6	.1	15.2	.4	28.2	1.4	36.8	2.2	46.3
TOTAL U.S. REVENUES	--	23.0	.1	29.0	.6	47.4	1.9	63.3	3.1	80.0
NON-U.S. MANUFACTURERS										
Captive	.3	--	.2	--	.3	--	.3	--	.4	--
OEM/Integrator	.4	--	.7	--	2.1	--	3.4	--	4.1	--
TOTAL NON-U.S. REVENUES	.7	--	.9	--	2.4	--	3.7	--	4.5	--
WORLDWIDE RECAP										
Captive	.3	8.4	.2	13.8	.5	19.2	.8	26.5	1.3	33.7
	--	--	-33.3%	+64.3%	+150.0%	+39.1%	+60.0%	+38.0%	+62.5%	+27.2%
OEM/Integrator	.4	14.6	.8	15.2	2.5	28.2	4.8	36.8	6.3	46.3
	--	--	+100.0%	+4.1%	+212.5%	+85.5%	+92.0%	+30.5%	+31.3%	+25.8%
Total Revenues	.7	23.0	1.0	29.0	3.0	47.4	5.6	63.3	7.6	80.0
	--	--	+42.9%	+26.1%	+200.0%	+63.4%	+86.7%	+33.5%	+35.7%	+26.4%
ANNUAL SHARE, BY DIAMETER	3.0%	97.0%	3.3%	96.7%	6.0%	94.0%	8.1%	91.9%	8.7%	91.3%

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

TABLE 47

OPTICAL LIBRARIES, 70 OR MORE DISKS

WORLDWIDE SHIPMENTS (SINGLE UNITS)

BREAKDOWN BY DISK DIAMETER

	1989 Shipments		FORECAST							
			1990		1991		1992		1993	
	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"	5.25"	12"
U.S. MANUFACTURERS										
U.S. Captive	--	44.0	--	70.0	4.0	96.0	9.0	133.0	17.0	174.0
OEM/Integrator	--	179.0	2.0	190.0	12.0	353.0	37.0	462.0	60.0	581.0
TOTAL U.S. SHIPMENTS	--	223.0	2.0	260.0	16.0	449.0	46.0	595.0	77.0	755.0
NON-U.S. MANUFACTURERS										
Captive	10.0	--	10.0	--	12.0	--	15.0	--	18.0	--
OEM/Integrator	20.0	--	35.0	--	90.0	--	150.0	--	197.0	--
TOTAL NON-U.S. SHIPMENTS	30.0	--	45.0	--	102.0	--	165.0	--	215.0	--
WORLDWIDE RECAP										
Captive	10.0	44.0	10.0	70.0	16.0	96.0	24.0	133.0	35.0	174.0
	--	--	--	+59.1%	+60.0%	+37.1%	+50.0%	+38.5%	+45.8%	+30.8%
OEM/Integrator	20.0	179.0	37.0	190.0	102.0	353.0	187.0	462.0	257.0	581.0
	--	--	+85.0%	+6.1%	+175.7%	+85.8%	+83.3%	+30.9%	+37.4%	+25.8%
Total Shipments	30.0	223.0	47.0	260.0	118.0	449.0	211.0	595.0	292.0	755.0
	--	--	+56.7%	+16.6%	+151.1%	+72.7%	+78.8%	+32.5%	+38.4%	+26.9%
ANNUAL SHARE, BY DIAMETER	11.9%	88.1%	15.3%	84.7%	20.8%	79.2%	26.3%	73.7%	28.0%	72.0%

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

TABLE 48

OPTICAL LIBRARIES, 70 OR MORE DISKS

WORLDWIDE SHIPMENTS (SINGLE UNITS)

ERASABLE/WRITE-ONCE DRIVE ANALYSIS

	1989		Forecast							
	--Shipments--		-----1990----		-----1991----		-----1992----		-----1993----	
	Units	%	Units	%	Units	%	Units	%	Units	%
U.S. MANUFACTURERS										
Captive Total	44.0		70.0		100.0		142.0		191.0	
Write-Once	44.0	100.0	70.0	100.0	96.0	96.1	133.0	93.8	174.0	91.2
Erasable	--	--	--	--	4.0	3.9	9.0	6.2	17.0	8.8
OEM/PCM Total	179.0		192.0		365.0		499.0		641.0	
Write-Once	179.0	100.0	192.0	100.0	355.0	97.4	466.0	93.5	589.0	92.0
Erasable	--	--	--	--	10.0	2.6	33.0	6.5	52.0	8.0
Total U.S.	223.0		262.0		465.0		641.0		832.0	
Write-Once	223.0	100.0	262.0	100.0	451.0	97.1	599.0	93.5	763.0	91.8
Erasable	--	--	--	--	14.0	2.9	42.0	6.5	69.0	8.2
NON-U.S. MANUFACTURERS										
Captive Total	10.0		10.0		12.0		15.0		18.0	
Write-Once	10.0	100.0	10.0	100.0	12.0	100.0	15.0	100.0	18.0	100.0
OEM/PCM Total	20.0		35.0		90.0		150.0		197.0	
Write-Once	20.0	100.0	35.0	100.0	50.0	55.7	65.0	43.3	72.0	36.5
Erasable	--	--	--	--	40.0	44.3	85.0	56.7	125.0	63.5
Total Non-U.S.	30.0		45.0		102.0		165.0		215.0	
Write-Once	30.0	100.0	45.0	100.0	62.0	60.9	80.0	48.5	90.0	41.9
Erasable	--	--	--	--	40.0	39.1	85.0	51.5	125.0	58.1
WORLDWIDE RECAP										
Total Worldwide Shipments	253.0		307.0		567.0		806.0		1,047.0	
	--		+21.3%		+84.6%		+42.1%		+29.9%	
Write-Once	253.0	100.0	307.0	100.0	513.0	90.6	679.0	84.3	853.0	81.6
	--		+21.3%		+67.1%		+32.3%		+25.6%	
Erasable	--	--	--	--	54.0	9.4	127.0	15.7	194.0	18.4
	--		--		--		+135.1%		+52.7%	

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

1990 DISK/TREND REPORT

OPTICAL DISK DRIVE SPECIFICATIONS

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

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

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

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

Speed control: Two abbreviations are used:

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

Capacities: Capacities are listed as "U" for unformatted and "F" for formatted. Because most optical drives currently can read only one side of the media, the capacity given is in terms of one side, even if the drive uses two-sided media. In general, optical drives are preformatted, so 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 this is the way almost all drives are used.

Servo type: Optical drive servo types are noted as:

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

Positioner type: Many optical drives have multi-stage head positioners. A coarse movement positions the head in the general 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.

1990 DISK/TREND optical disk product groups

For the 1990 report, products are classified in six groups.

Optical drives:

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

Optical libraries:

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

MANUFACTURER	ATG GIGADISC	ATG GIGADISC	ATG GIGADISC	CANON	CANON
DRIVE	GD 1002	GD 6000	GD 6001	MO-5001S	OM-500D
DISK/TREND GROUP	12	12	12	11	11
MARKET	OEM	OEM	OEM	Captive, OEM	Captive, OEM
MEDIA: Nominal disk diameter	12"	12"	12"	130 mm	130 mm
Recording medium	Au-Cr-Polymer	Au-Cr-Polymer	Au-Cr-Polymer	Tb-Fe-Co	Bilayer RE-TM
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Write Once	Write Once	Write Once	Rewritable-(MO)	Rewritable-(MO)
Interface	SCSI	SCSI	SCSI	SCSI	Modified ESDI
Speed control	CAV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 1,000	F: 3,200	F: 3,200	F: 256	F: 256
Capacity per track (Bytes)	F: 25,600	F: 52,428	F: 52,428	F: 16,384	F: 16,384
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	40000	62500	62500	15728	15728
Track density (TPI)	14514	25400	25400	15875	15875
Maximum linear density (BPI)	15200	28200	28200	21082	21082
Rotational speed (RPM)	1121.5	1143	1143	3000	3000
PERFORMANCE					
Positioner type	Crs: Voice Coil Fine: Galvonom.	Crs: Linear Motor Fine: Galvonom.	Crs: Linear Motor Fine: Galvonom.	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator
Servo type	Sampled	Sampled	Sampled	Continuous	Continuous
Average positioning time (msec)	110	100	100	80	80
Within fine band (msec)	8	0.8	0.8	18	18
Fine band capacity (Mbytes)	78	16	16	1.0	2
Average rotational delay (msec)	26.7	26.2	26.2	10	10
Average access time (msec)	136.7	126.2	126.2	90	90
Data transfer rate (KBytes/sec)	480	1000	1000	1138	1150
FIRST CUSTOMER SHIPMENT	2Q88	3Q89	4Q90	3/90	4Q88
COMMENTS			Differs from GD 6000 in the cartridge (single operation loading)	SCSI controller available. Exchange coupled MO media. External mount	SCSI controller available Exchange coupled MO media

MANUFACTURER	CHEROKEE DATA SYSTEMS	CHEROKEE DATA SYSTEMS	CHINON	CHINON	EASTMAN KODAK
DRIVE	M600 M610	Tracker	CDA-431 CDS-431 CDX-431	CDS-430	6800
DISK/TREND GROUP	11	11	10	10	12
MARKET	OEM	OEM	OEM	OEM	Captive, OEM
MEDIA: Nominal disk diameter	130 mm	130 mm	120 mm	120 mm	14"
Recording medium	Te-Ox	Te-Ox	Aluminum	Aluminum	Dye Polymer
Track format	Spiral	Concentric	Spiral	Spiral	Spiral (Zone)
DRIVE: Operating mode	Write Once	Write Once	Read Only	Read Only	Write Once
Interface	SCSI	SCSI	SCSI	Proprietary	SCSI, IPI-3
Speed control	CAV	CAV	CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 320	F: 300	F: 550	F: 550	F: 4,100
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	18750	18260	20750	20750	58200
Track density (TPI)	15875	15875	15875	15875	14111
Maximum linear density (BPI)	24924	24924	27600	27600	21000
Rotational speed (RPM)	1800	1613	500-200	500-200	800-1600
PERFORMANCE					
Positioner type	Crs: Rack & Pinion Fine: Lens Actuator	Crs: Rack & Pinion Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator	Crs: Motor Fine: Lens Actuator	Crs: Linear Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Sampled
Average positioning time (msec)	95	95	350	500	500
Within fine band (msec)	NS	NS	N/A	N/A	100
Fine band capacity (Mbytes)	NS	NS	N/A	N/A	N/A
Average rotational delay (msec)	16.5	18.6	110	110	27
Average access time (msec)	111.5	113.6	450	610	527
Data transfer rate (KBytes/sec)	522	468	153.6	153.6	1000
FIRST CUSTOMER SHIPMENT	3/89	9/87	1Q90	1988	1987
COMMENTS		Can be used in harsh environments	41.3 mm high CDA-431 and CDX-431 are external mount. Audio output	External mount Audio output	

MANUFACTURER	FUJITSU	FUJITSU	FUJITSU	FUJITSU	GOLDSTAR TELE-COMMUNICATION
DRIVE	M2505B	F6441A1 F6441B1	F6443	M2502A/B	GCDR-200
DISK/TREND GROUP	11	12	12	12	10
MARKET	OEM	Captive	Captive	OEM	OEM
MEDIA: Nominal disk diameter	130 mm	12"	200 mm	12"	120 mm
Recording medium	Te Alloy	Te Alloy	Tb-Fe-Co	Te Alloy	Aluminum
Track format	Spiral	Concentric	Spiral	Spiral	Spiral
DRIVE: Operating mode	Write Once	Write Once	Rewritable-(MO)	Write Once	Read Only
Interface	ESDI, SCSI	Mod. 3350, SCSI	Modified SMD	Mod. SMD, SCSI	Proprietary
Speed control	CAV	CAV	CAV	CAV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 300	F: 1,376	F: 8,900	F: 1,800	F: 552
Capacity per track (Bytes)	F: 16,325	F: 30,720	F: 24,576	F: 38,912	F: N/A
Data surfaces per spindle	1	1	16	1	1
Tracks per surface	18320	44800	23640	46260	20750
Track density (TPI)	15875	15875	15875	16383	15875
Maximum linear density (BPI)	24924	24144	19098	25133	27600
Rotational speed (RPM)	1800	900	1800	900	535-200
PERFORMANCE					
Positioner type	Crs: Stepping Motor Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator	Crs: Stepping Motor Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	100	216.7	200*	190	600
Within fine band (msec)	NS	NS	NS	NS	N/A
Fine band capacity (Mbytes)	NS	NS	NS	NS	N/A
Average rotational delay (msec)	16.67	33.3	16.6	33.3	110
Average access time (msec)	116.67	250	216.6	223.3	710
Data transfer rate (KBytes/sec)	693.6	783	979	816	153.6
FIRST CUSTOMER SHIPMENT	9/87	3Q85	6/89	1Q89	1990
COMMENTS		Available only in Japan F6441A1 has SCSI interface	8 fixed disks per spindle. 2 actuators, 4 heads/spindle. *Media to media seek is 5 sec.	M2502A has SCSI interface	Audio output

MANUFACTURER	GOLDSTAR TELE-COMMUNICATION	GOLDSTAR TELE-COMMUNICATION	HITACHI	HITACHI	HITACHI
DRIVE	GSO-5650R GSO-5650RS	GSO-5650WS	CDR 1503S	CDR 1600S CDR 1650S	CDR 3600 CDR 3650
DISK/TREND GROUP	11	11	10	10	10
MARKET	OEM	OEM	Captive,OEM,PCM	Captive,OEM,PCM	Captive,OEM,PCM
MEDIA: Nominal disk diameter	130 mm	130 mm	120 mm	120 mm	120 mm
Recording medium	Tb-Fe-Co	Te Alloy	Aluminum	Aluminum	Aluminum
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Rewritable-(MO)	Write Once	Read Only	Read Only	Read Only
Interface	ESDI	SCSI	SCSI, PC	SCSI, Prop.	SCSI, Prop.
Speed control	CAV	CAV	CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 326.4	F: 325	F: 552.9	F: 552.9	F: 552.9
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	15475
Maximum linear density (BPI)	24902*	24902	27600	27600	27600
Rotational speed (RPM)	2400	2400	535-200	535-200	535-200
PERFORMANCE					
Positioner type	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Linear Motor Fine: Lens Actuator	Crs: Linear Motor Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	60	60	640	290	290
Within fine band (msec)	15	15	N/A	N/A	N/A
Fine band capacity (Mbytes)	3.3	3.3	N/A	N/A	N/A
Average rotational delay (msec)	12.5	12.5	110	110	110
Average access time (msec)	72.5	72.5	750	400	400
Data transfer rate (KBytes/sec)	680	680	153.6	153.6	153.6
FIRST CUSTOMER SHIPMENT	1990	1990	2Q87	11/89	10/89
COMMENTS	RS model is external mount *2,7 RLL Code	External mount	External mount	CDR-1650S has SCSI interface	41.3 mm high CDR 3650 has SCSI interface

