

# Background

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## **Data Storage in the Pittsburgh Region**

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Every time anyone accesses the Internet, uses an ATM, watches television, listens to digital music, enjoys a movie with computer-generated special effects or uses a personal video recorder, he or she accesses and shares large amounts of digital information on disc drives.

Data storage requires the integration of physics, tribology (the study of surfaces in relative motion), aerodynamics, fluid mechanics, information theory, magnetics and other disciplines. The fundamental goals of data storage, however, are simply to reliably place as much information as possible (called maximizing areal density) on a hard disk or tape, using magnetic or optical methods, and to provide the means for its rapid access.

Since the mid-1950s, when initial attempts at these fundamental goals were successful, the quest has been to get more and more magnetic storage bits crammed into smaller areas. Up until 2007, the holy grail of data storage had been to squeeze 1,000 gigabits per square inch on a disk, opening the possibility of a one-terabyte drive. One terabyte is equal to one thousand gigabytes, or a trillion bytes, enough storage capacity to place a small black and white photo image of every man, woman and child on earth onto a CD-sized disk.

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To further place such large numbers in context, the entire print collection of the Library of Congress is thought to hold about 10 terabytes of text.

The hard drive turned 53 this year, and over the past five decades data capacity has increased at a fairly regular and rapid pace. The first drive, which came with the RAMAC computer, weighed about a ton and held 5MB of data. The hard drive has advanced about 65 million times in areal density since the RAMAC, and researchers estimate that we are three orders of magnitude from any truly fundamental limits.

Hard-drive scientists say that increases in capacity will continue because of technologies like heat-assisted recording, patterned media and nanostructures.

To continue to exceed the one terabyte goal with conventional data storage media, scientists must overcome the superparamagnetic effect, a phenomenon that is projected to limit the density of magnetically stored information, above which heat destroys the data. Going beyond that threshold will require significant changes in how data is recorded, the widths of tracks on discs, the protective coatings on components, the ultra-thin lubricants between them and the precision of the tiny suspension systems and sliders within the disk drive.

If cramming in the magnetic bits were the only requirement, the goal would be more easily met, but the magnets must be functional, too. Writing a digital “one” or “zero” in such small areas, then subsequently reading back the values requires extreme precision in discerning one bit from another. The bit also must be stable for long periods of time; if some “ones” switch to “zeros” the data will be filled with errors.

Data storage density and durability always have been mutually exclusive. The greater the density, the shorter the durability. One popular illustration of this is that information carved in stone is not dense but can last thousands of years, whereas previously silicon memory chips could hold their information for only a few decades.

Recently researchers at the U.S. Department of Energy have developed a new mechanism for digital memory storage that consists of a crystalline iron nanoparticle shuttle enclosed within the hollow of a multiwalled carbon nanotube, thereby creating a memory device that features both ultra-high density and ultra-long lifetimes. The new memory storage medium can pack thousands of times more data into one square inch of space than conventional chips and preserve this data for more than a billion years.

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### **The Pittsburgh Connection**

Research is extremely important in this fast-paced business that depends on being first with new products. Carnegie Mellon University's Data Storage Systems Center (DSSC) is an interdisciplinary research and educational organization, established by the National Science Foundation, where faculty, students and researchers from a broad swath of academic disciplines collaborate in pioneering theory and experimental research that will lead to the next generation of information storage technology. Collaborating Carnegie Mellon Departments include chemical engineering, chemistry, electrical and computer engineering, mechanical engineering and physics.

More than 60 Carnegie Mellon researchers are working on a variety of projects designed to advance information storage technology beyond the current frontiers of magnetic recording, optical data storage, probe-based systems, holographic and solid-state memory. The DSSC has been helping industry design nanometer-scale technology that will ultimately lead to very fast, low-cost and compact information storage devices.

The center works closely with industry partners to define projects that will contribute to the expansion of the \$60 billion information storage market. Major corporate partners and include ALPS, Fujitsu, Headway Technologies, Hitachi, Imation, LSI Logic, Quantum, SAE, Samsung, Seagate, Sony, STMicroelectronics, Sun Microsystems, TDK, Western Digital and others. The center's goals, among others, are to cooperate with industry to identify future data storage systems, to develop the more promising applications and to transfer the technology to commercial businesses.

To that end, the DSSC maintains state-of-the-art facilities for its research programs including high-tech recording test stands, materials synthesis and characterization facilities and various scanned probe capabilities. In addition, the DSSC makes use of the extensive nanofabrication labs on Carnegie Mellon's campus. Researchers at the DSSC are working closely with industry and the federal government to exploit nanotechnology in order to create a revolution, not only in information storage, but also in a wide variety of fields. (See related article, "Nanotechnology in the Pittsburgh Region.")

With more than \$4 million in government and corporate funding, some of the center's other aggressive projects span a wide range of disciplines, including thin film and particulate media, materials for magnetic and optical heads, tape dynamics, optical recording systems, magnetic disk systems, solid-state memory and more.

### **Regional Industry Base**

Seagate, one of the DSSC's corporate partners, introduced the first 5.25-inch hard drives specifically for personal computers in 1979, helping to fuel the personal computer revolution.

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Today, Seagate commands one-third of the nearly \$30 billion world-wide market for hard drives. Mark Kryder, who formerly served as head of Carnegie Mellon's DSSC, was instrumental in attracting Seagate's research facility to Pittsburgh by sheer virtue of his reputation in the field. Seagate since has closed its Pittsburgh research facility as a result of business strategy shifts, however Kryder succeeded in attracting more than 100 Ph.D.s from 25 countries to Pittsburgh, which is a legacy that will continue to benefit the region far beyond the Kryder years.

Beyond Seagate, the DSSC's successes include some five or six invention disclosures, patents and software licenses per year. A succession of spin-off companies also has been a by-product. Among the spin-offs is Ansoft, which was formed in 1989 to develop software for the design of electromagnetic devices, including recording heads. The software is based on advanced computer algorithms developed at the Center. Ansoft's HF product suite is a solution for system analysis, circuit design and electromagnetic simulation that go into developing wireless technology, broadband communication networks, antenna systems and aerospace electronics. Headquartered in Pittsburgh, Ansoft operated three other locations in the U.S. and five overseas, before it became a subsidiary of ANSYS in 2008.

Another spin-off is Advanced Materials Corporation, a premier manufacturer of permanent magnets and related materials. The company's facilities are located in the laboratories provided through a contractual relationship with the Carnegie Mellon. The facilities are fully equipped for the characterization of hard and soft magnetic materials and the exploitation of metal hydrides. They include equipment to fabricate alloys, ferrites and hydrides.

As these organizations continue to prosper, it will be a signal that the Pittsburgh region will be on the forefront of an emerging subcluster that places the most amount of information on the least amount of real estate.

Visit: [www.dssc.ece.cmu.edu/](http://www.dssc.ece.cmu.edu/)

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