

Kryder's Law

The doubling of processor speed every 18 months is a snail's pace compared with rising hard-disk capacity, and Mark Kryder plans to squeeze in even more bits **By CHIP WALTER**

Over the years there has been a lot of talk about Moore's Law and the way that doubling the power and memory of computer semiconductors every 18 months has driven technological advance. But from where Mark Kryder sits, another force is at least as powerful, perhaps more: the cramming of as many bits as possible onto shrinking magnetic hard drives.

The 61-year-old engineer might be on to something. Since the introduction of the disk drive in 1956,

the density of information it can record has swelled from a paltry 2,000 bits to 100 billion bits (gigabits), all crowded in the small space of a square inch. That represents a 50-million-fold increase. Not even Moore's silicon chips can boast that kind of progress.

Kryder is not denigrating the importance of faster computer processors, but he says, at the very least, both digital elements need each other. Without the continual squeezing of bits onto ever shrinking hard drives, the world of information as we know it today, and tomorrow, will come to a grinding halt.

Information storage has been Kryder's bailiwick most of his career. As founder and director of Carnegie Mellon University's Data Storage Systems Center and now as chief technology officer at hard-drive manufacturer Seagate Technology, he has often spearheaded the breakthroughs that have increased hard-disk densities (and accelerated their corresponding drop in price). But these days, he says, altogether unexpected trends are afoot: smaller, high-capacity drives are spawning not only new products and applications but entirely new industries.

"Who would have predicted the success of handheld digital audio players?" Kryder asks. "We completely missed seeing the iPod coming." Now, he points out, "disk drives are appearing in GPS systems for automobiles and enabling us to record and playback HDTV on TiVo and digital cable systems."

Such devices may relegate Moore's Law to secondary status. "Today the density of information we can get on a hard drive is much more important to enabling new applications than advances in semiconductors," Kryder remarks. Without them, Apple Computer's iTunes Music Store would not have sold hundreds of millions of songs and on-demand TV would still be a pipe dream.

But to Kryder, these new services are just the beginning. Now tiny, capacious hard drives are replacing low-capacity flash memory cards, which use electri-



MARK KRYDER: STORING DATA

- **Leading the way in boosting hard-disk capacity, which has enabled products such as the iPod. His next goal: a terabit in a square inch—equal to about 200 DVD movies—which will most likely spawn new industries.**
- **Predicts that in a few years the U.S. consumer will have 10 to 20 disk drives in various devices: "He may not realize that he has that many, but he will have them in appliances enabled by disk-drive technology."**

cally charged transistors rather than moving parts to record information. Soon hard drives will migrate into phones, still cameras, PDAs, cars and everyday appliances. "In a few years the average U.S. consumer will own 10 to 20 disk drives in devices that he uses regularly," Kryder predicts. These advances are forcing manufacturers to become much more nimble as their markets expand. Optimizing a drive for an Xbox or an automobile's diagnostic system is very different from creating a razor-thin, rugged one-inch drive for a flip phone.

Kryder began exploring digital storage in the 1970s as a postdoc at the California Institute of Technology. Later he spent five years at the IBM Thomas J. Watson Research Center, where he researched bubble memory, which records data by magnetizing small circles on gadolinium gallium garnet. When he joined Carnegie Mellon in 1978, Kryder continued his bubble memory work, but it became clear that the technology, used in cruise missiles and other niche applications, faced as obstacle as a mainstream product: gadolinium gallium garnet was expensive. When the fledgling personal computer industry made the hard drive its storage device of choice, Kryder switched gears, assembled a conference of hard-drive industry gurus in 1982, and asked them to name their greatest research needs. Next he persuaded businesses such as IBM and 3M to support an effort to develop those technologies. The result in 1983: the Magnetics Technology Center (MTC), the only operation of its kind in the U.S. For the next five years, the center incubated increasingly efficient hard-drive technologies, while cultivating the field's top thinkers.

But the MTC tended to react to what the industry wanted, Kryder says, rather than pushing the envelope. So, in 1987, after discussions with the National Science Foundation (NSF), he worked to create an organization that set a technological agenda. In 1990 the MTC became the Data Storage Systems Center (DSSC), one of a handful of NSF-funded engineering research centers. Kryder immediately set an ambitious goal: demonstrate hard drives that could store four gigabits of information in a square inch of disk space. Back then, four billion bits represented an enormous leap. Densities at the time hovered around 100 million bits. But in just four years the DSSC had met the new benchmark, a 40-fold increase.

By 1998, when Kryder joined Seagate to form its advanced research center, the DSSC had set an even loftier target: crowd 100 gigabits into a square inch by the early 21st century. In

2005, just seven years later, Seagate began shipping 110-gigabit drives. Inside of a decade and a half, hard disks had increased their capacity 1,000-fold, a rate that Intel founder Gordon Moore himself has called "flabbergasting."

But now current hard-drive technologies are hitting a new wall. Hard disks typically store bits of information using a tiny head that flies across the surface of the disk and magnetizes billions of discrete areas in horizontal space that represent zero or one, depending on whether they are facing clockwise or counterclockwise. The magnetized areas are becoming so small that it is difficult for them to remain stable.

Kryder and his team are reviving a method called perpendicular recording to fix the problem. It flips the charges north to south, permitting the use of stronger magnetic fields in media that can store smaller bits. Seagate's Pittsburgh lab has already prototyped this approach, which should pack in at least 200 gigabits per square inch within the next two years. Ultimately, Kryder thinks perpendicular drives will record 400 or 500 gigabits within four years. Because that is nothing more than a blink in the world of hard drives, Kryder has already set his next goal: a terabit per square inch, and he has tapped the 100 Ph.D.s at Seagate to work up still more exotic recording systems to make it a reality.

One project tackles a new method called heat-assisted magnetic recording (HAMR), which uses a burst of heat so the drive's head can more easily magnetize even smaller surfaces. When the disk cools, the magnetic field stabilizes. Beyond that he foresees patterned media recording, which would theoretically allow drives to magnetize 10 times more information.

Surprisingly, his team will not be working on holographic storage, considered by many as the ultimate storage technology. Holography uses all three dimensions to store data, and the goal has been to stuff a terabit into a space the size of a sugar cube. But Kryder predicts that in another six years or so, hard drives will reach the terabit benchmark, at which time they will be smaller and cheaper than holographic systems.

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TINY HARD DRIVES are creating new industries. This one, introduced by Hitachi in January, can hold 10 gigabytes.

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Chip Walter, based in Pittsburgh, is working on his third book, Six Traits (That Make Us Human).