MANUFACTURER	HITACHI	HITACHI	HITACHI	HONEYWELL	IBM
DRIVE	OD 101-1	OD 112-1	OD 301A-1	AN/MU-928	3363-A01 3363-A11 3363-B01 3363-8700
DISK/TREND GROUP	11	11	12	11	11
MARKET	Captive, OEM	Captive, OEM	Captive, OEM	OEM	Captive
MEDIA: Nominal disk diameter	130 mm	130 mm	300 mm	130 mm	130 mm
Recording medium	Te-Se-Pb	Tb-Fe-Co	Te-Se-Pb	Te Alloy	Doped Te-Ox
Track format	Spiral	Spiral	Spiral	Concentric	Spiral
DRIVE: Operating mode	Write Once	Rewritable-(MO)	Write Once	Write Once	Write Once
Interface	SCSI	SCSI	SCSI, GPIB, SMD	Modified SCSI	IBM
Speed control	CAV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 300	F: 322	F: 1,310	F: 260	F: 201.36
Capacity per track (Bytes)	F: 16,400	F: 17,408	F: 31,700	F: 20,480	F: 11,776
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	18624	18751	41300	12695	17100
Track density (TPI)	16000	16000	16000	NS	15875
Maximum linear density (BPI)	24000	24000	19500	NS	21166
Rotational speed (RPM)	1800	2400	600	1800	875
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: Galvonom.
Servo type	Continuous	Continuous	Continuous	Sector	Continuous
Average positioning time (msec)	93	62.5	200	125	230
Within fine band (msec)	NS	NS	NS	NS	NS
Fine band capacity (Mbytes)	NS	NS	NS	NS	NS
Average rotational delay (msec)	16.7	12.5	50	17	34.3
Average access time (msec)	109.7	75	250	142	264.3
Data transfer rate (KBytes/sec)	690	925	440	562	171
FIRST CUSTOMER SHIPMENT	2Q87	7/89	3Q85	2Q89	2Q87
COMMENTS		ISO standard		Embedded controller Militarized	Mechanism by Matsushita Electric

MANUFACTURER	JVC	KAWASAKI STEEL	KAWASAKI STEEL	LASER MAGNETIC STORAGE	LASER MAGNETIC STORAGE
DRIVE	XR-R100 XR-R1001	KL200S	KL1200S	CM 131 CM 132	CM 201 CM 221
DISK/TREND GROUP	10	11	11	10	10
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	120 mm	130 mm	130 mm	120 mm	120 mm
Recording medium	Aluminum	Te Alloy	Te Alloy	Aluminum	Aluminum
Track format	Spiral	Concentric	Concentric	Spiral	Spiral
DRIVE: Operating mode	Read Only	Write Once	Write Once	Read Only	Read Only
Interface	SCSI	SCSI, PC	SCSI, PC	SCSI	Serial
Speed control	CLV	CAV	CAV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 540	F: 122	F: 630	F: 600	F: 600
Capacity per track (Bytes)	F: N/A	F: 8,192	F: 20,480	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	14901	31500	20750	20750
Track density (TPI)	15875	15875	36000 max.	15875	15875
Maximum linear density (BPI)	27600	11500	27000 max.	27600	27600
Rotational speed (RPM)	530-200	1800	1800	500-200	500-200
PERFORMANCE					
Positioner type	Crs: Voice Coil Fine: Lens Actuator	Crs: Stepping Motor Fine: Galvonom.	Crs: Stepping Motor Fine: Galvonom.	Rotary Galvonometer	Rotary Galvonometer
Servo type	Continuous	Sector	Sector	Continuous	Continuous
Average positioning time (msec)	300	135	90	500	500
Within fine band (msec)	N/A	21.6	8	N/A	N/A
Fine band capacity (Mbytes)	N/A	1.2	4	N/A	N/A
Average rotational delay (msec)	110	16.7	16.7	110	110
Average access time (msec)	410	151.7	106.7	610	610
Data transfer rate (KBytes/sec)	153.6	240	600	153.6	153.6
FIRST CUSTOMER SHIPMENT	3Q87	1Q87	3Q89	8/88	8/88
COMMENTS	41.3 mm high XR-R100 is free standing	Grooveless tracking system	Grooveless tracking system	CM 132 is 2 drive package	41.3 mm high CM 221 is external mount

MANUFACTURER	LASER MAGNETIC STORAGE	LASER MAGNETIC STORAGE	LASER MAGNETIC STORAGE	LASER MAGNETIC STORAGE	LASER MAGNETIC STORAGE
DRIVE	CM 210	CM 212 CM 231	510	1200E 1250E	LD 4100
DISK/TREND GROUP	10	10	11	12	12
MARKET	OEM	OEM	OEM	OEM	Captive, OEM
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	SCSI, PC XT	SCSI	SCSI	SCSI, ISI	SCSI-2
Speed control	CLV	CLV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 600	F: 600	F: 327	F: 1,000	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)	500-230	500-200	2160	480	855
PERFORMANCE					
Positioner type	Rotary Galvonometer	Rotary Galvonometer	Linear, Voice Coil	Linear, Voice Coil	Crs: Linear, Voice Coil Fine: Lens Actuator
Servo type	Continuous	Continuous	Sampled	Sampled	Sampled
Average positioning time (msec)	415	290	61.3	150	80
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	13.7	62.5	35
Average access time (msec)	525	400	75	212.5	130*
Data transfer rate (KBytes/sec)	153.6	153.6	600	313	700
FIRST CUSTOMER SHIPMENT	2Q87	2Q89	4Q88	3Q83	2Q90
COMMENTS		CM 231 is external mount		Has Direct Read During Write 1250E is rack mounted	*Includes command latency

MANUFACTURER	LITERAL	LITERAL	LITERAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL
DRIVE	525 GB 525 GBX2	525 WC	M810 M820 M840 M850	CR-501-B CR-501-S	LF-5000 LF-5001
DISK/TREND GROUP	11	11	11	10	11
MARKET	OEM, PCM	OEM, PCM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	130 mm	130 mm	130 mm	120 mm	130 mm
Recording medium	Te Alloy	Te Alloy	Te-C, Te Alloy	Aluminum	Te-Ox
Track format	Concentric	Concentric	Spiral	Spiral	Spiral
DRIVE: Operating mode	Write Once	Write Once	Write Once	Read Only	Write Once
Interface	SCSI, Prop., PC	ESDI, PC	SCSI, Prop.	SCSI	SCSI
Speed control	CAV	CAV	CLV	CLV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 640	F: 122	F: 405	F: 540	F: 200
Capacity per track (Bytes)	F: 20,000	F: 8,192	F: 22,016 avg.	F: N/A	F: 11,776
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	32000	14901	18750	20750	17100
Track density (TPI)	35000	15875	15875	15875	15875
Maximum linear density (BPI)	32000	11500	20159	27600	21166
Rotational speed (RPM)	1800	1800	1114-557	500-200	875
PERFORMANCE					
Positioner type	Crs: Stepping Motor Fine: Lens Actuator	Crs: Stepping Motor Fine: Galvonom.	Crs: Stepping Motor Fine: Galvonom.	Crs: NS Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator
Servo type	Sector	Sector	Continuous	Continuous	Continuous
Average positioning time (msec)	90	135	135	390	190
Within fine band (msec)	8	21.6	21	N/A	45
Fine band capacity (Mbytes)	4	1.2	3.2 avg.	N/A	.588
Average rotational delay (msec)	16.7	16.7	40	110	34.3
Average access time (msec)	106.7	151.7	175	500	224.3
Data transfer rate (KBytes/sec)	812.5	312.5	347	153.6	171
FIRST CUSTOMER SHIPMENT	4/88	3Q85	4Q87	1989	2Q88
COMMENTS	525 GBX2 is external mount; dual drive available	Grooveless tracking system Literal will certify media	M810 for PC/AT M820 for Apple M840 for Microvax II M850 for PS/2	41.3 mm high S is external mount	

MANUFACTURER	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRONIC COMPONENTS	MATSUSHITA ELECTRONIC COMPONENTS
DRIVE	LF-5010 LF-5012 LF-5014 LF-5110 LF-5210	LF-7010 LF-7014 LF-7110	LF-9000 LF-9000S	EMO-103	SQ-D1
DISK/TREND GROUP	11	11	11	10	10
MARKET	OEM	OEM, Captive	OEM	OEM	Captive, OEM
MEDIA: Nominal disk diameter	130 mm	130 mm	130 mm	120 mm	120 mm
Recording medium	Te-Ox	Ge-Te-Sb	Tb-Fe-Co	Aluminum	Aluminum
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Write Once-(PC)	Rewritable-(PC)	Rewritable-(MO)	Read Only	Read Only
Interface	SCSI-2	SCSI-2	SCSI-2	Proprietary	SCSI, PC
Speed control	MCAV	MCAV	CAV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 470	F: 500/470*	F: 326	F: 540	F: 540
Capacity per track (Bytes)	F: 25,600 avg.	F: NS	F: 17,408	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	18360	19968/18360*	18727	20750	20750
Track density (TPI)	16925	16925	15875	15875	15875
Maximum linear density (BPI)	NS	30480	24937	27600	27600
Rotational speed (RPM)	1200	1800	2400	500-200	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: Geared Motor Fine: Lens Actuator	Crs: Voice Coil Fine: Voice Coil
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	90	90	62.5	2400	540
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)	25	16.7	12.5	110	110
Average access time (msec)	115	106.7	75	2510	650
Data transfer rate (KBytes/sec)	861.25	990	925	153.6	153.6
FIRST CUSTOMER SHIPMENT	3Q89	4Q90	4/88	3/89	1Q87
COMMENTS	LF-5010 is external mount. LF-51XX series sold in Japan. LF-52XX series sold in Europe.	*Will operate with WORM media: 470 MB capacity. LF-7110 sold in Japan.	Glass substrate LF-9000S is external mount		41.3 mm high

MANUFACTURER	MATSUSHITA ELECTRONIC COMPONENTS	MATSUSHITA GRAPHIC COMMUNICATION	MATSUSHITA GRAPHIC COMMUNICATION	MAXIMUM STORAGE	MAXIMUM STORAGE
DRIVE	SQ-D101	PF-10 PF-10B PF-3000	PF-3010F PF-3010S PF-3010X	APX-3200	APX-5100 APX-5200
DISK/TREND GROUP	10	11	11	11	11
MARKET	Captive, OEM	Captive, OEM	Captive	OEM	OEM
MEDIA: Nominal disk diameter	120 mm	200 mm	130 mm	130 mm	130 mm
Recording medium	Aluminum	Te-Ox	Te-Ox	Te Alloy	Te Alloy
Track format	Spiral	Spiral	Spiral	Concentric	Concentric
DRIVE: Operating mode	Read Only	Write Once	Write Once	Write Once	Write Once
Interface	SCSI, PC	Proprietary	SCSI	Mod. ESDI, PC	Modified ESDI
Speed control	CLV	CLV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 540	F: 700	F: 600	F: 122	F: 501.8
Capacity per track (Bytes)	F: N/A	F: N/A	F: 16,400	F: 8,192	F: 16,384
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	23330	18624	14901	30626
Track density (TPI)	15875	23333	16000	14100	26458
Maximum linear density (BPI)	27600	15394	24000	11400	17665
Rotational speed (RPM)	530-200	900	1800	1800	1800
PERFORMANCE					
Positioner type	Crs: Voice Coil Fine: Voice Coil	Linear, Voice Coil	Linear, Voice Coil	Crs: Stepping Motor Fine: Lens Actuator	Crs: Stepping Motor Fine: Lens Actuator
Servo type	Continuous	Sampled	Sampled	Sector	Sector
Average positioning time (msec)	540	200	95	118	NS
Within fine band (msec)	N/A	N/A	NS	20	NS
Fine band capacity (Mbytes)	N/A	N/A	NS	1.31	NS
Average rotational delay (msec)	110	33.3	17	16.7	16.7
Average access time (msec)	650	233.3	112	134.7	NS
Data transfer rate (KBytes/sec)	153.6	675	690	312.5	625
FIRST CUSTOMER SHIPMENT	1Q87	2Q86	3Q89	3Q87	10/89
COMMENTS	Free standing	Available only in Japan 30 disk library available	Available only in Japan 24 and 48 disk libraries are available		APX-5200 is external mount Rack & Pinion coarse positioner

MANUFACTURER	MAXOPTIX	MITSUBISHI ELECTRIC CORPORATION	MITSUBISHI ELECTRIC CORPORATION	MITSUBISHI ELECTRIC CORPORATION	MITSUMI ELECTRIC
DRIVE	Tahiti	ME-5E1 ME-5U1	MW-5D1 MW-5U1	MW-5E3 MW-5U3	CRMC-SR001N
DISK/TREND GROUP	11	11	11	11	10
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	130 mm	130 mm	130 mm	130 mm	120 mm
Recording medium	RE-TM Alloy	Tb-Fe-Co	Te-Se	Te-Se	Aluminum
Track format	Spiral, (Zone)	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Rewritable-(MO)	Rewritable-(MO)	Write Once	Write Once	Read Only
Interface	SCSI	ESDI, SCSI	ESDI, SCSI	SCSI	SCSI, Prop.
Speed control	CAV	CAV	CAV	CAV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 512/326	F: 297/326	F: 300	F: 297/326	F: 540
Capacity per track (Bytes)	F: 25,000	F:15,872/17,408	F: 15,872	F:15,874/17,408	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	25000	18750	18750	18750	20750
Track density (TPI)	16933	15875	15875	15875	15875
Maximum linear density (BPI)	25000*	25400*	25400*	25400*	27600
Rotational speed (RPM)	2200	2400	1800	2400	500-200
PERFORMANCE					
Positioner type	Crs: Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Motor Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	35	35.5	63	35.5	500
Within fine band (msec)	20.5/16	1.5	1.5	1.5	N/A
Fine band capacity (Mbytes)	2	.317	.317	0.317	N/A
Average rotational delay (msec)	13.6	12.5	17	12.5	110
Average access time (msec)	48.6	48	80	48	610
Data transfer rate (KBytes/sec)	850/1250	925	687.5	925	153.6
FIRST CUSTOMER SHIPMENT	11/89	2Q90	1Q88	1Q91	1990
COMMENTS	Actuator has split optics *2,7 RLL Code	ME-5U1 is external mount *2,7 RLL Code	MW-5U1 includes controller; free standing package *2,7 RLL Code	MW-5U3 is external mount *2,7 RLL Code	41.3 mm high

MANUFACTURER	MOST	MOUNTAIN OPTECH	MOUNTAIN OPTECH	MOUNTAIN OPTECH	MOUNTAIN OPTECH
DRIVE	RMD 5128-S	CS-400	CS-1000 R/W	SEL-2C	SE-400M
DISK/TREND GROUP	11	11	11	11	11
MARKET	OEM, PCM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	90 mm	130 mm	130 mm	130 mm	130 mm
Recording medium	RE-TM	Te Alloy	RE-TM Alloy	Te Alloy	Te Alloy
Track format	Spiral	Concentric	Spiral (Zone)	Concentric	Concentric
DRIVE: Operating mode	Rewritable-(MO)	Write Once	Rewritable-(MO)	Write Once	Write Once
Interface	SCSI, ESDI	SCSI, PC AT	SCSI	SCSI, PC AT	SCSI, PC AT
Speed control	CAV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 128	F: 202	F: 512/236	F: 202	F: 202
Capacity per track (Bytes)	F: 12,800	F: 10,752	F: 25,000	F: 10,752	F: 10,752
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	10000	18826	25000	18826	18826
Track density (TPI)	15875	15625	16933	15625	15625
Maximum linear density (BPI)	15875	14620	25000	14620	14620
Rotational speed (RPM)	2400	1200	2200	1200	1200
PERFORMANCE					
Positioner type	Crs: Voice Coil Fine: Lens Actuator	Crs: Stepping Motor Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator	Crs: Stepping Motor Fine: Lens Actuator	Crs: Stepping Motor Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	28	170	35	170	170
Within fine band (msec)	3.5	15	20.5/16	15	15
Fine band capacity (Mbytes)	1.638	.32	2	.32	.32
Average rotational delay (msec)	12.5	25	13.6	25	25
Average access time (msec)	40.5	195	48.6	195	195
Data transfer rate (KBytes/sec)	512	275	1250/880	275	275
FIRST CUSTOMER SHIPMENT	4Q90	1986	4Q90	1987	4Q90
COMMENTS		Mechanism from Shugart Corp.	Ruggedized version of Maxtor Tahiti Preliminary specification	Ruggedized CS-400 MicroVax interface available	Designed to meet MIL-SPEC 883 for space applications

