Projecting the Cost of Magnetic Disk Storage Over the Next 10 Years

The following table shows the cost per GigaByte and the cost per TeraByte (one thousand GigaBytes) in each year from 1992 through the year 2010. As shown in the table, one GigaByte is sufficient storage for two file cabinets of scanned documents and one TeraByte is sufficient storage for two thousand file cabinets of scanned documents. The table is generated using an estimated price reduction assumption of 45 percent each year. Disk configurations, of varying complexity, are given for each year to explain possible variations in quoted prices.

Annual Decline	Cost For 1 GigaByte	Cost For 1 TeraByte = 1,000 GigaBytes (US Dollars) (Storage for 2,000 Scanned File Cabinets) (Holding 20 Million Scanned Letter Size Pages)				
45%	1,000 MBytes	Non-FC/SCSI	Non-FC/SCSI	SAN	SCSI/FC SAN/PC	
Year	(US Dollars) (Storage for 2 Scanned File Cabinets)	PC Disk No Online Redundancy	PC Disk Software RAID Redundancy	FC Disk FC Fabric Hardware RAID	Name Brand Fault Awareness Hardware RAID	Mainframe
		1 X	2 X	4 X	8 X	12 X
1992	1,000.00	1,000,000.00	2,000,000.00	4,000,000.00	8,000,000.00	12,000,000.00
1993	550.00	550,000.00	1,100,000.00	2,200,000.00	4,400,000.00	6,600,000.00
1994	302.50	302,500.00	605,000.00	1,210,000.00	2,420,000.00	3,630,000.00
1995	166.38	166,375.00	332,750.00	665,500.00	1,331,000.00	1,996,500.00
1996	91.51	91,506.25	183,012.50	366,025.00	732,050.00	1,098,075.00
1997	50.33	50,328.44	100,656.88	201,313.75	402,627.50	603,941.25
1998	27.68	27,680.64	55,361.28	110,722.56	221,445.13	332,167.69
1999	15.22	15,224.35	30,448.70	60,897.41	121,794.82	182,692.23
2000	8.37	8,373.39	16,746.79	33,493.58	66,987.15	100,480.73
2001	4.61	4,605.37	9,210.73	18,421.47	36,842.93	55,264.40
2002	2.53	2,532.95	5,065.90	10,131.81	20,263.61	30,395.42
2003	1.39	1,393.12	2,786.25	5,572.49	11,144.99	16,717.48
2004	0.77	766.22	1,532.44	3,064.87	6,129.74	9,194.61
2005	0.42	421.42	842.84	1,685.68	3,371.36	5,057.04
2006	0.23	231.78	463.56	927.12	1,854.25	2,781.37
2007	0.13	127.48	254.96	509.92	1,019.84	1,529.75
2008	0.07	70.11	140.23	280.45	560.91	841.36
2009	0.04	38.56	77.13	154.25	308.50	462.75
2010	0.02	21.21	42.42	84.84	169.68	254.51

The Basis for the Assumptions in the Table

The above decreases in price are based on estimated increases in disk storage density by IBM, which are based on IBM's predictions for its magnetoresistive (MR) head technology. IBM invented the MR technology, and MR is currently the technological basis for advancements in the magnetic disk industry. IBM had been increasing the areal bit density of magnetic disks at a rate of 60 percent per year from 1989 to 1994. In 1994, IBM projected that the 60 percent rate of increase would continue for the foreseeable future. (Source: The Era of Magnetoresistive Heads, Ed Grochowski, IBM Research Division, Almaden Research Center, San Jose, CA., 1994).

With IBM's projected rate of increase in areal bit density, of 60 percent per year, for a given price and a given year, one could purchase 1.6 times as much storage capacity the following year. This corresponded to a constant decrease in the price of magnetic storage of 37.5 percent per year.

In a press release issued on December 29, 1997, IBM stated that the percent of price decrease was continuing on track. On October 4, 1999 IBM issued a press release stating that the rate of increase in disk storage density had increased from 60 to 100 percent per year in each of the last two years. IBM also announced that it had demonstrated very stable bit densities of 35.3 billion data bits per square inch in the lab. IBM anticipated that the increase in density would continue. On October 15, 1999, IBM announced a 73 GigaByte, 3.5 inch, multi-platter, disk with a 2 Gigabit per second, serial, fiber channel, interface.

