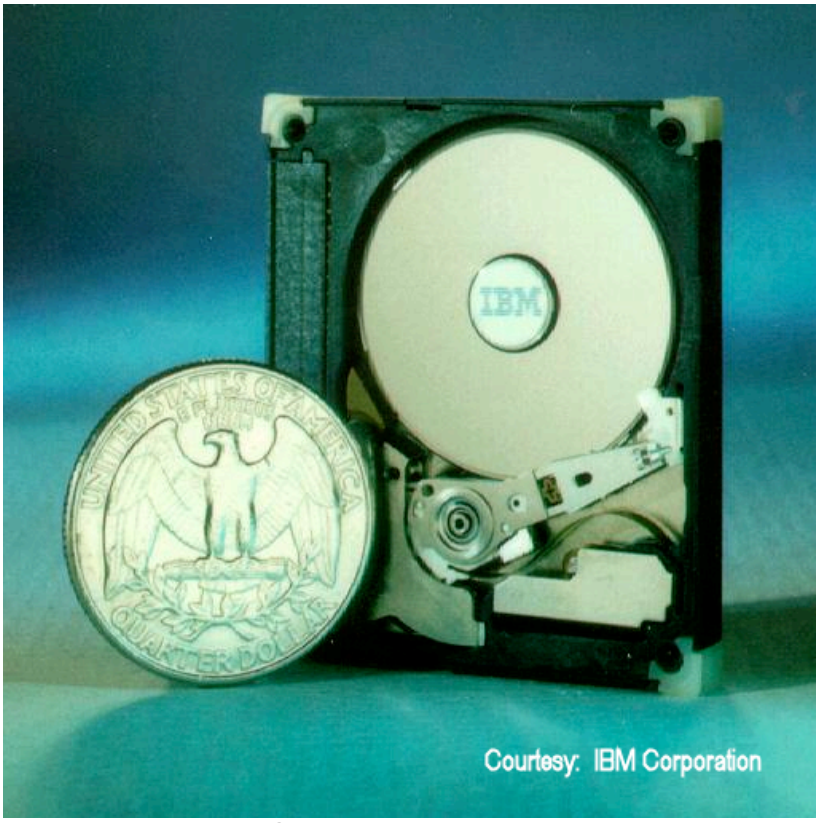
The First 1 Inch Disk Drive
IBM Microdrive 1999

The Microdive was introduced in 1999 with capacities of 170MB and 340MB. Seagate, Western Digital, and a number of startups such as Halo Data Devices, Marqlin, Microstor, RioSpring, and Cornice sought opportunities in the 1-inch marketplace. IBM and its competitors held the market for storage in high-end digital cameras and compact digital music players until rapid progress in solid-state Flash memory brought an end to 1-inch drive production in 2007.



One-inch Microdrive

The concept came out of the IBM Almaden Research Center in San Jose. Tim Reiley, considered the father of the product, envisioned a small form factor disk to provide high capacity storage for mobile devices. Tim's original idea was to exploit micro-electro-mechanical systems (MEMS) for the spindle motor, head actuator, and other components. Two Silicon Valley startups (Halo Data Devices and Marqlin) later received funding based on a similar perspective of the potential of MEMS motor technology.

Several IBM employees played major roles in the product and business development of the Microdrive. Tom Albrecht, also at the Research Center, collaborated closely with Reiley, and guided the project towards the exploitation of miniaturized conventional technologies instead of MEMS (which would have had higher cost and increased technical risk).

Hideya Ino, leader of mobile drive development at the Fujisawa, Japan disk development site, was the first influential executive within IBM to grasp the potential of the 1-inch drive. Ino-san directed a few members of his team to develop working prototypes in collaboration with IBM Research, and used the prototypes to help persuade the storage division's product planning and marketing teams to join him in supporting the project. Mitsuhiko Aoyagi and Kenji Kuroki were prominent among the many technical contributors from the Fujisawa development team that launched the actual product line. Bill Healey and John Osterhout of the Storage Technology Division in San Jose were responsible for business development and product marketing

One key to the Microdrive's success was making it compatible with the existing CompactFlash (CF) standard for removable data storage cards. At the time, CF had emerged as the leading standard among several

competitors, and its disk-like host interface made it a natural choice. There was one major problem. Even though the CF form factor was among the largest for removable storage cards used in cameras, at 3.3 mm it was too thin for a drive.

Fortunately the CompactFlash Association was amenable to the creation of variants to the standard, and a new working group of the association, chaired by Tom Albrecht, defined and introduced the CF Type II form factor. This standard defined a 5 mm thickness and a new CF Plus functional specification which defined the necessary power supply and command infrastructure to support non-storage devices as well as disk drives. CF Plus was a success, with Type II slots becoming commonplace in subsequent years.

Hewlett-Packard's Kittyhawk was a 1.3-inch design which failed in an earlier attempt to sell disk drives into the mobile market. There were other reasons, but one barrier would have been lack of compatibility with a standard such as CF. Another likelihood is that Kittyhawk was too early as the demand from digital cameras and the market for digital music players had not yet emerged in 1992.

The success of the Microdrive was based upon optimal miniaturization of conventional components. It was the technical trends in 2.5-inch and 1.8-inch drives, including the use of ramp load/unload, inertia latches, and head gimbal assemblies with integrated wiring which set the stage for development of the tiny form factor.

Ramp load/unload (a low-cost system for removing the heads from the disk surfaces when the spindle is powered off) was pioneered in the late 1960s by Memorex on its Model 630 disk drive (IBM 2311 plug compatible) and later used by Control Data Corporation, Integral Peripherals, PrairieTek, Quantum and SyQuest, amongst others.