MANUFACTURER	MOUNTAIN OPTECH	NEC	NEC	NEC	NEC
DRIVE	SE-650 I	CDR-30	CDR-35	CDR-72 CDR-82	CDR-90
DISK/TREND GROUP	11	10	10	10	10
MARKET	OEM	Captive	PCM	OEM, PCM	OEM
MEDIA: Nominal disk diameter	130 mm	120 mm	120 mm	120 mm	120 mm
Recording medium	Te Alloy	Aluminum	Aluminum	Aluminum	Aluminum
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Write Once	Read Only	Read Only	Read Only	Read Only
Interface	SCSI	Proprietary	Modified SCSI	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	18272	20750	20750	20750	20750
Track density (TPI)	15625	15875	15875	15875	15875
Maximum linear density (BPI)	14620	27600	27600	27600	27600
Rotational speed (RPM)	1800	535-200	535-200	530-200	535-200
PERFORMANCE					
Positioner type	Crs: NS Fine: Lens Actuator	Crs: Gear Mechanism Fine: Lens Actuator	Lead Screw, DC Motor	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Stepping Motor Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	70	1390	1390	350	500
Within fine band (msec)	50	N/A	N/A	N/A	N/A
Fine band capacity (Mbytes)	1.74	N/A	N/A	N/A	N/A
Average rotational delay (msec)	16.6	110	110	110	110
Average access time (msec)	86.6	1500	1500	460	610
Data transfer rate (KBytes/sec)	687.5	153.6	153.6	153.6	153.6
FIRST CUSTOMER SHIPMENT	4Q90	12/88	8/89	3/90	2Q88
COMMENTS	Ruggedized Preliminary specification	Used with NEC PC engine or PC-8801	Portable model	CDR-72 is external model	41.3 mm high Automotive use available in Japan only

MANUFACTURER	NEC	NEC	NEC	NEC	NEC
DRIVE	N5267-31	PC-CD102	PC-OD101 N7915	N6329-21 N7911	N6513
DISK/TREND GROUP	10	10	11	12	12
MARKET	Captive	Captive	Captive	Captive	Captive
MEDIA: Nominal disk diameter	120 mm	120 mm	130 mm	12"	12"
Recording medium	Aluminum	Aluminum	Tb-Fe-Co	Tri-layer	Te Alloy
Track format	Spiral	Spiral	Spiral	Concentric	Spiral
DRIVE: Operating mode	Read Only	Read Only	Rewritable-(MO)	Write Once	Write Once
Interface	SCSI	SCSI	SCSI	SCSI, Prop.	SCSI, Prop.
Speed control	CLV	CLV	CAV	CAV	Zone CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 540	F: 540	F: 305	F: 1,016	F: 1,800
Capacity per track (Bytes)	F: N/A	F: N/A	F: 17,408	F: 32,768	F:29,500-56,500
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	20750	18751	31000	41000
Track density (TPI)	15875	15875	15875	15900	15875
Maximum linear density (BPI)	27600	27600	25000	20000	20000
Rotational speed (RPM)	530-200	535-200	1800	900	600-330
PERFORMANCE					
Positioner type	Linear, Voice Coil	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	650	500	68	270	650
Within fine band (msec)	N/A	N/A	NS	NS	NS
Fine band capacity (Mbytes)	N/A	N/A	NS	NS	NS
Average rotational delay (msec)	110	110	16.7	33.3	70
Average access time (msec)	760	610	84.7	270	720
Data transfer rate (KBytes/sec)	153.6	153.6	1500	785	452
FIRST CUSTOMER SHIPMENT	2Q87	3/89	8/89	4Q83	1Q87
COMMENTS	External model	External model For PC9800			

MANUFACTURER	NEC	NIKON	NIPPON COLUMBIA	NIPPON COLUMBIA	NIPPON COLUMBIA
DRIVE	N7913	MO-DD120C	DRD-251 DRD-253	DRD-250 DRD-252	DRD-550 DRD-552 DRD-554
DISK/TREND GROUP	12	12	10	10	10
MARKET	Captive	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	12"	12"	120 mm	120 mm	120 mm
Recording medium	Te Alloy	Tb-Fe,Gd-Fe-Co	Aluminum	Aluminum	Aluminum
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Write Once	Rewritable-(MO)	Read Only	Read Only	Read Only
Interface	Prop., SCSI	SCSI	SCSI	Proprietary	SASI, SCSI
Speed control	MCAV	CAV	CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 2,500	F: 2,000	F: 553	F: 553	F: 553
Capacity per track (Bytes)	F: NS	F: 44,444	F: N/A	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	49000	45000	20750	20750	20750
Track density (TPI)	16940	15875	15475	15475	15475
Maximum linear density (BPI)	25000	30600	26008	26008	26008
Rotational speed (RPM)	600	1800	535-194	535-194	535-194
PERFORMANCE					
Positioner type	Crs: Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: Galvonom.	Linear, Voice Coil	Linear, Voice Coil	Linear, Voice Coil
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	200	70	300	300	190
Within fine band (msec)	NS	10	N/A	N/A	N/A
Fine band capacity (Mbytes)	NS	4.4	N/A	N/A	N/A
Average rotational delay (msec)	50	16.7	110	110	110
Average access time (msec)	150	86.7	410	410	300
Data transfer rate (KBytes/sec)	900	1500	153.6	153.6	153.6
FIRST CUSTOMER SHIPMENT	1990	3Q90	3Q86	3Q86	4Q85
COMMENTS			41.3 mm high DRD-253 mounts externally	41.3 mm high DRD-252 mounts externally	DRD-550 mounts in full height slot DRD-554 has audio output

MANUFACTURER	NIPPON COLUMBIA	OPTIMEM	OPTIMEM	OPTIMEM	PENTAX TEKNOLOGIES
DRIVE	DRD-551 DRD-553 DRD-555	1000 1/2 1000 6/7	2400 1/2	4400	LW-S501
DISK/TREND GROUP	10	12	12	12	11
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	120 mm	12"	12"	12"	130 mm
Recording medium	Aluminum	Te Alloy	Te Alloy	Te Alloy	Te Alloy
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Read Only	Write Once	Write Once	Write Once	Write Once
Interface	Proprietary	SCSI, Prop.	SCSI	SCSI	SCSI
Speed control	CLV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 553	F: 1,000	F: 1,200	F: 1,979	F: 326
Capacity per track (Bytes)	F: N/A	F: 25,000	F: 25,000	F: 40,960	F: 17,386
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	40000	46900	48333	18751
Track density (TPI)	15475	14514	16933	16900	15875
Maximum linear density (BPI)	26008	15339	15339	22088	24923
Rotational speed (RPM)	535-194	1122	1122	1122	1800
PERFORMANCE					
Positioner type	Linear, Voice Coil	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	Continuous
Average positioning time (msec)	190	150	150	150	40
Within fine band (msec)	N/A	3	3	NS	NS
Fine band capacity (Mbytes)	N/A	8.3	8.3	NS	NS
Average rotational delay (msec)	110	26.7	26.7	26.7	16.7
Average access time (msec)	300	176.7	176.7	176.7	56.7
Data transfer rate (KBytes/sec)	153.6	625	625	723	530
FIRST CUSTOMER SHIPMENT	4Q85	2Q84	4Q87	3Q89	1989
COMMENTS	External mount except for DRD-551 DRD-555 has audio output		2400 1 includes controller		

MANUFACTURER	PIONEER	PIONEER	PIONEER	PIONEER	RICOH
DRIVE	DRM-600/610	DD-M5001	DD-U5001	DE-S7001 DE-U7001	RO-5030E RO-5030E-II
DISK/TREND GROUP	10	11	11	11	11
MARKET	OEM	OEM	OEM	OEM	OEM, Captive
MEDIA: Nominal disk diameter	120 mm	130 mm	130 mm	130 mm	130 mm
Recording medium	Aluminum	Cyanine Dye	Cyanine Dye	Tb-Fe-Co/Dye	RE-TM(Tb-Fe-Co)
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Read Only	Write Once	Write Once	Wr.Once/Rewrit.	Rewritable-(MO)
Interface	SCSI	Proprietary	SCSI, Prop.	SCSI	SCSI
Speed control	CLV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 3,240	F: 327	F: 327	F: 327	F: 297.6
Capacity per track (Bytes)	F: N/A	F: 16,384	F: 16,384	F: 16,384	F: 15,872
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	19958	19958	19958	18750
Track density (TPI)	15875	15875	15875	15875	18875
Maximum linear density (BPI)	27600	15875	15875	15875	24902
Rotational speed (RPM)	530-220	1800	1800	1800	1800
PERFORMANCE					
Positioner type	Crs: Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: Galvonom.	Crs: Voice Coil Fine: Galvonom.	Crs: Linear, Voice Coil Fine: Galvonom.	Crs: Voice Coil Fine: Voice Coil
Servo type	Continuous	Sampled	Sampled	Sampled	Continuous
Average positioning time (msec)	490	60	60	53.3	50
Within fine band (msec)	NS	NS	NS	27	NS
Fine band capacity (Mbytes)	NS	NS	NS	.819	NS
Average rotational delay (msec)	110	16.7	16.7	16.7	16.7
Average access time (msec)	600	76.7	76.7	70	66.7
Data transfer rate (KBytes/sec)	153.6	742.5	491	1875	625
FIRST CUSTOMER SHIPMENT	4Q89	2Q88	2Q88	6/90	1Q90
COMMENTS	Integral with 6 disk changer. Disk change time is 7 sec. Includes audio output.	41.3 mm high Mechanism only. External SCSI controller board available		DE-S7001 is external	Embedded SCSI controller E-II supports ISO and E format

MANUFACTURER	RICOH	RICOH	RICOH	RICOH	SANYO
DRIVE	RO-5040WL	RO-5041	RO-5042D	RO-5043	ROM-3000U ROM-3000US
DISK/TREND GROUP	11	11	11	11	10
MARKET	Captive, OEM	Captive, OEM	Captive, OEM	Captive, OEM	OEM
MEDIA: Nominal disk diameter	130 mm	130 mm	130 mm	130 mm	120 mm
Recording medium	Cyanine Dye	Cyanine Dye	Dye/Tb-Fe-Co	Cyanine Dye	Aluminum
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Write Once	Write Once	Wr.Once/Rewrit.	Write Once	Read Only
Interface	SCSI	SCSI	SCSI	SCSI	Proprietary
Speed control	CLV	CLV	CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 400	F: 400	F: 393/220	F: 393	F: 540
Capacity per track (Bytes)	F: N/A	F: N/A	F: N/A	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	18750	18750	18750	18750	20750
Track density (TPI)	15900	15900	15900	15900	15875
Maximum linear density (BPI)	32200	32200	32200	32200	27600
Rotational speed (RPM)	668-334	668-334	1196-597*	668-334	530-200
PERFORMANCE					
Positioner type	Crs: Voice Coil Fine: Voice Coil	Crs: Voice Coil Fine: Voice Coil	Crs: Voice Coil Fine: Voice Coil	Crs: Voice Coil Fine: Voice Coil	Crs: Linear Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	108	108	168/180	108	500
Within fine band (msec)	NS	NS	NS	NS	N/A
Fine band capacity (Mbytes)	N/A	N/A	N/A	N/A	N/A
Average rotational delay (msec)	60	60	60/33	60	108
Average access time (msec)	168	168	228/213	168	608
Data transfer rate (KBytes/sec)	312.5	312.5	312.5	312.5	153.6
FIRST CUSTOMER SHIPMENT	4Q86	2Q89	2Q90	2Q90	2/88
COMMENTS	Embedded SCSI controller	41.3 mm high Embedded SCSI controller	Non-ISO standard format *668-334 rpm in write once mode Embedded SCSI controller	41.3 mm high. SCSI controller included Cache controller	S models have audio output External mount

MANUFACTURER	SANYO	SANYO	SANYO	SANYO	SANYO
DRIVE	ROM-3001U ROM-3001US	ROM-4005U	ROM-4006U	ROM-7005	ROM-7006
DISK/TREND GROUP	10	10	10	10	10
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	120 mm	120 mm	120 mm	120 mm	120 mm
Recording medium	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Read Only	Read Only	Read Only	Read Only	Read Only
Interface	SCSI	Proprietary	SCSI	Proprietary	SCSI
Speed control	CLV	CLV	CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 540	F: 540	F: 540	F: 540	F: 540
Capacity per track (Bytes)	F: N/A	F: N/A	F: N/A	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	20750	20750	20750	20750
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	27600	27600	27600	27600
Rotational speed (RPM)	530-200	530-200	530-200	530-200	530-200
PERFORMANCE					
Positioner type	Crs: Linear Fine: Lens Actuator	Crs: Linear Fine: Lens Actuator	Crs: Linear Fine: Lens Actuator	Crs: Linear Fine: Lens Actuator	Crs: Linear Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	500	500	500	500	500
Within fine band (msec)	N/A	N/A	N/A	N/A	N/A
Fine band capacity (Mbytes)	N/A	N/A	N/A	N/A	N/A
Average rotational delay (msec)	108	108	108	108	108
Average access time (msec)	608	608	608	608	608
Data transfer rate (KBytes/sec)	153.6	153.6	153.6	153.6	153.6
FIRST CUSTOMER SHIPMENT	5/88	5/89	8/89	8/89	8/90
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	41.3 mm high Preliminary specification. Optional XA format support	41.3 mm high Preliminary specification. Optional XA format support

MANUFACTURER	SHARP	SHARP	SHINANO KENSHI	SHINANO KENSHI	SONY
DRIVE	JY-500	JY-700	DM-3020 DM-5000	DM-3120	CDU-510
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	RE-TM(Tb-Fe-Co)	RE-TM(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	SCSI	SCSI	SCSI
Speed control	CAV	CAV	CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 190	F: 297.4	F: 600	F: 600	F: 540
Capacity per track (Bytes)	F: 10,133	F: 15,872	F: N/A	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	18750	18751	20750	20750	20750
Track density (TPI)	15875	15875	15475	15475	15875
Maximum linear density (BPI)	NA	33200*	26008	26008	27600
Rotational speed (RPM)	900	2400	530-200	530-200	500-200
PERFORMANCE					
Positioner type	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator	Crs: Lead Screw Fine: Lens Actuator	Linear, Voice Coil
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	150	60	470	700	390
Within fine band (msec)	NS	NS	N/A	N/A	N/A
Fine band capacity (Mbytes)	NS	NS	N/A	N/A	N/A
Average rotational delay (msec)	33.2	12.5	110	110	110
Average access time (msec)	183.2	72.5	570	570	500
Data transfer rate (KBytes/sec)	150	925	153.6	153.6	153.6
FIRST CUSTOMER SHIPMENT	12/87	1/90	2/90	2/90	--
COMMENTS	Media uses glass or plastic substrate External mount	512 byte sectors *2,7 RLL Code	Uses Sony caddy DM-5000 is external mount	Uses Sony caddy Ruggedized mechanism	41.3 mm high