On May 18, 2001 IBM announced that a new process achieved 100 billion data bits per square inch in the lab and was projected to provide a 48 GigaByte notebook computer hard drive in 2001. The new drives will have glass substrates (platters) and their ball bearings will be replaced with fluid dynamic bearing spindle motors attractive for minimizing Non Repeatable Runout (NRRO) (Achieving a NRRO of 10 nanoinches = 250 picometers.), lowering acoustical noise, and improving reliability. In 2003, the technology is projected to provide a notebook hard drive of 200 GigaBytes, a 3.5 inch desktop hard drive of 400 GigaBytes (three of these drives would store 1.2 TeraBytes in a desktop computer), and a 1 inch (25 mm) (the size of a US quarter) 6 GigaByte hard drive. This 1 inch drive (in the current 1 GigaByte capacity) is the drive used in the Kodak Pro Back 16 megapixel camera back. With a 6 GigaByte capacity, the 1 inch hard drive will make it possible to record 3 hours of DVD quality video with the smallest of cell phones. Videotape will disappear. The new media, called antiferromagnetically coupled (AFC) media, will delay for several years the impact of superparamagnetism in limiting future areal density increases, and is know in the press as 'pixie dust'.

Since 1992, when 1 GigaByte cost 1 thousand US dollars, and 1 TeraByte was too expensive for most applications, at 1 million US dollars, memory costs have declined at about 45 percent per year. This is the percent decline used to project the next ten years in the chart above. A decline of 45 percent per year is slower than the 50 percent per year decline for the last two years (1998-1999), and slightly faster than the average decline of more than 40 percent over the preceding 6 years (From 1992 to 1997).

A Longer Perspective for Retention Periods

IBM introduced the 5 MegaByte RAMAC disk on September 13, 1956, at a monthly rental of US$ 3,200.00 (in 1956 dollars). (Source: IBM's Early Computers, by Charles J. Bashe, MIT Press, Cambridge, MA, 1986.) IBM shipped the first RAMAC (Random Access Method of Accounting and Control) System magnetic disks (known historically as RAMAC disks) to Zellerbach Paper in San Francisco. The RAMAC disks cost 100 thousand US dollars per MegaByte, or 100 million US dollars per GigaByte, to purchase. (Adjusted to current US dollars, and adjusted for IBM's historic practice of renting rather than selling.) In 2001, magnetic disk storage cost 4 US dollars per GigaByte. This represents a decline of over ten-million-to-one (from 100 million US dollars to less than 10 US dollars per GigaByte) in forty-five years, or a price decline of about 32 percent per year.

The advances described here are based on magnetic disk technology. The study of the history of technology has shown that over long periods of time, as older technologies are exhausted, new technologies replace them, and a steady rate of advancement is maintained. Holographic and molecular machine nano-technology (see [http://www.Foresight.org]) have been under development for some time and promise several more orders of magnitude improvement in price and physical size reduction, as well as increases in speed, when advances in magnetic disk technology slow.

Cost Adjustment for Advanced Hardware and Support Technology

There are many configurations of magnetic disks available. The simplest disk configuration is in the PC (Personal Computer) on one's desk. In the preceding table, this configuration is assigned an approximate relative cost of 1X. 1X is the base cost for the cost comparison of the disk configurations. The next configuration adds redundancy by storing the same data on two or more disks. This is assigned a relative approximate cost of 2X because the disk storage cost is roughly twice as much as the disk storage cost in a generic PC. The third configuration adds hardware support and fault awareness to the redundancy in a SAN (Storage / System Area Network) configuration using FC (Fiber Channel) interfaces. This is assigned a relative approximate cost of 4X. The fourth configuration adds hardware support, fault awareness, and name branding to the redundancy using either a name brand high end server PC or a name brand SAN using SCSI (Small Computer System Interface) or FC interfaces. This is assigned a relative approximate cost of 8X. Finally, mainframe disk configurations add more hardware and software features to data storage, again with name branding, resulting in a relative approximate cost of 12X. (All trademarks are the property of their respective holders.)

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