More Ways to Play

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This year marks a significant change in the recent history of hard disk drive development. During the final years of the last century and for the last two years the areal density of magnetic recording had been increasing at rates close to or exceeding 100% per year. That meant that each generation of hard disk drive had a digital data capacity that was close to twice that of the previous generation from the prior year's product. At the same time the average price of ATA/IDE interface hard disk drives (the type normally used in desktop PCs and consumer electronic devices) had been dropping more than 10% per year. In contrast in 2003 the ATA/IDE hard disk drive areal density looks like it has increased by less than 60% annually. Furthermore the price of hard disk drives looks at mid-year like it may decline by less than 10% in 2003. Table 1 and Figure 1 show my projections for magnetic recording areal density growth as well as disk drive average prices respectively. These are major changes for the data storage industry!

Table 1. **Shipping Product Disk Capacity Projections (GB)**

Year	95mm Mainstream Capacity Per Platter
2002	40
2003	80
2004	120
2005	180
2006	270

The race for higher areal densities in the last few years was like an expensive arms race for the companies that made hard disk drives and hard disk drive components. Hundreds of millions of dollars were spent annually by the hard disk industry to maintain the breakneck development of higher areal density products. The result of this intensive technological competition was significant consolidation in the industry (today there are only 7 hard disk producers in the world as well as 2 start-up companies making small hard disk drives for mobile applications) and losses or meager profits for many of the hard disk drive and component companies during that period. Another consequence of this areal density competition was the creation of inexpensive hard disk drives with very high data capacities. By 2003 it is possible to buy a 160 GB hard disk drive for less than $80!

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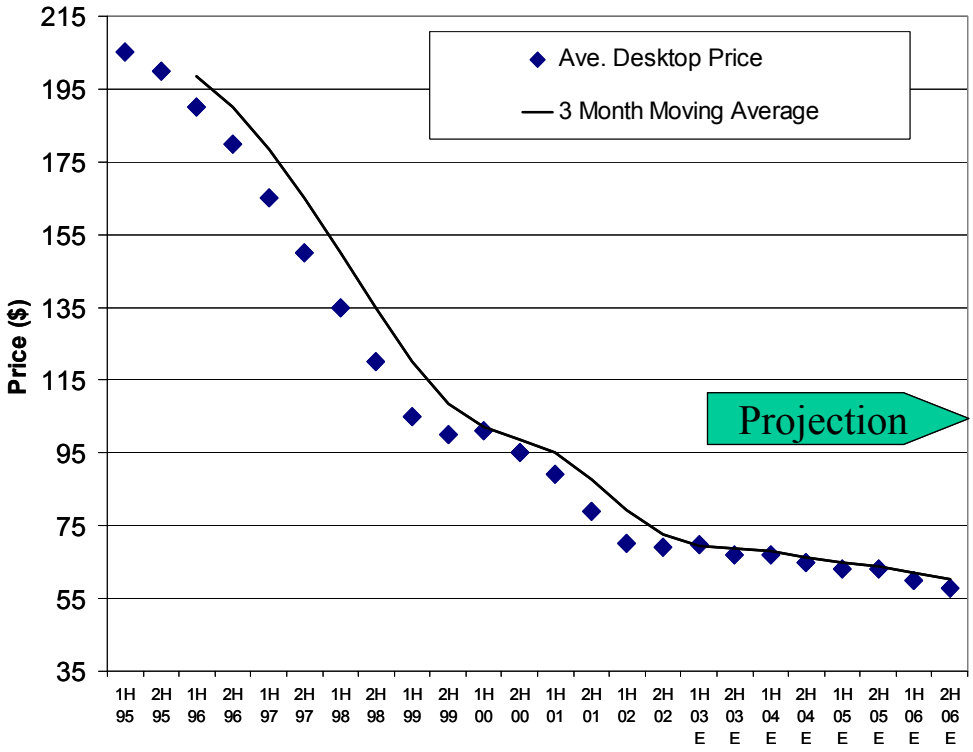


Figure 1. **Average Desktop Drive Prices vs. Time**

The slow down in areal density development is caused in part by the difficulty in developing and ramping up production of ever-higher areal density disk drives. High volume manufacturing of 80 GB per platter disk drives has taken almost a year to achieve at many companies and Western Digital is just now ramping up these products. Many component suppliers have held back on the purchase of new capital equipment because the increasing areal density significantly reduced demand expectations in the late 1990's and because there was little cash available for reinvestment in new production technology. Together these factors have finally slowed the growth of areal densities in 2003.