MANUFACTURER	SONY	SONY	SONY	SONY	SONY
DRIVE	CDU-520	CDU-541	CDU-6100 CDU-6101 CDU-6110 CDU-6111	CDU-7101	CDW-W1
DISK/TREND GROUP	10	10	10	10	11
MARKET	OEM	OEM	OEM	Captive	OEM
MEDIA: Nominal disk diameter	120 mm	120 mm	120 mm	120 mm	120 mm
Recording medium	Aluminum	Aluminum	Aluminum	Aluminum	NS
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Read Only	Read Only	Read Only	Read Only	Write Once
Interface	Proprietary	SCSI	SCSI, Prop.	IBM PC XT	Proprietary
Speed control	CLV	CLV	CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 540	F: 540	F: 540	F: 540	F: 540
Capacity per track (Bytes)	F: N/A	F: N/A	F: N/A	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	20750	20750	20750	20750	20750
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	27600	27600	27600	27600
Rotational speed (RPM)	500-200	500-200	500-200	500-200	NS
PERFORMANCE					
Positioner type	Crs: NS Fine: Lens Actuator	Linear, Voice Coil	Linear, Voice Coil	Linear, Voice Coil	Crs: Linear, Voice Coil Fine:
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	390	380	390	390	NS
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	N/A
Average rotational delay (msec)	110	110	110	110	NS
Average access time (msec)	500	490	500	500	NS
Data transfer rate (KBytes/sec)	153.6	150	153.6	153.6	153.6
FIRST CUSTOMER SHIPMENT	--	1989	--	5/88	1990
COMMENTS		Has audio output	External mount. CDU-6110 & 6111 have SCSI intf. CDU-6101 & 6111 have audio output.		Sold only with mastering system Preliminary specification

MANUFACTURER	SONY	SONY	SONY	TOSHIBA	TOSHIBA
DRIVE	SMO-D501 SMO-S501	WDD 3000	WDD-600	XM-2200A	XM-3201B
DISK/TREND GROUP	11	12	12	10	10
MARKET	Captive, OEM	Captive, OEM	Captive, OEM	OEM	OEM
MEDIA: Nominal disk diameter	130 mm	300 mm	300 mm	120 mm	120 mm
Recording medium	Tb-Fe-Co	Se-Sb, Bi-Te	Se-Sb, Bi-Te	Aluminum	Aluminum
Track format	Spiral	Spiral	Spiral	Spiral	Spiral
DRIVE: Operating mode	Rewritable-(MO)	Write Once	Write Once	Read Only	Read Only
Interface	SCSI, ESDI	SCSI	SCSI	SCSI	SCSI
Speed control	CAV	CAV, CLV	CAV/CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 325	F: 1,100/1,600	F: 2,180/3,275	F: 599	F: 599
Capacity per track (Bytes)	F: 17,408	F: 25,600/N/A	F: NS	F: N/A	F: N/A
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	18751	43750	43750	20750	20750
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	24902	24937	49874	27600	27600
Rotational speed (RPM)	2400	720/720-360	720/720-360	530-200	530-200
PERFORMANCE					
Positioner type	Crs: Linear, Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator	Crs: Voice Coil Fine: Lens Actuator	Crs: Linear Motor Fine: Lens Actuator	Crs: Linear Motor Fine: Lens Actuator
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	90	250/620	180/400	250	250
Within fine band (msec)	20	25	20	N/A	N/A
Fine band capacity (Mbytes)	22	1.25	1.25	N/A	N/A
Average rotational delay (msec)	12.5	42/62.5	41/55	110	110
Average access time (msec)	102.5	292/682.5	221/455	350	350
Data transfer rate (KBytes/sec)	680	300	600	153.6	153.6
FIRST CUSTOMER SHIPMENT	2Q88	1Q85	3Q89	2Q89	4Q88
COMMENTS	ISO standard SMO-S501 is external mount		Downward compatible with WDD 3000	Embedded SCSI controller and audio External mount	41.3 mm high Embedded SCSI controller and audio

MANUFACTURER	TOSHIBA	TOSHIBA	TOSHIBA	YAMAHA	
DRIVE	XM-5100A	WM-D070 WM-D071 WM-S070 WM-S071	WM-S500 WM-S500A	YPR-1	
DISK/TREND GROUP	10	11	12	11	
MARKET	OEM	OEM, Captive	OEM, Captive	Captive	
MEDIA: Nominal disk diameter	120 mm	130 mm	12"	120 mm	
Recording medium	Aluminum	Te-C	Te-C	In-Ge	
Track format	Spiral	Spiral	Spiral	Spiral	
DRIVE: Operating mode	Read Only	Write Once	Write Once	Write Once	
Interface	SCSI	SCSI, Prop.	SCSI, Prop.	Proprietary	
Speed control	CLV	MCAV, CAV	MCAV	CLV	
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 599	F: 450/300	F: 2,500	F: 540	
Capacity per track (Bytes)	F: N/A	F: 17,000(CAV)	F: 36,000 avg.	F: N/A	
Data surfaces per spindle	1	1	1	1	
Tracks per surface	20750	18750	45000	20750	
Track density (TPI)	15875	15875	15875	15875	
Maximum linear density (BPI)	27600	24900	22400	27600	
Rotational speed (RPM)	530-200	900-1800	617	530-200	
PERFORMANCE					
Positioner type	Crs: Linear Motor 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	
Average positioning time (msec)	280	90	160	NS	
Within fine band (msec)	N/A	.5	2	N/A	
Fine band capacity (Mbytes)	N/A	50 (tracks)	60 (tracks)	N/A	
Average rotational delay (msec)	110	16.7 (CAV)	48.8	110	
Average access time (msec)	380	106.7 (CAV)	208.8	NS	
Data transfer rate (KBytes/sec)	153.6	528 (CAV)	500-1000	153.6	
FIRST CUSTOMER SHIPMENT	2Q89	1Q89	4Q88	1989	
COMMENTS	External mount Embedded SCSI controller and audio	WM-D071 excludes SCSI controller WM-S series is subsystem	WM-S500A includes SCSI controller	Sold only as part of PDS system	

1990 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 only 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 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 elevator, a two axis X-Y elevator, a rotary elevator or a carousel.

Robot motions: In a library, each movement of the robot mechanism during a full media exchange operation counts as one motion, except that simultaneous motions (e.g. flip while translate) count as one motion.

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.

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

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

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

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

1990 DISK/TREND optical disk product groups

For the 1990 report, products are classified in six groups.

Optical drives:

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

Optical libraries:

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

See the previous specification section for optical disk drive data.

MANUFACTURER	ACCESS	AISIN SEIKI	CYGNET	CYGNET	CYGNET
LIBRARY	ODSR	JC2000	5250/W	1800/A	1800/H
DISK/TREND GROUP	51	51	51	53	53
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	300 mm	130 mm	130 mm	300 mm	300 mm
Nominal disk capacity (MB)	2,000	600-650	650	2,000	2,600
Cartridge type	LMSI	ANSI/ISO	ANSI/ISO, Other	ATG	Proprietary
DRIVE: Type	Write Once	Various	Write Once	Write Once	Write Once
Drive models	LMSI LD 1250E	Various	LMS LD510	ATG GD 1002	Hitachi OD301A1
LIBRARY MECHANISM					
Minimum disk capacity (units)	16*	20	25	61	61
Maximum disk capacity (units)	20	20	25	141	141
Number of drives: Maximum	2	2	2	5	5
Interface: Library	RS232C	SCSI	RS232C, SCSI	RS232C, SCSI	RS232C, SCSI
Drive	SCSI	Drive dependent	SCSI	SCSI	SCSI
Library capacity (Gbytes) (with maximum disk capacity)	40	12-13	16.25	282	366.6
Import/export module (disks)	1	1	1	1	1
PERFORMANCE					
Positioner type	Elevator	Elevator	Rotary, with sliding disk tray	Elevator	Y Axis Elevator
Robot motions for full exchange	9	8	4	8	8
Average media exchange time (sec)	9	5	4	18	8
Spin-up + drive ready time (sec)	3	Drive dependent	5.9	NS	4.5
Spin-down time (sec)	3	Drive dependent	1.9	NS	3.5
Average drive access time (msec)	212.5	Drive dependent	75	227	250
Non-queued access time (sec)	12	Drive dependent	8	15	10
Drive data transfer rate (KB/s)	1500	Drive dependent	1250	3830	1200
Number of drive data paths: Max.	2	1 or 2	2	5	5 (1 per drive)
FIRST CUSTOMER SHIPMENT	--	2Q88	4Q88	1987	1987
COMMENTS	*With 2 drives				

MANUFACTURER	CYGNET	CYGNET	CYGNET	CYGNET	DOCUMENT IMAGING SYSTEMS
LIBRARY	1800/L	1800/O	1800/S	1800/T	600-75-6-1 DocuStore
DISK/TREND GROUP	53	53	53	53	52
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	300 mm	300 mm	300 mm	300 mm	130 mm
Nominal disk capacity (MB)	2,000	2,400	3,200	5,000	650
Cartridge type	LMSI LD1250E	Optimem	Sony	Toshiba WM7500	ANSI/ISO
DRIVE: Type	Write Once	Write Once	Write Once	Write Once	Wr.Once,Rewrit.
Drive models	LMSI	Optimem 2400	Sony WDD 3000	Toshiba WMS500A	Various
LIBRARY MECHANISM					
Minimum disk capacity (units)	42	61	61	53	15 (6 drives)
Maximum disk capacity (units)	95	141	141	124	65
Number of drives: Maximum	5	5	5	5	6
Interface: Library Drive	RS232C, SCSI SCSI	RS232C, SCSI SCSI	RS232C, SCSI SCSI	RS232C, SCSI SCSI	RS232C SCSI
Library capacity (Gbytes) (with maximum disk capacity)	190.0	338.4	451.2	620	42.3
Import/export module (disks)	1	1	1	1	1
PERFORMANCE					
Positioner type	Y Axis Elevator	Y Axis Elevator	Elevator	Elevator	X-Y Elevator
Robot motions for full exchange	8	8	8	8	7
Average media exchange time (sec)	8.7	8.7	8	8.7	5
Spin-up + drive ready time (sec)	4	5	3.8	5 max.	Drive dependent
Spin-down time (sec)	4	5	3.8	5 max.	Drive dependent
Average drive access time (msec)	212.5	177	190	160	Drive dependent
Non-queued access time (sec)	10	11	9	11	4
Drive data transfer rate (KB/s)	1200	1200	1100	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)	Drive dependent
FIRST CUSTOMER SHIPMENT	1987	1987	2Q89	1Q90	6/90
COMMENTS		Optimem 1000 drive also available			Exact system configuration per customer request

MANUFACTURER	DOCUMENT IMAGING SYSTEMS	DOCUMENT IMAGING SYSTEMS	DOCUMENT IMAGING SYSTEMS	DSM	DSM
LIBRARY	675-90-4-2	900-2310-110-2	900-960-48-24	20/27/30	28/38
DISK/TREND GROUP	53	53	53	51	51
MARKET	OEM	OEM	OEM	OEM, Captive	OEM, Captive
MEDIA: Nominal disk diameter	130 mm	130 mm	130 mm	12"	12"
Nominal disk capacity (MB)	650	650	650	2,000	Drive dependent
Cartridge type	ANSI/ISO	ANSI/ISO	ANSI/ISO	Proprietary	Proprietary
DRIVE: Type	Wr.Once,Rewrit.	Wr.Once,Rewrit.	Wr.Once,Rewrit.	Write Once	Write Once
Drive models	Various	Various	Any SCSI, ANSI/ ISO w/sys. cont load/unload	LMSI 1200	ATG Gigadisc Optimem Sony, Toshiba
LIBRARY MECHANISM					
Minimum disk capacity (units)	50 (4 drives)	1210(110 drive)	480 (48 drives)	20	28
Maximum disk capacity (units)	80	2300	950	30 (2 drives)	28
Number of drives: Maximum	4	110	48	2	2
Interface: Library Drive	RS232C SCSI	RS232C SCSI	RS232C SCSI	RS232C SCSI	RS232C SCSI
Library capacity (Gbytes) (with maximum disk capacity)	52	1495	617.5	60	Drive dependent
Import/export module (disks)	1	1	1	1	1
PERFORMANCE					
Positioner type	X Axis Elevator (2)	X-Y Elevator	X Axis Elevator (24)	Elevator	Elevator
Robot motions for full exchange	7	7	7	8	8
Average media exchange time (sec)	3	7	4	6	8
Spin-up + drive ready time (sec)	Drive dependent	Drive dependent	Drive dependent	Drive dependent	Drive dependent
Spin-down time (sec)	Drive dependent	Drive dependent	Drive dependent	Drive dependent	Drive dependent
Average drive access time (msec)	Drive dependent	Drive dependent	Drive dependent	Drive dependent	Drive dependent
Non-queued access time (sec)	2.5 + spin-up	6 + spin-up	3.5 + spin-up	6 + spin-up	8 + spin-up
Drive data transfer rate (KB/s)	Drive dependent	Drive dependent	Drive dependent	Drive dependent	Drive dependent
Number of drive data paths: Max.	Drive dependent	Drive dependent	Drive dependent	2	2
FIRST CUSTOMER SHIPMENT	9/90	6/90	9/90	4/90	11/89
COMMENTS	Exact system configuration per customer request	Exact system configuration per customer request	Exact system configuration per customer request	Model 27 has 1 drive, 27 disks	Model 38 has 1 drive, 38 disks

MANUFACTURER	DSM	DSM	DSM	DSM	EASTMAN KODAK
LIBRARY	48	5100	300	5500	560
DISK/TREND GROUP	52	52	53	54	52
MARKET	OEM, Captive	OEM, Captive	OEM, Captive	OEM, Captive	Captive, OEM
MEDIA: Nominal disk diameter	12"	5.25"	12"	5.25"	130 mm
Nominal disk capacity (MB)	Drive dependent	Drive dependent	Drive dependent	Drive dependent	654
Cartridge type	Proprietary	Proprietary	Proprietary	Proprietary	Various
DRIVE: Type	Write Once	Wr.Once,Rewrit.	Write Once	Wr.Once,Rewrit.	Wr.Once,Rewrit.
Drive models	ATG Gigadisc Optimem	Various	ATG Gigadisc Optimem	Various	Various
LIBRARY MECHANISM					
Minimum disk capacity (units)	48	24 (4 drives)	104	86 (8 drives)	37
Maximum disk capacity (units)	48	40 (2 drives)	329	134 (2 drives)	61
Number of drives: Maximum	2	4	10	8	5
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	39.8
Import/export module (disks)	1	1	4 or 5	1	1
PERFORMANCE					
Positioner type	Elevator	X-Y Elevator	Elevator	X-Y Elevator	Elevator
Robot motions for full exchange	8	8	8	8	8
Average media exchange time (sec)	8	6	12	7	3.7
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)	8 + spin-up	Drive dependent	8 + spin-up	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	2 to 4	2	2 to 8	5 (1 per drive)
FIRST CUSTOMER SHIPMENT	11/89	10/89	9/87	--	1Q90
COMMENTS		Subtract 8 disks for each drive for >2 drives installed		Subtract 8 disks for each drive for >2 drives installed	Positioner can hold 2 disks simultaneously