IBM had introduced ramp load/unload in its Travelstar line of 2.5-inch mobile HDDs in 1997. Load/unload was vital for the Microdrive, because it would have been difficult to design a compact spindle motor with sufficient torque to spin up the disk using the Winchester contact start-stop system.

1.8 and 2.5-inch drives could derive emergency power from the spinning spindle motor to retract heads to the ramp in the event of unexpected power loss. The tiny spindle motor of the Microdrive did not provide enough room for windings to generate the necessary counter electromotive force (back-EMF) to get the job done. Instead, a highly efficient pulsed capacitive retraction system was developed. The storage capacitors for power-off retraction were relatively large but using a pulsed retraction system reduced the space they needed.

The bidirectional inertia latch of the 2.5-inch Travelstar line was adopted to maximize robustness to mechanical shock. Earlier styles of inertia latches could, under some circumstances, allow a head parked on the ramp to land on the disk, for example, should the drive be dropped. If there was sufficient stiction from the head sitting on the media, the drive would be rendered inoperative. The optimally scaled bidirectional latch solved this problem, and helped make Microdrive the industry's most shock resistant drive. Another contributor to this achievement was the adoption of fluid bearing spindle motors in later generations. The eventual rating attained was over 1,000G for non-operational shock.

When 1 megapixel digital cameras were introduced in 1998, they signaled the transition from technical gadget to a high-quality image capture device that would eventually replace the film camera. Digital cameras were the first target market for 1-inch drives, and CF Type II slots were included in many of the higher-quality cameras.

Although the Microdrive only captured a small fraction of the storage business for cameras, this market was vital to the product launch. At the time, drives provided higher capacity at a lower cost per megabyte than Flash cards. Even more important to professional markets was the superior write performance that enhanced the speed at which digital cameras could acquire and store pictures.

In the late 1990s, IBM Fellow Steve Hetzler recognized that a small drive could be an ideal storage medium for handheld MP3 players. The typical storage of early MP3 players was 16MB - 64MB Flash memory. This may have seemed more than enough to the product planners but it limited their attractiveness to consumers who wanted much greater capacity.

IBM pursued the idea of disk-based MP3 players with multiple mainline consumer electronics companies, but was rebuffed by all of them because they believed that CD-based MP3 players were the best choice. Apple was not approached, as the company was not a player in consumer electronics at the time.

However, the potential for disk-based digital music players was recognized by Apple. Innovative disk caching approaches, which solved power consumption issues, resulted in players achieving the same long battery life as those that used Flash. Apple became the dominant player after introducing its first iPod with a 5GB Toshiba 1.8- inch drive in October 2001. As Jon Rubinstein, senior vice-president of Apple's iPod division said about the state of disk storage that year:

> *"The key element was the drive," he insists. "Before that, we had two choices - do a big clunky device or do a device that held a dozen songs. Neither made sense. But once I saw the 1.8- inch drive I said, 'Okay, now I know how to do it'."*
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> Tekla S. Perry "From Podfather to Palm's Pilot" IEEE Spectrum/September 2008

To emphasize the dramatic increase in capacity over conventional Flash-based MP3 players, when it was launched, Apple co-founder and CEO Steve Jobs proudly stated: the iPod “puts 1,000 songs in your pocket.”

In 2004, the Apple iPod "mini" was introduced using 2GB and 4GB (and later 6GB) versions of the Microdrive, which resulted in the highest sales volumes ever reached. As the volumes grew, removability and compatibility with the CF standard no longer mattered: the drives designed into digital music players were embedded versions with a flex cable connection. Eventuallly, the disk drives that played such an important role in creating the market for mobile music ceded the market to high capacity Flash memory storage.

The Microdrive capacity catapulted from 170MB in 1999 to 8GB in late 2006. Along the way, in 2003, IBM's disk drive business was merged with that of Hitachi, to form Hitachi Global Storage Technologies (HGST). Seagate and Cornice announced 12GB disks in 2007, but as of mid-2007, no companies were producing 1-inch drives (Cornice announced discontinuation of operations in February 2007).

In a contest with solid state NAND Flash technology, the primary disadvantage of drives is the cost of mechanical components (which includes two motors) and electronics vs the electronics-only cost for a Flash device. The fixed costs of a drive do not scale with physical size. In fact, the miniaturization of components for 1-inch drives resulted in a somewhat higher cost than for larger form factors. Flash could scale down to a much lower cost than a drive, and always commanded the major market share for low-capacity units.

The drive's original write performance advantage over Flash eroded as Flash write time improved at a much faster rate than the disk transfer rate. One perceived disadvantage of Flash is that it suffers from a limited number of write cycles (unlike HDDs, which allow unlimited writing and rewriting of data). However, in the key markets for mobile storage in digital cameras and music players, unlimited writes was not a factor. The 10,000+ lifetime write cycle rating proved to be more than enough for most customers.

The demise of 1-inch drives in 2007 occurred because Flash technology achieved the same or lower cost per megabyte in the capacities achievable in that form factor. It is at the higher capacities where disk drives have retained their price advantage over Flash.

Flash technology has progressed to the detriment of lower capacity drives. As of this writing, the sole remaining small form factor drive is the 1.8-inch drive from Toshiba. Barring unforeseen circumstances, with volume representing less than 0.5% of the 2012 market, production could end in 2013. As solid state Flash and disk drive technology evolve, the crossover point of which costs less will depend on which technology moves faster at lowering the cost per megabyte.

Additional Information:

IBM 340 MB Microdrive announcement