Slower areal densities have several positive side effects. If disk drive product generations last longer than the 9 months or so that was common for the last few years the yields for critical components such as heads will increase. This lowers the costs of manufacturing these components. The yields of the disk drives themselves will also increase. The effects of these improved yields is lower cost for disk drives and if the drop in drive prices is not as fast as the decrease in costs this means increasing profitability for the surviving hard disk drive and drive component companies. Disk drive companies need to have greater profitability to invest in future disk drive technology and to reward their investors.

Slower areal densities may also change the focus of hard disk drive research. Prior disk drive development focused on developing components such as heads and disks capable of

supporting these ever-greater areal densities. If part of this research spending is refocused on developing disk drives better suited for particular applications there may be several advantages. For instance hard disk drive companies could develop disk drives suited for consumer electronics applications such as personal video recorders (PVR's, also known as digital video recorders, DVR's) but at lower cost and price points than those used in PC's and high end networked storage.

If disk drives were tailored to their applications (such as focusing on audio-video streaming rather than 100% recorded data accuracy for AV applications) and had attractive price points for these applications (which are much lower than disk drives for PC's) then the overall cost of implementing PVR/DVR capability into common consumer devices such as set-top boxes will be lower and the result could be an explosion in demand for these products. Figure 2 shows projections of the growth in PVR/DVR disk drives. If these drives were designed to be unsuitable for PC applications (where accuracy of the stored data is more important than continuous streaming of storage content) then drive companies could create some true differentiation in their products and grow the CE applications of disk drives without endangering the prices of disk drives for other applications.

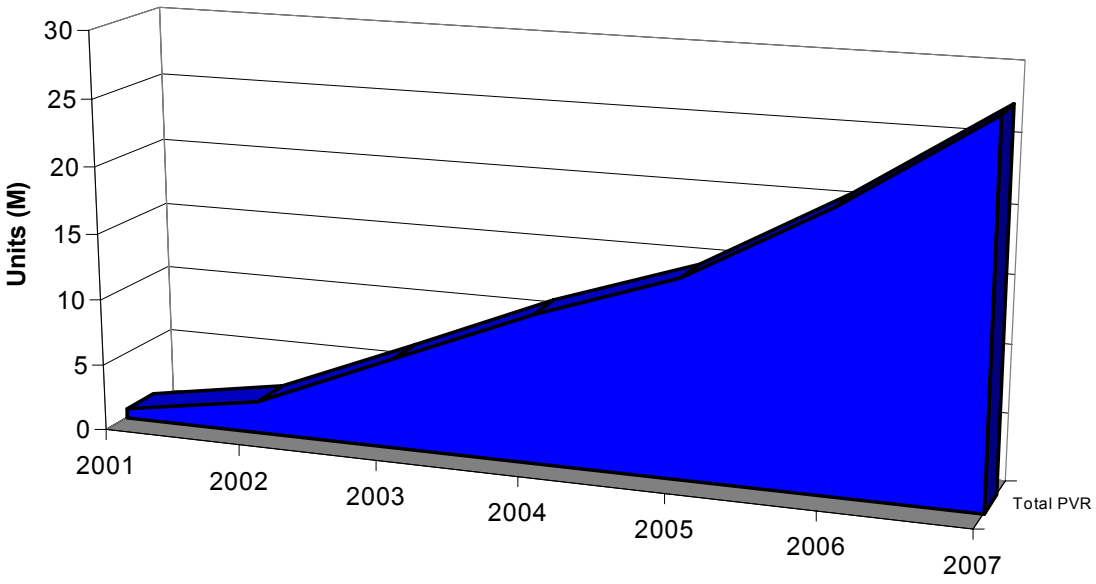
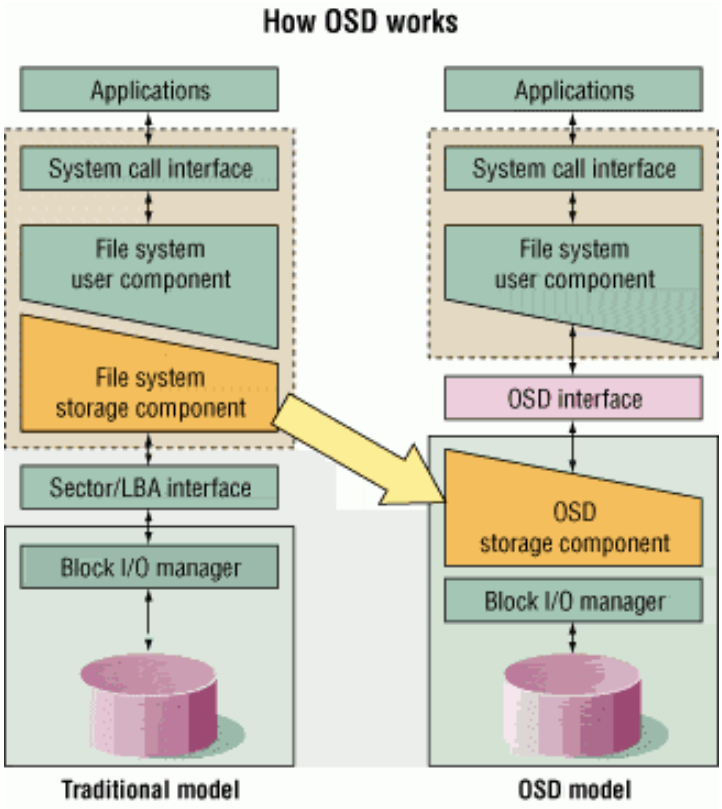