MANUFACTURER	EASTMAN KODAK	FILENET	FILENET	FILENET	FILENET
LIBRARY	6800 ADL	OSAR 64 Model 0100	OSAR 200 Model 4321	OSAR 288 Model 0131	OSAR 64 GT OSAR 79 GT Model 0120
DISK/TREND GROUP	53	52	53	53	53
MARKET	Captive, OEM	OEM	OEM	Captive, OEM	OEM
MEDIA: Nominal disk diameter	14"	300 mm	300 mm	300 mm	300 mm
Nominal disk capacity (MB)	6,800/8,200	2,000	2,000	2,600	2,000
Cartridge type	Proprietary	LMSI	LMSI	Hitachi	LMSI
DRIVE: Type	Write Once	Write Once	Write Once	Write Once	Write Once
Drive models	Kodak 6800	LMSI LD 1250	LMSI LD 1250	Hitachi OD 301	LMSI LD 1250
LIBRARY MECHANISM					
Minimum disk capacity (units)	50	64	204	288	64
Maximum disk capacity (units)	150	64	204	288	79
Number of drives: Maximum	3	4	4	4	4
Interface: Library Drive	RS232C SCSI	RS232C, RS422 SCSI, ISI	RS232C, RS422 SCSI, ISI	RS232C, RS422 SCSI, GPIB	RS232C, RS422 SCSI, ISI
Library capacity (Gbytes) (with maximum disk capacity)	1020/1230	128	408	749	128
Import/export module (disks)	1	1	1	1	1
PERFORMANCE					
Positioner type	Elevator	X-Y Axis Elevator	X-Y Axis Elevator	X-Y Axis Elevator	X-Y Axis Elevator
Robot motions for full exchange	8	NS	NS	7	NS
Average media exchange time (sec)	6.5	3.5	NS	NS	3.5
Spin-up + drive ready time (sec)	2.5	4.0	4.0	4.5	4.0
Spin-down time (sec)	1.5	4.0	4.0	3.5	4.0
Average drive access time (msec)	570	212.5	212.5	250	212.5
Non-queued access time (sec)	7.0	9.5	10.7	NS	7.2
Drive data transfer rate (KB/s)	1000	262	262	328	262
Number of drive data paths: Max.	3 (1 per drive)	4	4	2	4
FIRST CUSTOMER SHIPMENT	3Q88	1/87	7/85	--	--
COMMENTS	Expandable in modules of 50 disks	Elevator can hold 2 disks	Elevator can hold 2 disks	Elevator can hold 2 disks	Elevator can hold 2 disks Maximum capacity with 2 drives

MANUFACTURER	FILENET	FILENET	FUJITSU	HEWLETT-PACKARD	HITACHI
LIBRARY	OSAR 90 OSAR 111 Model 0130	OSAR 90 GT OSAR 111 GT Model 0110	F6442-B2	C1710A 20GB/A	OL101-11 OL101-21
DISK/TREND GROUP	53	53	51	51	51
MARKET	Captive, OEM	Captive, OEM	Captive	Captive, OEM	Captive, OEM
MEDIA: Nominal disk diameter	300 mm	300 mm	300 mm	130 mm	130 mm
Nominal disk capacity (MB)	2,600	2,600	2,752	650	600
Cartridge type	Hitachi	Hitachi	Proprietary	ANSI/ISO	ANSI/ISO
DRIVE: Type	Write Once	Write Once	Write Once	Rewritable	Write Once
Drive models	Hitachi OD 301	Hitachi OD 301	Fujitsu 6441	Sony SMO-D501	Hitachi OD101
LIBRARY MECHANISM					
Minimum disk capacity (units)	90	90	32	32	24
Maximum disk capacity (units)	111	111	32	32	24
Number of drives: Maximum	4	4	2	2	2
Interface: Library Drive	RS232C, RS422 SCSI, GPIB	RS232C, RS422 SCSI, GPIB	Mod. 3350	SCSI-2 SCSI	SCSI SCSI
Library capacity (Gbytes) (with maximum disk capacity)	289	289	88.1	20.8	14.4
Import/export module (disks)	1	1	1	1	1
PERFORMANCE					
Positioner type	X-Y Axis Elevator	X-Y Axis Elevator	X-Y Axis Elevator	Elevator	Elevator
Robot motions for full exchange	NS	NS	8	7	10
Average media exchange time (sec)	NS	3.7	15	7	7.7
Spin-up + drive ready time (sec)	4.5	4.5	4.5	5.4	3.7
Spin-down time (sec)	3.5	3.5	5	3.6	2.7
Average drive access time (msec)	250	250	216.7	95	110
Non-queued access time (sec)	10.2	7.7	13.4	16.0	7.8
Drive data transfer rate (KB/s)	328	328	783	1200	1500
Number of drive data paths: Max.	2	2	2	2	1
FIRST CUSTOMER SHIPMENT	--	10/89	1Q87	4Q89	1987
COMMENTS	Elevator can hold 2 disks Maximum capacity with 2 drives	Elevator can hold 2 disks Maximum capacity with 2 drives	Sold only in Japan		Differential interface: -11 has single ended interface

MANUFACTURER	HITACHI	HITACHI	HITACHI	HITACHI	HITACHI
LIBRARY	OL112-11 OL112-21	OL301-11 OL301-21	OL301-12 OL301-22	OL101-12 OL101-22	OL112-12 OL112-22
DISK/TREND GROUP	51	51	51	52	52
MARKET	Captive, OEM	Captive, OEM	Captive, OEM	Captive, OEM	Captive, OEM
MEDIA: Nominal disk diameter	130 mm	300 mm	300 mm	130 mm	130 mm
Nominal disk capacity (MB)	644	2,620	2,620	600	644
Cartridge type	ANSI/ISO	Proprietary	Proprietary	ANSI/ISO	ANSI/ISO
DRIVE: Type	Rewritable-(MO)	Write Once	Write Once	Write Once	Rewritable-(MO)
Drive models	Hitachi OD112-1	Hitachi OD301A1	Hitachi OD301A1	Hitachi OD101	Hitachi OD112-1
LIBRARY MECHANISM					
Minimum disk capacity (units)	24	16	32	48	48
Maximum disk capacity (units)	24	16	32	48	48
Number of drives: Maximum	2	2	2	4	4
Interface: Library Drive	SCSI SCSI	SCSI SCSI	SCSI SCSI	SCSI SCSI	SCSI SCSI
Library capacity (Gbytes) (with maximum disk capacity)	15	42	83.9	28.8	30
Import/export module (disks)	1	1	1	1	1
PERFORMANCE					
Positioner type	Elevator	Elevator	Elevator	Elevator	Elevator
Robot motions for full exchange	10	10	10	10	10
Average media exchange time (sec)	7.7	8.7	8.7	7.7	7.7
Spin-up + drive ready time (sec)	3.7	4.3	4.3	3.7	3.7
Spin-down time (sec)	2.7	3.5	3.5	2.7	2.7
Average drive access time (msec)	70	250	250	110	70
Non-queued access time (sec)	7.8	8.8	8.8	7.8	7.8
Drive data transfer rate (KB/s)	1500	1500	1500	1500	1500
Number of drive data paths: Max.	1	1	1	2	1
FIRST CUSTOMER SHIPMENT	1989	1985	1985	1987	1989
COMMENTS	Differential interface: -11 has single ended interface	Differential interface: -11 has single ended interface IEEE-488 interface available	Differential interface: -12 has single ended interface IEEE-488 interface available	Differential interface: -12 has single ended interface	Differental interface: -12 has single ended interface

MANUFACTURER	INTERNATIONAL DATA ENGINEERING	KUBIK ENTERPRISES	KUBIK ENTERPRISES	LASER MAGNETIC STORAGE	MATSUSHITA ELECTRIC INDUSTRIAL
LIBRARY	Personal Library	DDC-240	MULTI-SERVER	LF 4500 RapidChanger	LF-J5000A LF-J5080
DISK/TREND GROUP	51	50	50	51	52
MARKET	OEM	OEM	OEM	OEM	Captive, OEM
MEDIA: Nominal disk diameter	130 mm	120 mm	120 mm	12"	130 mm
Nominal disk capacity (MB)	654	550	550	5,600	940/1,000*
Cartridge type	ANSI/ISO	N/A	N/A	LMSI	ANSI/ISO
DRIVE: Type	Wr.Once,Rewrit.	Read Only	Read Only	Write Once	Wr.Once,Rewrit.
Drive models	Various	LMSI, Sony	LMSI, Sony	LMSI LD 4100	MEI LF-5012 LF-7010
LIBRARY MECHANISM					
Minimum disk capacity (units)	10	240	240	5	50
Maximum disk capacity (units)	10*	240	240	5	50
Number of drives: Maximum	1	1	5	1	2
Interface: Library Drive	SCSI-2 SCSI	RS232C SCSI	RS232C SCSI	SCSI-2 SCSI-2	SCSI-2 SCSI-2
Library capacity (Gbytes) (with maximum disk capacity)	6.5	132	132	28	47/50*
Import/export module (disks)	1	1	1	5	1
PERFORMANCE					
Positioner type	Elevator	Rotary	Rotary	Moving Magazine	Elevator
Robot motions for full exchange	10	4	4	3	10
Average media exchange time (sec)	6	7	7	3	10
Spin-up + drive ready time (sec)	Drive dependent	1	1	2.5	5
Spin-down time (sec)	Drive dependent	1	1	1.5	5
Average drive access time (msec)	Drive dependent	Drive dependent	Drive dependent	130*	115
Non-queued access time (sec)	Drive dependent	NS	NS	5.5	10
Drive data transfer rate (KB/s)	Drive dependent	153.6	153.6	1800**	1500
Number of drive data paths: Max.	1	1	5	1	1
FIRST CUSTOMER SHIPMENT	1/90	1990	--	2Q90	1/90
COMMENTS	*11 with Panasonic drive		Preliminary specification	*Includes command overhead **Asynchronous mode	*With rewritable drive

MANUFACTURER	MATSUSHITA GRAPHIC COMMUNICATION	MATSUSHITA GRAPHIC COMMUNICATION	MITSUBISHI ELECTRIC CORPORATION	MITSUBISHI ELECTRIC CORPORATION	MITSUBISHI ELECTRIC CORPORATION
LIBRARY	LD-30 TQ-3050	LD-24 LD-48	MW-5G2-Z	MW-5G2-A	MW-5G2-B
DISK/TREND GROUP	52	52	51	52	53
MARKET	Captive, OEM	Captive	Captive, OEM	Captive, OEM	Captive, OEM
MEDIA: Nominal disk diameter	210 mm	130 mm	130 mm	130 mm	130 mm
Nominal disk capacity (MB)	1,200	600	600	600	600
Cartridge type	Proprietary	Proprietary	Proprietary	Proprietary	Proprietary
DRIVE: Type	Write Once	Write Once	Write Once	Write Once	Write Once
Drive models	MCGS LD-10	DU-05	Mitsub. MW-5D1	Mitsub. MW-5D1	Mitsub. MW-5D1
LIBRARY MECHANISM					
Minimum disk capacity (units)	30	24	24	54	150
Maximum disk capacity (units)	30	48	24	54	150
Number of drives: Maximum	2	4	2	2	2
Interface: Library Drive	Proprietary Proprietary	SCSI SCSI	SCSI SCSI	SCSI SCSI	SCSI SCSI
Library capacity (Gbytes) (with maximum disk capacity)	36	14.4	14	32	90
Import/export module (disks)	1	1	1	1	1
PERFORMANCE					
Positioner type	X-Y Elevator	X-Y Elevator	X-Y Axis Elevator	X-Y Axis Elevator	X-Y Axis Elevator
Robot motions for full exchange	NS	NS	2	2	2
Average media exchange time (sec)	12	12	5.5	7.5	9.5
Spin-up + drive ready time (sec)	2	2	3	3	3
Spin-down time (sec)	2	2	2.5	2.5	2.5
Average drive access time (msec)	220	110	85	85	85
Non-queued access time (sec)	7	7	6	7	8
Drive data transfer rate (KB/s)	675	690	480	480	480
Number of drive data paths: Max.	1	1	1	1	1
FIRST CUSTOMER SHIPMENT	1984	1989	1Q91	3Q90	3Q90
COMMENTS					

MANUFACTURER	MITSUBISHI ELECTRIC CORPORATION	NEC	NEC	NEC	NEXT TECHNOLOGY
LIBRARY	MW-5G2-C	N7923	N7921	N7925	Voyager
DISK/TREND GROUP	53	51	52	52	50
MARKET	Captive, OEM	Captive	Captive	Captive	OEM
MEDIA: Nominal disk diameter	130 mm	300 mm	300 mm	130 mm	120 mm
Nominal disk capacity (MB)	600	5,000	2,000	610	550
Cartridge type	Proprietary	Proprietary	Proprietary	ANSI/ISO	N/A
DRIVE: Type	Write Once	Write Once	Write Once	Rewritable-(MO)	Read Only
Drive models	Mitsub. MW-5D1	NEC N7913	NEC N7911	NEC N7915	Sony 541 or user selected
LIBRARY MECHANISM					
Minimum disk capacity (units)	134	36	48	46	90
Maximum disk capacity (units)	134	36	48	67	270
Number of drives: Maximum	4	2	2	4	8
Interface: Library	SCSI	NEC	NEC	SCSI	RS232C
Drive	SCSI	Proprietary	Proprietary	SCSI	SCSI
Library capacity (Gbytes) (with maximum disk capacity)	80	180	96	40	148.5
Import/export module (disks)	1	1	1	1	1
PERFORMANCE					
Positioner type	X-Y Axis Elevator	Elevator	Elevator	Elevator	X-Y Elevator
Robot motions for full exchange	2	10	10	10	7
Average media exchange time (sec)	9.5	30	30	10	5
Spin-up + drive ready time (sec)	3	8	8	3.5	Drive dependent
Spin-down time (sec)	2.5	8	8	3.5	Drive dependent
Average drive access time (msec)	85	150	170	84.7	Drive dependent
Non-queued access time (sec)	8	23	23	9	Drive dependent
Drive data transfer rate (KB/s)	480	900	785	1500	153.6
Number of drive data paths: Max.	1	1	1	1	8 (1 per drive)
FIRST CUSTOMER SHIPMENT	3Q90	1989	1985	1990	3Q89
COMMENTS					

MANUFACTURER	NKK	NKK	RICOH	RICOH	SONY
LIBRARY	N-556E	N-556W	RJ5160	RJ5330E	WDA 3000
DISK/TREND GROUP	52	52	51	52	52
MARKET	OEM	OEM	OEM	OEM	Captive, OEM
MEDIA: Nominal disk diameter	130 mm	130 mm	130 mm	130 mm	300 mm
Nominal disk capacity (MB)	654	900	800	646	3,200
Cartridge type	ANSI/ISO	ANSI/ISO	Proprietary	ANSI/ISO	Proprietary
DRIVE: Type	Rewritable	Write Once	Write Once	Rewritable	Write Once
Drive models	Sony SMO-D501	Toshiba DO70	Ricoh RO-5040WL	Ricoh RO-5030EII	Sony WDD 3000
LIBRARY MECHANISM					
Minimum disk capacity (units)	56	56	20	56	50
Maximum disk capacity (units)	56	56	20	56	50
Number of drives: Maximum	2	2	2	2	2
Interface: Library	SCSI	RS232C, SCSI	SCSI	SCSI	SCSI
Drive	SCSI	SCSI	SCSI	SCSI	SCSI
Library capacity (Gbytes) (with maximum disk capacity)	36	50	16	36.2	160
Import/export module (disks)	16	16	1	16	1
PERFORMANCE					
Positioner type	Elevator	Elevator	Elevator	Elevator	Elevator
Robot motions for full exchange	8	8	8	8	NS
Average media exchange time (sec)	5	5	7	5	7
Spin-up + drive ready time (sec)	7	7	.5	9.0	2.5
Spin-down time (sec)	4	4	.5	5.0	2.5
Average drive access time (msec)	100	100	168	67	500
Non-queued access time (sec)	9.5	9.5	8.2	11.5	4
Drive data transfer rate (KB/s)	1200	1200	1400	1400	300
Number of drive data paths: Max.	1/2	1/2	1/2	1/2	1
FIRST CUSTOMER SHIPMENT	12/89	1/90	2Q88	4Q89	1/85
COMMENTS			Can attach 7 units to 1 SCSI port		Can attach 7 units to 1 SCSI port

MANUFACTURER	SONY				
LIBRARY	WDA-610				
DISK/TREND GROUP	52				
MARKET	Captive, OEM				
MEDIA: Nominal disk diameter	300 mm				
Nominal disk capacity (MB)	6,550				
Cartridge type	Proprietary				
DRIVE: Type	Write Once				
Drive models	WDD 600				
LIBRARY MECHANISM					
Minimum disk capacity (units)	50				
Maximum disk capacity (units)	50				
Number of drives: Maximum	2				
Interface: Library	SCSI				
Drive	SCSI				
Library capacity (Gbytes) (with maximum disk capacity)	327.5				
Import/export module (disks)	1				
PERFORMANCE					
Positioner type	Elevator				
Robot motions for full exchange	NS				
Average media exchange time (sec)	5				
Spin-up + drive ready time (sec)	2.5				
Spin-down time (sec)	2.5				
Average drive access time (msec)	400				
Non-queued access time (sec)	3.0				
Drive data transfer rate (KB/s)	600				
Number of drive data paths: Max.	1				
FIRST CUSTOMER SHIPMENT	9/89				
COMMENTS	Can attach 7 units to 1 SCSI port				

MANUFACTURER PROFILES

1990 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 1989, this figure is reported explicitly only for firms with major 1989 sales. "1989 total net sales" covers the fiscal year ending in 1989 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, 1989, unless otherwise noted.

