Coughlin Associates

High-Capacity Hard Disk Drives Lower Data Center Total Cost of Ownership (TCO)

Coughlin Associates, Inc.

9460 Carmel Road, Atascadero, CA

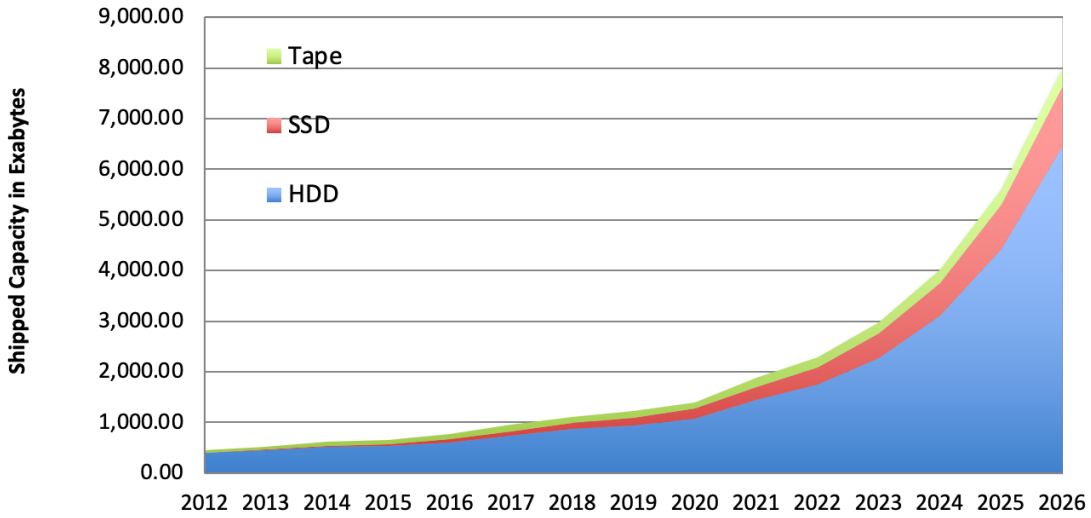
https://tomcoughlin.com

Introduction

The world's demand for data is exploding to meet the needs of an AI, immersive video and internet of things driven future. According to IDC, the cumulative annual growth rate for data generation is 23%[1] and although only a small percentage of this data is retained long term, this is driving the demand for digital storage. Various digital storage technologies are required to retain this data or the results of data analysis. Although solid state drives (SSDs) using NAND flash memory are becoming the primary storage in client, industrial and data center (cloud) applications, their higher cost for storage capacity means that less active data is stored on less expensive storage, in particular hard disk drives (HDDs).

This is good because modern high-capacity HDDs provide a lower total cost of ownership (TCO), consume less power and generate less heat per unit of capacity than lower capacity HDDs. Thus modern HDDs contribute to sustainable data centers. Sustainability has become an important metric for companies and data center sustainability is an important element in reaching many companies' overall sustainability goals.

The bulk of the world's data lives on HDDs. The figure below[2] shows historical and projected annual shipped storage capacity for SSDs, HDDs and magnetic tape. In 2021, we estimate that about 77% of the shipped storage capacity was in HDDs, rising to about 81% by 2026.



All storage media are growing in storage capacity to meet their customer's demands to more effectively manage data, at lower cost per byte. This is enabling the digital transformation of all industries and has driven the growth of hyperscale cloud services, including cloud storage. As the costs of digital storage go down, more data can be kept at the same cost, which might otherwise have been discarded. Data retention, curation and management are vital capabilities for organizations to compete in today's market.

Western Digital (WDC) supplies both SSDs and HDDs at scale for a variety of applications. In the nearline high-capacity HDD market that enables the cost-effective storage of the world's cloud data, the company

[1] Data Creation and Replication Will Grow at a Faster Rate than installed Storage Capacity, According to the IDC Global DataSphere and StorageSphere Forecasts, https://www.idc.com/getdoc.jsp?containerId=prUS47560321

[2] Digital Storage Technology Newsletter, May 2022, Coughlin Associates, Inc., https://tomcoughlin.com/product/digital-storage-technology-newsletter/

is a pioneer in developing high storage capacity and performance. This enables the continued growth and lower cost of cloud storage.