Figure 2. **PVR/DVR Projections.**

Disk drive companies have held back in the past from creating such focused disk drives products due to the low volumes of the applications. However volumes for some of these applications such as PVR/DVR described above are just about to take off. PVR/DVR functions and the disk drives they depend on are becoming a key element in the intense competition between rapidly growing satellite TV companies that are already

implementing PVR/DVRs in their products and the TV cable companies that must do the same to remain competitive.

At the same time that drive companies use their research to create differentiation in disk drives for different applications they can also play a role in developing the standards necessary to make home networking and home gateway or entertainment servers a reality. One approach that could be taken by CE disk drive companies as well as high-end network storage companies is to move to object-based data storage architectures rather than the traditional file-based architectures. In object-based data storage the disk drive has some knowledge of the content that is stored on it. This additional intelligence in object based disk drives could allow faster access and searches of data on disk drives or arrays of disk drives as well as simpler commands to access and use that data. An object-based storage architecture could simplify management of multiple CE devices containing data storage devices and simplify the creation and maintenance of networked storage whether used in "enterprise" applications or in a simpler home network. Usage of object-based storage may also facilitate implementation of digital rights management features. Figure 3 shows a comparison of an object-based disk drive design vs. traditional file-based architecture.



In an Object-based Storage Device (OSD) model, the file system storage component is moved from the operating system to the storage device.

Figure 3. **Comparison of Object Based Storage to Traditional Storage (from InfoStor, September 2000).**

Areal densities are not expected to growth less than 50% per year for hard disk drives in the future. That means that hard disk drive capacities for the same number of heads will double every two years at least. Hard disk drive areal density still has a lot of room to grow. Dr. Mark Kryder, Senior VP and Director of Seagate Research at Seagate Technology has said that technology improvements for hard disk drives could allow areal densities in the future as high as 50 TB/square inch (today about 60 GB/square inch magnetic recording densities are common in hard disk drives). No other technology offers the same economics for data and digital media content storage that hard disk drives now offer and will offer in the next 10 years. Hard disk drives are key components in the development of new content creation, archiving, delivery and reception devices. Hard disk drives are also making inroads into mobile consumer applications. There are several drive companies such as Hitachi GST, Cornice, MagicStor and Fujitsu that are developing products for mobile consumer applications.

If disk drive companies and their customers want to get an edge on their competition they need to refocus part of their technology development on creating new types of disk drive storage that is optimized for particular applications. If they do this properly they will be able to sustain profitability on data storage for computer applications while creating new types of disk drives for AV intensive consumer applications. The overall increase in the use of disk drives in CE devices will cause additional growth in the storage networks that support the creation and distribution of digital media content. The resulting growth in the distribution of digital content will be a key factor in the recovery of the telecommunications industry and a major stimulus in the recovery of the technology economy.

The net result is that data storage proliferation in all elements of the content value chain is a major enabler of economic recovery for our economy! Viva la disk drive! Viva la revolution (now was that 7,200 or 15,000 RPM).