Manufacturers located in the United States that have majority owners headquartered in another country are grouped in the geographical area covering the owner's home office.

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 1989 is used, as cited by the Federal Reserve Bulletin and rounded to 3 significant figures.

Country	Currency	Currency units/U.S. dollar
France	Franc	6.38
Japan	Yen	138.0
Netherlands	Guilder	2.12
West Germany	Deutschmark	1.88

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

U.S. Manufacturers

ACCESS CORPORATION
1101 Glendale-Milford Road
Cincinnati, Ohio 45215

Access is a manufacturer of digital and micrographic image management and distribution systems. The company was founded in 1963. As an adjunct to its systems business, Access, in conjunction with Laser Magnetic Storage, designed a 12" optical library unit which it supplied exclusively to LMSI for a few years. Access now supplies the library to its own end users and on an OEM basis to system vendors. While not the largest producer of optical libraries, the firm ranks in the top ten in terms of numbers of units shipped annually. The Access libraries incorporate drives from LMSI.

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

BOSCO, as it is familiarly known, has developed a 5.25", half-high write-once drive using flexible media which it is now offering to license to other companies. Target capacity is 1.3 gigabyte on two sides of the cartridge. Average access time will be in the 40-50 millisecond range. If placed into production soon, this will be the first 5.25" optical drive to have dual optical heads and independent actuators. Media is being supplied by ICI, which is an investor in BOSCO. A prototype drive and media were shown at the 1989 AIIM show and at subsequent events, but BOSCO is not currently planning to produce the drive itself and currently offers licenses on its technology.

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

Cherokee was founded in March, 1984. Key founders include managers previously with Storage Technology Corporation and Sperry Corporation. The firm has designed a 300 megabyte ruggedized 5.25" write-once drive that it supplies to customers in the defense and mineral resources industries: Shipments began in 1988. The first major customer for the Cherokee product 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 have brought Lockheed's share of ownership to 36%. Cherokee shipped a modest number of drives in the first half of 1988, and 1989 shipments remained small. Increasing government procurement activity is expected by Cherokee to gradually improve shipments. A non-ruggedized version of the drive became available in late 1989, which Cherokee also expects to build shipment volume.

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.

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

DIGITAL EQUIPMENT CORPORATION
146 Main Street
Maynard, MA 01754

1989 total net sales: $12,741,956,000 (FY ending 7/01/89 Net income: $1,072,610,000

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

DOCUMENT IMAGING SYSTEMS CORPORATION
543 Weddell Drive
Sunnyvale, CA 94089

DISC was founded in 1986 specifically to develop and manufacture customized optical libraries. The firm's products are built around a modular concept of configuring a system with an appropriate number of 5.25" optical drives, disk storage slots and picker mechanisms to meet customer performance needs. Tradeoffs may be made between the number of drives (up to 110), pickers (up to 12) and disk storage slots (up to 2290). The first commercial showing of the systems was at the 1990 AIIM conference.

EASTMAN KODAK COMPANY
343 State Street
Rochester, NY 14650

1989 total net sales: $18,398,000,000 Net income: $529,000,000

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

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

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

FILENET CORPORATION
3565 Harbor Boulevard
Costa Mesa, CA 92626

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 include IBM, N. V. Philips, Eastman Kodak and others. International system sales are handled by distributors, most notably Olivetti.

Production of optical libraries began in 1985. The Filenet product line is built around 12" drives, and offers some of the larger storage capacities available in a non-customized optical library. Up to 288 disks can be stored in the largest Filenet system. Filenet has a major share of the 12" optical library market, with claimed cumulative shipments of over 320 systems, mostly 12", as of mid-1990. Filenet also sells 5.25" libraries to its end user customers, but these are purchased from other sources.

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

1989 total net sales: $11,899,000,000 (FY ending 10/31/89) Net income: $829,000,000

Hewlett-Packard does not currently produce optical disk drives, but has an active technology evaluation program. The Greeley, Colorado facility began producing optical libraries in 1989 and also is the site for work on small diameter magneto-optic drives using technology and staff acquired from Optotech. Some related work on optical and rigid drive technology is being done at HP Laboratories.

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 by commencing distribution of UNIX support information on CD-ROM. At the 1989 Spring Comdex show, HP 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. This is the end result of a development effort using Sony rewritable technology that began in 1985.

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

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

INTERNATIONAL BUSINESS MACHINES CORPORATION
Route 22
Armonk, NY 10504

1989 total net sales: $62,710,000,000 Net income: $3,758,000,000

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

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

In April, 1987, IBM announced the model 3363 write-once drive for use with its personal computers. The mechanism for this drive was obtained from Matsushita Electric; IBM supplied the electronics, software, and final assembly and test. The product has been unsuccessful, and shipments of mechanisms to IBM ceased in 1988. While IBM has not revealed its future product plans, it is widely believed in the industry that IBM is working on 3.5" and 5.25" erasable optical technology for use with workstations, desktop computers, and mass storage subsystems. As a result of a mid-1988 reorganization, IBM's future optical products may be made in a location other than Tucson, but development staff and laboratories remained in Tucson. Development of 3.5" drives is also underway at IBM's facility in Fujisawa, Japan.

IBM has been purchasing 12" optical drives and library modules for integration into subsystems since 1988, and now offers optical library systems as attachments to large and mid-range systems used in image management applications.

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 product is a tabletop library offering modest performance and capable of holding ten 5.25" cartridges and a single 5.25" drive. The library is being remarketed by subsystem producers and some optical drive producers. Because of the library's very low OEM price, IDE may be able to sell more units in 1990 than any other library producer and establish a market niche as an accessory device to workstations.

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

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

LASERDRIVE, LTD.
1101 Space Park Drive
Santa Clara, CA 95054

Laserdrive was founded in 1984 with financial support from Acorn Computer and BSR International. Olivetti also acquired about 25% of ownership at that time. The firm's first product, a 5.25" write-once drive with 400 megabyte capacity, was formally introduced in 1987. Laserdrive invested substantially in software that permits the optical drive to appear to the

using system as a standard rigid drive and developed special hardware for on-the-fly ECC. Production of the drive mechanism is done in Japan by Sansui, but the electronics and final assembly is done in the U.S. Media is provided by Daicel Chemical Industries or Sumitomo Chemical.

Laserdrive obtained considerable financial and management support from Olivetti, which purchased 80% of Acorn Computer in mid-1985 and as a result, obtained an 80% position in Laserdrive. In the second quarter of 1989, Eastman Kodak purchased half of Olivetti's interest and transferred its 3.5" magneto-optic drive development program to Laserdrive.

In 1990, Laserdrive and ISI merged to become Literal Corporation, resulting in a transfer of operations to Colorado Springs.

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. Operations were transferred to Colorado Springs by mid-1990. Olivetti and Eastman Kodak each own about 26% of Literal, and Kawasaki 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 absorbing Laserdrive and ramping up production the ISI line of newer optical drives and developing device drivers for various operating systems. Development on a small diameter magneto-optic drive is proceeding based upon the Verbatim technology obtained from Laserdrive.

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

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

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

1989 total net sales: $27,775,000
(FY ending 3/31/90)

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

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

In May, 1988, Maxtor announced a 5.25" magneto-optic rewritable drive offering 35 millisecond average seek time, the industry's fastest. 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.

Maxoptix leverages its optical program through Maxtor's sub-system subsidiary Storage Dimensions, which serves the personal computer and system integrator markets. U.S. Design, a firm specializing in storage sub-systems for the DEC market was also acquired by Maxtor and subsequently merged into Storage Dimensions. Storage Dimensions accounts for a substantial fraction of Maxtor's sales of write-once optical disk drives and is expected to be equally successful with Maxoptix products.

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

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

Mountain Optech, founded in 1985, specializes in optical disk drives for ruggedized and military applications. Its first product was a modified version of the Optotech 5.25" write-once drive, delivered in 1986. Mechanisms for the Optotech-type drives are obtained from Shugart Associates, which acquired the product line from Optotech in 1988. 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 will be delivered in late 1990. An upgraded ISO-compatible version is planned for 1991 production, as is a ruggedized version of a currently available 5.25" magneto-optic rewritable drive.

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

1989 total net sales: $181,400,000 Net income: $15,300,000

Optimem began in 1980 as a development program managed by Shugart Associates based on Xerox technology, and functioned as the Optimem Division of Shugart until Shugart ceased operations, at which time it became a Xerox subsidiary company. In mid-1986, control of Optimem was acquired from Xerox by Cipher Data Products. Xerox retained a 10% minority ownership position. 3M Company subsequently acquired a small ownership position.

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

Optimem was hurt in 1987 by the departure of most of its senior management, and but the firm weathered the changes and may benefit from the acquisition of Cipher by Archive in 1990.

OPTOTECH, INC.
770 Wooten Road
Colorado Springs, CO 80915

Founded in 1984, Optotech was one of the early suppliers of 5.25", 400 megabyte write-once drives. Initial production began in mid-1986 in Colo-

rado, but Optotech, expecting a rapid ramp up, stated that its eventual plan was to manufacture offshore in Taiwan. Slow market growth and product problems limited production, however, and after a period of management instability, in mid-1988 Optotech announced that it was selling its write-once drive product line to Shugart Corporation. Optotech never was able to regain momentum and when investors declined to commit further funds, the firm sold its erasable drive development effort to Hewlett-Packard in late 1989 and gracefully ceased operations.

REFERENCE TECHNOLOGY, INC.
1832 North 55th Street
Boulder, CO 80301

Reference Technology has developed and manufactured a 12" read-only unit, but the firm has also begun to remarket the Hitachi CD-ROM. Replication services for media are available through 3M. Reference Technology has entered into marketing agreements with database publishers aimed at providing complete subsystem packages to the ultimate end users. The 12" media used is a video laserdisk which can be used for either data or images. Reference Technology has shifted its emphasis to system integration; its product line now includes hardware and software to interface optical disk drives to small systems. Only a few drives have been made by the firm after 1987, mostly to service existing customer accounts.

SHUGART CORPORATION
9292 Jeronimo
Irvine, CA 92718

Shugart Corporation, formerly the Narlinger Group, acquired the rights to the Shugart name in 1986 from Xerox Corporation, along with manufacturing rights to the 8" floppy drive product line. The firm has since acquired manufacturing rights and certain assets of other storage products companies including Tandon, Control Data, Kennedy and Optotech. In general, these have been obsolescent products that the firm continues to make (in small numbers) and service for existing customers. In 1988, Optotech sold its write-once optical drive product line to Shugart, which continues to supply parts and maintenance services to Optotech's former customers.

VERBATIM CORPORATION
Subsidiary of Mitsubishi/Kasei Verbatim
1200 W. T. Harris Boulevard
Charlotte, NC 28213

Verbatim, known primarily as a maker of floppy disk media, began developing an erasable optical disk drive in early 1983. Based upon technology developed at Philips, the Verbatim design, a 3.5" magneto-optical erasable drive, was announced in preliminary form at NCC in 1985. In its final form, the drive was expected to be a low cost, moderately fast drive that would offer at least 50 megabytes of capacity. Eastman Kodak, which acquired Verbatim in 1985, continued to support the development of the pro-

duct at a high level, and brought in several key employees from its operations in Rochester, New York, to strengthen the program. A non-operating prototype was demonstrated at the 1986 NCC and several later shows. The drive was to be produced by Eastman Kodak; media for the drive was to be produced by Verbatim at its Charlotte facilities. However, the firm was unable to move the drive into manufacturing status, and in 1989 Eastman Kodak transferred the 3.5" program to Laserdrive as part of Kodak's deal to acquire 40% of Laserdrive from Olivetti. Laserdrive was merged into Literal Corporation in 1990.

Kasei Verbatim, a Japanese joint venture between Verbatim and Mitsubishi Chemical, announced in 1987 that it would also make 3.5" magneto-optical media. In 1990, Mitsubishi/Kasei Verbatim acquired Verbatim from Eastman Kodak.

Asian Manufacturers

(All fiscal years end in March, 1989, unless otherwise noted. All firms are in Japan unless otherwise noted.)

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

1989 total net sales: $2,941,663,000 Net income: $64,660,000

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

Optical libraries are produced under Aisin's own name and are also produced for other firms on a contract basis. At present, only library units with 5.25" drives are produced. Production started in 1988.

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

1989 total net sales: $2,728,015,000 Net income: $39,719,000

Alps Electric is a high growth manufacturer of electronic components and sub-assemblies for audio, television, instrument and computer applications. Peripheral devices, including printers, floppy and rigid disk drives, accounted for 17% of revenues in 1989. 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

1989 total net sales: $9,784,291,000 (FY ending 12/31/89) Net income: $277,345,000

Canon is a major supplier of business machines, copiers, and cameras, but about 27% of the firm's business is in computer peripherals and another 25% is in other data and communications equipment. Disk drive products include flexible and erasable optical drives. Canon's rewritable drive and media were announced in 1988 when it was revealed that Canon had an exclusive agreement with NeXT to supply a 256 megabyte 5.25" magneto-optic drive. Shipments began in 1988, making Canon, along with Sony, one of the few major suppliers of rewritable drives in 1988. In 1989, Canon acquired a 16% interest in NeXT. In addition to supplying NeXT, Canon has begun shipping optical drives in its own document management systems.

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

1989 total net sales: $379,829,000 Net income $3,035,000

Chinon is best known for its cameras and audio equipment, but 34% of its sales come from floppy disk drives, printers and other equipment for information systems. Eastman Kodak holds approximately 12.7% ownership through Kodak Japan. Chinon has been producing head assemblies for CD equipment and in 1988 began supplying CD-ROM drives to Atari as a custom product. A similar drive has since appeared under Chinon's own label for use with IBM and Apple personal computers.

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

1989 total net sales: $17,291,533,000 Net income: $506,613,000

Fujitsu is Japan's largest producer of computer systems and also manufactures a wide variety of other electronic equipment. Computer products represent about 68% of Fujitsu's sales.

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

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

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

Goldstar Telecommunications is a joint venture between the Lucky Goldstar Group and several other firms, including Fuji Electric and the German firms, Siemens and DEG. About 11% of total sales is computer related equipment. Goldstar has announced a CD-ROM drive that is scheduled to begin shipping in 1990. An internal development program targeted at rewritable drives exists and Goldstar expects to begin shipments in 1990.

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

1989 total net sales: $46,363,562,000 Net income: $1,344,152,000

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

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

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

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

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

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

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

1989 total net sales: $5,945,586,000 Net profit: $108,814,000

JVC, as it is commonly known, is a major producer of consumer audio equipment, including CD players. Video tape recorders accounted for 50% of JVC sales in 1989, but JVC has been expanding into computer peripherals and has been shipping rigid disk drives since 1985. Computer related products now account for about 9% of revenues. The firm has introduced CD-ROM drives and went into low volume production in the last half of 1987. Shipments have been nominal.

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

1989 total net sales: $8,264,301,000 Net income: $351,517,000

Kawatetsu Advantech is a smaller company specializing in electronic instrumentation. The firm began producing 5.25" write-once optical disk drives at its Nishinomiya plant in December of 1986 under license from ISI, now Literal Corp. Kawatetsu Advantech markets the drives to OEM customers in Asian markets through Kanto Denshi, a trading company, and may act as a second 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 Corp., and has begun shipping 5.25" drives based on the ISI 600 megabyte design.

MATSUSHITA COMMUNICATION INDUSTRIAL CO., LTD.
4-3-1, Tsunashima-Higashi
Kohoku-ku, Yokohama 223

1989 total net sales: $2,620,439,000 Net income: $87,021,000

The primary products of MCI include key telephones, car audio equipment and floppy disk drives. In 1987, MCI announced a 5.25" 300 megabyte write-once optical disk drive offering 75 millisecond average access time and 925 kilobyte per second data transfer rate. A rewritable drive having similar specifications began shipping in late 1988. In 1989, responsibility for the MCI optical disk drive products was transferred to Matsushita Electric Industrial Company.

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

1989 total net sales: $39,865,648,000 Net income: $1,546,042,000

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 MEI Electronic Components Division is offering CD-ROM products, including half-high models that became available in late 1987. The parent firm has also developed an 8" write-once drive that is now manufactured by Matsushita Graphics Communication Systems and used in captive document storage systems.

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

In 1989, the Disk Division of MEI acquired the responsibility for manufacturing and marketing of the MCI optical disk drive product line, adding rewritable drives and optical libraries to the MEI product line. A 470 megabyte 5.25" write-once drive started production in the fall of 1989.

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

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

MGCS is best known for facsimile systems, but has, for the past three years, marketed a line of office automation equipment. These include document storage systems using an 8" write-once optical drive developed by MGCS' parent, Matsushita Electric Industrial Company. MGCS now manufactures the drive itself along with an 8" library unit for use in the Panafile series of document storage systems. As of mid-1990, these systems were marketed only in Japan.

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

1989 total net sales: $19,677,106,000 Net income: $385,573,000

Mitsubishi is most noted for heavy machinery production, but is also quite active in defense electronics and consumer electronics. Data and communication systems represent 35% of sales. In 1987, Mitsubishi introduced a 5.25" 300 megabyte write-once optical drive with 80 millisecond average access time. The drive is sold as part of an optical storage library system that can contain as many as two drives and 152 disks. Higher performance 5.25" M-O type rewritable drives began to ship in the second quarter of 1990 and an improved version of the write-once drive is expected in the first quarter of 1991. All of Mitsubishi's library products are configured with 5.25" drives.

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

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

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

1989 total net sales: $110,458,000 (FY ending 2/28/89) Net income: $3,795,000

Best known for its top of the line audio equipment, Nakamichi has had an optical disk drive development program for several years, and is currently selling laboratory equipment for optical disk drive development. About 30% of 1989 sales were computer related items. Nakamichi has established or purchased several organizations in the United States, including MOST, Mountain Computer, and Ocean Micro, in which Mountain has a 20% interest. Responsibility for Nakamichi's line of optical disk test equipment has been transferred to Mountain Computer, which manufactures a variety of test and certification equipment. A 128 megabyte 3.5" rewritable drive developed by MOST and Nakamichi, appeared in 1990, the first 128 megabyte 3.5" M-O drive to reach the marketplace.

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

1989 total net sales: $22,327,805,000 Net income: $466,988,000

NEC has defined its product area as communications and computers, with computer products accounting for about 44% of annual revenues. The firm has the largest share of the Japanese personal computer market. NEC makes

a variety of disk products, including floppy, rigid and optical disk drives. The firm's first optical drive, introduced in 1983, was a 1 gigabyte, 12" unit used primarily for NEC captive document storage systems but also sold on an OEM basis. A 1.8 gigabyte drive was marketed in 1987 and a 2.5 gigabyte drive was introduced in 1990. A 5.25" M-O rewritable drive started production in mid-1989. NEC offers optical libraries with 12" drives and with 5.25" drives.

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

NIKKYO SEISAKUSHO CO.,. LTD.
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. Metal parts remain a major focus.

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

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

1989 total net sales: $1,841,841,000 Net income: $83,364,000

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

basis of its own rewritable drive. Olympus has an exclusive agreement with Ricoh to provide drive mechanisms to which Ricoh then adds the electronics.

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

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

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

1989 total net sales: $1,628,609,000 Net income: $70,986,000

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

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

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

1989 total net sales: $5,282,907,000 Net income: $128,884,000

Copiers, photographic equipment, and sensitized papers provide most of Ricoh's revenues, but the firm also produces a growing line of data processing equipment which now accounts for 29% of sales. This product line,

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

1989 total net sales: $764,069,000 Net income: $2,151,000

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

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

1989 total net sales: $9,554,735,000 Net income: $318,280,000

NKK, founded in 1919, 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 72% of the firms revenues.

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

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

1989 total net sales: $1,388,050,000 Net income: $48,360,000

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

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

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

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

1989 total net sales: $10,064,692,000 (FY ending 11/30/89) Net income: $121,989,000

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 25% 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.

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

Epson is a member of the privately held Suwa Seikosha/Epson group owned by members of the Hattori family, which also control Japan's Seiko companies, known for watches and electronics. Epson is best known for its line of printers, but also manufactures a portable computer, displays, paper tape equipment, and floppy and rigid disk drives. In 1988, Epson agreed to

supply Maxtor with a 160 megabyte 3.5" erasable optical disk drive and media then under development. While plans to deliver such a drive to Maxtor have been terminated, industry expectations are for Seiko Epson to be an early entrant in the 3.5" rewritable drive market.

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

1989 total net sales: $9,117,824,000 Net income: $210,784,000

Sharp is a supplier of electrical and electronic equipment. About 46% of sales are derived from computer or computer related products, including desktop and transportable personal computers. Sharp has been actively developing magneto-optic disk drives and media for several years and has made several technology announcements during this period. In mid-1987, the firm announced a 5.25" 190 megabyte erasable optical drive. An improved 300 megabyte version is scheduled for production in 1990.

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

1989 total net sales: $15,944,608,000 Net income: $524,871,000

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

Sony is fielding a product line of CD-ROM, write-once and rewritable optical drives. The write-once product is a 12" drive, while the rewritable drive is a 5.25" model. An 8" write-once drive produced earlier has been discontinued. To support its write-once drives, Sony offers an automated library unit, first shown at COMDEX in the fall of 1985.

Sony is vertically integrated and supplies its own media. 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 1987, Sony announced an erasable 5.25" optical drive using magneto-optical technology. Evaluation units were first shipped in late 1987, and additional improved evaluation units were shipped in mid-1988. Production units were shipped in late 1988, and Sony has been successful in capturing several OEM accounts for its rewritable drive. In 1989, Sony was the major supplier of rewritable optical disk drives and claimed over 50,000 shipments by mid-1990.

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

1989 total net sales: $27,528,478,000 Net income: $864,793,000

Toshiba is a major factor in consumer electric and electronic products, and also has a leading position in the office computer market in Japan. About 56% of sales in 1989 were related to data communications or computer products. Optical, rigid and floppy drives are produced by Toshiba, which was one of the first firms to market a 12" write-once drive. A 12" 2.5 gigabyte drive began shipments in 1988. Toshiba shipped production level 5.25" write-once optical disk drives in early 1989, although it began shipping samples of its 5.25" write-once drive in 1986. However, 5.25" drive shipments have not been emphasized due to the lack of a well developed market.

CD-ROM shipments also began in 1986, with half high drives scheduled for the latter half of 1987. Toshiba's later CD-ROM models have unusually short seek times for CD-ROM drives, and this has helped Toshiba capture a significant and growing market share. The drives are particularly favored by system integrators building file servers incorporating CD-ROM, and in 1990, Toshiba CD-ROM drives appeared in the product lines of major system manufacturers.

YAMAHA CORPORATION
10-1 Nakazawa-machi
Hamamatsu, Shizuoka

1989 total net sales: $3,524,857,000 Net income: $26,733,000

Yamaha is the world's largest manufacturer of musical instruments, which account for 62% of the firm's sales. Among more recent activities is the development of a CD format system capable of recording on write-once media. The media is supplied by Fuji Photo Film. The Yamaha system is intended for use in situations where fast preparation of a master disk is required or where relatively few copies are needed. It contains the first commercial write-once CD format drive. The drive is not available as a separate item.

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. A 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.

New products include 3.2 gigabyte, 12" write-once drives; a 5.25" drive is also under development with a 1990 introduction target. ATG also designed a library storage unit for 12" media, but has elected to market Cygnet's line of library units in order to concentrate its resources on drive development and manufacturing.

DETERNER STEURERUNGS UND MACHINENBAU GMBH & CO.
Birkenstrasse 2
D-2951 Deternerlehe
West Germany

DSM 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 both 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 libraries with up to 2100 storage slots for disks.

LASER MAGNETIC STORAGE INTERNATIONAL
Subsidiary of N.V. Philips
4425 ArrowsWest Drive
Colorado Springs, CO 80907

LMSI was formed in 1986 through the combination of Optical Storage International, Computer Peripherals International, and Philips' CD-ROM 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.

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. LMSI has also begun marketing a rewritable 5.25" drive made by a Japanese company.

Media is obtained from an LMSI manufacturing operation sharing Philips media manufacturing facilities at Blackburn in the UK. PDO also is a qualified media supplier.

ING. C. OLIVETTI & C., S.P.A.
Via G. Jervis 77
10015 Ivrea
Italy

1989 total net sales: $7,254,000,000 Net income: $163,000,000

Olivetti's major participation in the optical drive business is through its 40% equity in Laserdrive, now merged into Literal Corp. The firm had an 80% share of Laserdrive, but sold half of its holdings to Eastman Kodak in 1989. Olivetti retains a 26% interest in Literal.

While Olivetti had major internal disk storage projects under development, a change of emphasis in 1988 resulted in the formation of joint ventures with other firms. A joint venture with Conner Peripherals has absorbed Olivetti's magnetic disk drive manufacturing and development in Italy. Some optical recording research projects have been continued. Olivetti has negotiated some optical technology sharing agreements with Toshiba.

MAP INFORMATION UND ARCHIVSYSTEME GMBH
D 6352 Ober-Morlen
Schulstrasse 2
West Germany

MAP is a specialized producer of document storage systems and optical library systems using 5.25" drives. The systems are typically offered for use with IBM and Siemens mainframes and with network interfaces. 32 to 256 disk cartridges can be stored in four different product configurations. MAP has used primarily the Ricoh write-once drives in its systems.

NEXT TECHNOLOGY CORPORATION LIMITED
St. Johns Innovation Centre
Cambridge CB4 4WS
England

Next Technology (no relationship to NeXT Computer exists) is a producer of optical libraries using CD-ROM drives. Up to 270 disks may be routed to as many as 8 drives by the mechanism. Shipments began in early 1990, although a few evaluation and test units were shipped in 1989.

N. V. PHILIPS
5600 MD Eindhoven
The Netherlands

1989 total net sales: $29,960,000,000 Net income: $414,700,000

The Philips organization, established in 1891 as a manufacturer of electrical equipment, has been active for many years in the development of optically based information systems. Initial development work was spun off to joint ventures with Control Data. Philips' initial digital optical developments were a 12" write-once drive and the CD-ROM. Philips, together with Sony, has been instrumental in establishing standards for CD and CD-ROM drives. The Philips CD-ROM has the distinction of being the first CD-ROM to be accepted by a major system OEM: Digital Equipment Corporation offered it as a peripheral on its Micro-Vax line. Philips and Sony continue to innovate standards for CD-ROM, including CD-I and CD-ROM XA.

In 1986, OSI, a joint venture between Philips and Control Data, was reorganized as Laser Magnetic Storage and charged with the responsibility of manufacturing and marketing the Philips CD-ROM, write once optical disk drives designed by OSI using Philips-developed technology, and magnetic tape drives previously produced by another CDC joint venture. Philips owned 51% of LMS; Control Data held the other 49%. In 1990, Philips purchased Control Data's share and is now the sole owner of LMSI.

Philips is also involved in a joint effort with Sun Microsystems to develop CD-ROM and CD-I authoring systems using Sun workstations. Philips is a producer of CD media through its Polygram operation and several joint ventures with Japanese companies. In 1985, Philips also entered into a joint venture with DuPont named Philips and DuPont Optical (PDO) to produce optical media of various types in large quantities.

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.

1990 DISK/TREND REPORT

INTRODUCTION

DISK/TREND ON DISK is a set of floppy disks containing the statistical tables and specification tables from the annual DISK/TREND Reports. The disk files have been prepared in a format usable on IBM or IBM-compatible computers running under the MS-DOS or PC-DOS operating system. A system with a hard disk is highly recommended, but a system with two floppy disks can be used if necessary. All DISK/TREND ON DISK files contain data only -- manipulation of data is the user's responsibility. Because some of the files can be very large, system memory of 640K or more is recommended.

A file translation program, AutoImport, is available from DISK/TREND to assist in converting the data supplied to the formats of several popular spreadsheet programs.

Two types of diskette files are supplied for each DISK/TREND disk drive report. The first type contains the statistical tables in ASCII format. File names are keyed to the table numbers in the report for easy identification. The second type contains the specification section in a Lotus 1-2-3 data base format. Multiple disks of each type are provided where the files are too numerous or too large to fit on a single floppy disk. The color used on the label of each floppy disk is similar to the color used on the cover of the corresponding report for ease in identification.

Because the statistical tables are provided in ASCII format, they can be used with any spreadsheet program that can import ASCII text files. However, the specification tables have been prepared specifically in Lotus 1-2-3 format to allow them to be searchable using Lotus 1-2-3 data base commands. If you are using a spreadsheet program other than Lotus 1-2-3 that can translate Lotus WK1 formatted files to its own format, it may be able to import the specification tables.

The authors of this manual assume that you are familiar with personal computers, Lotus 1-2-3 or other spreadsheets, and MS-DOS, and do not cover their operation in this manual. This manual deals specifically with how to load and use the files supplied on the floppy disks.

One copy of AutoImport is provided automatically at no extra charge to DISK/TREND subscribers who have purchased an original copy of DISK/TREND ON DISK but is provided only in the first year DISK/TREND ON DISK is purchased. Updates to AutoImport may be provided in following years at DISK/TREND's discretion. Extra copies of AutoImport may be purchased at any time. If you have not purchased DISK/TREND ON DISK, but would find AutoImport useful with other file translation tasks, it may be purchased independently from DISK/TREND or White Crane Systems, Inc.

Note: Please read the license information on the following page.

DISK/TREND ON DISK
Information License

DISK/TREND supplies diskettes containing selected information from the 1990 DISK/TREND Report as a separately purchased option to subscribers to the corresponding 1990 DISK/TREND Report volume.

YOU MAY:

1. Install and use the information on a single computer system, provided that you or the organization by which you are employed has purchased at least one copy of the DISK/TREND report volume associated with the information.

2. Make backup copies of the information for your own use. Such backup copies may be used only on the computer on which the information is installed. You must reproduce the copyright notice on any copies.

3. Reproduce the information, but not the associated programs or documentation, contained in the Product for use within internal documents distributed within the organization by which you are employed.

YOU MAY NOT:

1. Install, or allow the use of, the information on more than a single computer system.

2. Transfer the information through or within a computer network.

3. Distribute the information or any portion thereof in any form outside the organization by which you are employed or modify the information for purposes of distribution.

4. Transfer this license to another party.

AUTOIMPORT

Use of AutoImport is subject to the terms and conditions provided by White Crane Systems, Inc.

Trademarks

IBM is a trademark of International Business Machines Corporation.

Lotus and Lotus 1-2-3 are trademarks of Lotus Development Corporation.

MS-DOS is a trademark of Microsoft Corporation.

AutoImport is a trademark of White Crane Systems, Inc.

Getting started

The first thing you should do is to make working copies of the original DISK/TREND diskettes. Place the originals in a safe location and use only the working copies for day-to-day operations. This procedure will help to protect your data from inadvertent destruction or loss due to a malfunction of the computer or its operator. We also recommend that you place a write protect tab on the working copies (after you create them) for the same reason. Use the hard disk or another floppy disk copy for day-to-day manipulations of the files.

The statistical tables are provided in ASCII text format. This allows you to use any word processor to edit the file prior to importing it into Lotus 1-2-3. Appropriate editing removes any material you don't wish to work with and allows you to add figures or text to the data tables. You may also embed the data in internal documents or reports you are preparing for use within your company.

To convert the statistical tables to a spreadsheet you may use the Auto-Import utility software, which is probably quicker and easier than the typical text file import and conversion procedure provided with spreadsheet programs. One copy of AutoImport is provided automatically at no extra charge to each DISK/TREND subscriber who has purchased an original copy of DISK/TREND ON DISK and is provided in the first year DISK/TREND ON DISK is purchased. Updates to AutoImport may be provided in following years at DISK/TREND's discretion. Extra copies of AutoImport may be purchased at any time.

STATISTICAL TABLES

Loading and Installation

1. Place the floppy disk marked 'Tables' in a floppy disk drive able to read 5.25" disks. This is usually drive A, but if you are using a dual floppy only system, use drive B and put the Lotus 1-2-3 system disk in drive A. Use the DOS 'DIR' command to examine the file directory on the 'Tables' disk. If there are any special instructions, they will be in a file named READ.ME. To see these instructions, at the DOS prompt type:

   TYPE A:READ.ME (Use the appropriate drive letter if not A)

   If you wish to print the instructions, turn on your printer and type:

   TYPE A:READ.ME>PRN

2. Do this step if you have a hard disk. Log into the hard disk directory in which Lotus 1-2-3 normally stores worksheet files. Using the DOS 'COPY' command, copy all the statistical table files to the hard disk. This can be done in one step using the copy command as follows:

   COPY A:?T*.*

   Several utility files should also be copied. The command is:

   COPY A:*.PRN

   The utility file names are of the form FORMLIN?.PRN. The files are specific to use with Lotus 1-2-3 data parsing if you prefer not to use AutoImport for file translation.

   Installing AutoImport: If you have a hard disk, create a directory named AIMP (You could use other names if you prefer). Now place Auto-Import 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 Auto-Import disks and use only the copies in following steps. In a floppy-only system, AutoImport disk 1 should be in drive A when AutoImport is in use for file translation.

3. If you are using AutoImport (highly recommended) for translation of files to spreadsheet format, do the translation at this point. See the following section on using AutoImport for details.

4. Now you are ready to start your spreadsheet. If you are using a two floppy system, place the DISK/TREND disk in drive B and the spreadsheet

system disk in drive A. If you are using a rigid disk system, place a copy of the spreadsheet system disk in floppy drive A if required by the security provisions of your spreadsheet program. Now start your spreadsheet as usual. After obtaining the blank spreadsheet image on the screen, use the appropriate file retrieval command to select a file. An example of a Lotus 1-2-3 command is:

/FR<filename>

The file names are in the format XTYY.WK1, where:

X= Type of data
F (Flexible disk drive data)
R (Rigid disk drive data)
O (Optical disk drive data)

YY= Table number, as shown in the appropriate report volume

ZZ= Year of Report.

Examples:
File RT10.WK1 is Rigid Disk Drive Report Table 10
File FT2.WK1 is Flexible Disk Drive Report Table 2
File OT1.WK1 is Optical Disk Drive Report Table 1

The file selected will be loaded as a worksheet. If this is the first time the file has been loaded, you may want to create your own formulas linking the cells of the spreadsheet. See your spreadsheet reference manual for details on numerical manipulations and graphics.

If you don't use AutoImport

If you don't use AutoImport but still want to translate ASCII files to your spreadsheet format, you will have to use spreadsheet tools such as the Lotus 1-2-3 Data Parse commands. They allow the user to convert a table which has been imported in the form of a block of text to a form in which the individual numbers and labels can be manipulated as spreadsheet elements or used to prepare graphics. Let's take Lotus 1-2-3 as an example. Before proceeding, it would be useful to read the Lotus reference manual on this subject if you are not a regular user of the Data Parse commands.

The trickiest and most-time consuming part of using the Data Parse commands is setting up the format line. Several utility files have been provided on the tables disk to make this process easier. These are used with various table formats encountered in the DISK/TREND Reports and correspond with the precomputed masks provided for use with AutoImport:

- FORMLINA.PRN — Used with Table 1 and the Revenue and Unit Shipment tables found in the product group sections of all DISK/TREND reports.

- o FORMLINB.PRN — Used with Table 2.
- o FORMLINF.PRN — Used with Tables 3 and 4.
- o FORMLIND.PRN — Used with Application tables.
- o FORMLINE.PRN — Used with Track Height and Track Density tables. in Flexible Disk Drive Report

There are no FORMLIN format files for disk diameter tables or market share tables, as these are variable in format. You will have to construct the format line directly, but after you have seen how it is done for the other tables, this should not be too big a job.

After you have used spreadsheet tools to translate a file, you will understand why we recommend AutoImport for this function.

Using AutoImport:

Using AutoImport is a two-step process. Step one is creation of a translation mask for each format used in files to be converted. The typical DISK/TREND Report uses 5 to 7 standard mask designs (which have been precomputed and included on your Statistical Tables disk) plus additional masks that are dependent upon table content, as some table types have variable numbers of columns. You will have to create your own masks for such tables, but this can be done easily as shown below.

Step two is the translation process. Once the mask has been created, it can be used with any table matching the mask format. See the table below which relates table types to specific masks.

MASK TABLE

Mask File Name	Rigid Report	Flexible Report	Optical Report
MASKA	<-------- Table 1--------->		Tables 1,2
	<------------ Product Group Revenue ---------->		
	<------------ Product Group Shipment ---------->		
MASKB	<-------- Table 2 -------->		Tables 3,4
MASKC	Tables 3 to 8	Tables 3,4	Tables 5 to 12
MASKD	<----- All Product Group Application Tables ------->		
MASKE	N/A	Track Height, Track Density	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	1989 Rigid Report	1989 Flexible Report	1990 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	--	--	--
23	MASKA	MASKD	MASKA
24	MASKA	MASKG	MASKA
25	--	MASKA	--
26	--	MASKA	--
27	MASKD	--	MASKE
28	--	--	MASKD
29	MASKA	MASKD	MASKA
30	MASKA	MASKG	MASKA
31	--		MASKD
32	--		MASKA
33	MASKD		MASKA
34	--		MASKA
35	MASKA		MASKA
36	MASKA		--
37	--		--
38	--		MASKE
39	MASKD		MASKA
40	--		MASKA
41	MASKA		--
42	MASKA		--
43	--		MASKE
44	--		MASKA
45	MASKD		MASKA
46	--		--
47	MASKA		--

Cross reference (continued)

Mask File Name	1989 Rigid Report	1989 Flexible Report	1990 Optical Report
48	MASKA		MASKE
49	--		
50	--		
51	MASKD		
52	--		
53	MASKA		
54	MASKA		
55	--		
56	--		
57	MASKD		
58	--		
59	MASKA		
60	MASKA		
61	--		
62	--		
63	--		
64	MASKD		
65	--		

-- 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 /IFT (Input:File:Type-in)
   Enter the name of the file, including the extension, which will be of the form yy? where yy is the year of the report and ? is the report type as above.

   Examples: RT4.90R FT12.90F OT14.900

6. The default spreadsheet type to which the translation is made is Lotus 1-2-3 version 2.x. If you wish to translate to a different spreadsheet format you may choose it by typing /TS and then selecting your preference from the menu of choices displayed.

7. You are ready to translate. Type 'G' for 'GO' or select 'GO' using the arrow keys. You will see the file being translated scroll by as the translation proceeds.

8. If you want to do more translations, repeat from step 3.

9. When you are done translating, leave AutoImport by typing /Q (Quit) to return to the AutoImport main menu and then /E (Exit) to leave AutoImport and return to DOS. It will save you some keystrokes if you copy your new spreadsheet files to your spreadsheet directory. If you are using a two floppy system, just remove the AutoImport disk from drive A and substitute your spreadsheet disk.

Mask Generation

1. Start AutoImport as above. When the opening screen appears, select 'Mask' using the arrow keys or type 'M'.

2. Name the file you will use as the template to create the mask. The file name will be of the form ?Tnn.yy?, where ? is the type of report (R, F, or O), nn is the table number and yy is the report year.

   Example: OT50.900

   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 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 cursor in first space to the right of the left margin label column. Type /C and then adjust the column width to encompass all places in the values column you have been working with. This will restore the mask column, also.

5. Save the mask in a mask file. Type /FMS (File:Mask:Save). Fill in the name of the mask file.

   Example: OT50MSK

6. Save the output file. Type /FOT (File:Output:Type-in). Now enter the file name.

   Example: OT50. You don't need to enter the file extender.

7. To make more masks, repeat from step 2. To quit the mask function, type /Q (quit). This returns you to the AutoImport main menu. To leave AutoImport, type /E.

Other AutoImport Functions

AutoImport can do much more than the functions described above, which are those concerned with a basic understanding of how to create spreadsheets from DISK/TREND ON DISK files. See the separate AutoImport manual provided for details of these other functions.

SPECIFICATION TABLES

Loading

1. Place the floppy disk marked 'Specifications' in a floppy disk drive able to read 5.25" 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: OS190 Optical disk specification table
LS190 Optical library specification table

Note that the specification tables load directly as a data base. You can use the data base functions of Lotus 1-2-3 to sort, count or otherwise manipulate the data for purposes of special analysis. Other spreadsheets may have similar capabilities.

Using the specification data base

Introduction: If you have not used the Lotus 1-2-3 /DATA QUERY commands, it will be helpful for you to review the sections of the Lotus 1-2-3 reference manual that pertain to their use before proceeding further.

The specification data base fits into a worksheet format of 25 to 30 columns, depending upon whether rigid, optical or floppy drives are involved, and a row count of up to 500 rows. Each row represents a specific record, and is equivalent to a single column in the Specifications section of the DISK/TREND report. Each column represents a specific specification parameter, and is equivalent to one row of the DISK/TREND report.

The data base has been set up for data extraction using Lotus 1-2-3 commands. The Input, Output and Criterion ranges have been predefined, but you, the user, will have to decide how you want the extracted data manipulated and place the appropriate Lotus functions, such as @COUNT, in the appropriate cells. Some rows between the bottom of the input range and the top of the output range have been left empty so that you can do this easily. When the database is first loaded, you will see the top of the input range, showing the first column (manufacturer name) for the first several manufacturers. Use the arrow keys to find other manufacturers or specific product specifications. If you are not using Lotus 1-2-3, use the equivalent procedure for your spreadsheet.

Operating tips

Expanding the input or output ranges: The predefined output range is of a nominal size, and a search with broad parameters may result in overflowing the output range. In such a case, merely extend the output range (add more rows) using the Lotus 1-2-3 /DQEO command. Similarly, it is possible to extend the input range to add more products, but be sure you move the output range so that there is no overlap.

Memory overflow: If you should receive a memory overflow message while manipulating the specification data, it is usually because:

- o There are other 'pop-up' programs resident in the memory of your computer. These should be removed.

- o You have selected too large an output range. Use a smaller output range or delete some of the columns that contain data not relevant to your analysis. If you delete data, be sure that if you save your spreadsheet you use a different file name, otherwise you will overwrite the original file with the modified spreadsheet.

- o If you receive a memory overflow message while loading the data base, the data base is too large for your computer's available memory. You probably will have to remove other resident programs and reload Lotus 1-2-3 and the data base. If your computer doesn't have 640K memory, you will probably get this message.

Saving time

The specification data base is large and takes significant time to recompute or perform other operations. If you are interested in drives that belong to only a few product groups, it will probably save you time in the long run if you extract only those groups you are interested in into a new worksheet and use that for the analysis. Use spreadsheet FILE EXTRACT and FILE COMBINE commands for this purpose.

Another way to save time is to use the SORT capabilities of your spreadsheet to organize the data the way you find it most useful. The most commonly done sorts are by manufacturer name and by DISK/TREND product group, but it would also be possible to sort by average seek time, price, and so on.

Make sure that when you save a worksheet using the FILE SAVE command that you save it in a new file name. If you save it in the file name from which it was loaded, the original copy will be overwritten. If a file is overwritten unintentionally, it can take a long time to recreate.

If you are interested in only a subset of product groups, use the FILE EXTRACT and FILE COMBINE commands to move these records to another file and then use the second file for analysis. The smaller file will take less time to process.

Technical support

Just about all of your questions regarding the use of DISK/TREND ON DISK should be answered in this manual or in the Lotus 1-2-3 reference manual. However, if you need to contact us to resolve any points of confusion, report errors, or otherwise receive comfort:

Call us at: 415-961-6209

Ask for Technical Support

In order to make this process efficient, when you call--

1. Tell us what is on the diskette label.

2. Have your computer up and displaying the data or operation that is the subject of your call.

3. Have this manual and the Lotus 1-2-3 reference manual handy.

If you have questions about AutoImport as it is used with DISK/TREND ON DISK, contact DISK/TREND at the number above. Questions about other functions of AutoImport should be referred to White Crane Systems.