HDD innovations are critical for data @scale

Because of the competition and ever lowering prices for digital storage technologies, none of these technologies can stand still. Constant innovation is required to lower storage costs, increase capacity, improve performance in critical areas, reduce power consumption and even to provide CPU offload capabilities with computing in or near the storage devices. HDDs continue to have the $/TB cost advantage over SSDs, particularly for enterprise and data center applications where nearline HDDs are over 8X less expensive per byte than comparable enterprise SSDs.

This cost difference is what drives demand for HDDs for the bulk of cloud storage. However, the initial cost of the storage device is only one factor in lowering total cost of ownership of storage.

Innovations are needed to reduce digital storage costs:

There are many considerations in HDD design and characteristics that impact TCO for their use in data centers. These include the storage capacity in a given HDD, the overall storage density in the data center, the number of HDDs managed for a given storage capacity, the energy consumed for various HDD operations, the heat generated by the HDDs, the replacement rate for the HDDs, the HDD utilization and the HDD performance and data access time. Another important consideration in the choice of storage technology is the utilization requirements for the physical data storage.

Often times data centers use several types of digital storage together. For instance, data accessed frequently may live on higher performing SSDs, while colder data lives on HDDs. The individual workload for a particular application using digital storage may determine how much data is stored on the SSDs versus in less expensive HDDs. For instance, data storage near the network edge may live in a very different environment than inside a large data center and because of the environment and because this data is in active use, SSDs may be used, rather than HDDs.

Wherever it is stored, many organizations would store and keep more data if they could. This is because modern data analysis algorithms, including artificial intelligence (AI), can process lots of data quickly. The results of that processing are often more accurate when more good data is available. This is particularly true for various types of AI, such as machine learning. Lowering the overall cost of storage enables an organization to retain more valuable data.

Factors in the total cost of ownership

Let's look a bit deeper at the various factors that determine the costs of storge and how today's higher capacity HDDs reduce the costs of retaining data. The figure below shows the various elements that go into a storage TCO model[3].

According to the Storage Networking Industry Association (SNIA), "We define a TCO model that is well suited for storage by looking at the capital expenditures (CapEx) of the storage and everything else in typical datacenter rack that has typically dominated IT budgets, and model operational expenditures

[3] Total Cost of Ownership Model for Storage, https://www.snia.org/forums/cmsi/programs/TCOcalc

(OpEx) which are dominated by power, cooling, and cost of device failures. This is useful for comparing a solution where the sole purpose is durable storage[3].”

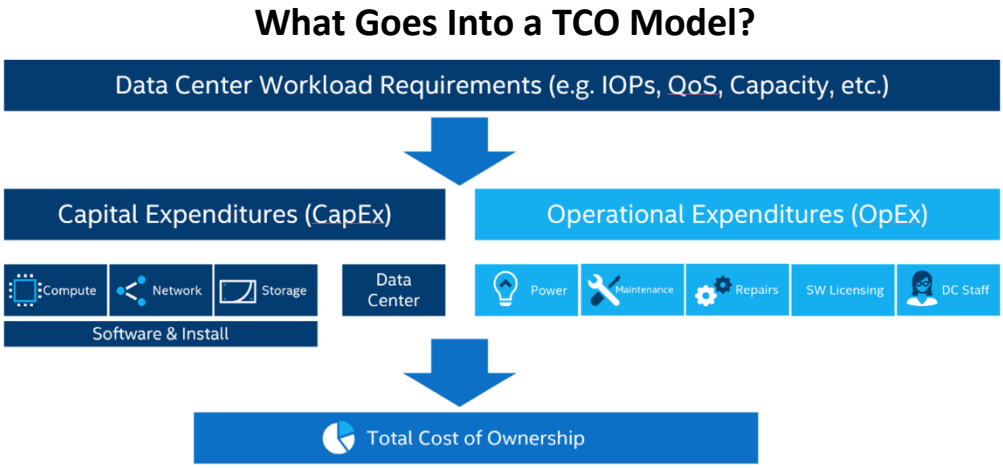


Image used with permission from SNIA CMSI

The first factor to consider in calculating a TCO is that the costs of storing a certain amount of data over a period of time includes the initial purchase price of the storage media (the HDDs) and various other equipment required to provide and operate the storage system that the media are part of. Higher capacity HDDs allow storing this data on fewer HDDs. This eliminates the extra costs to purchase and maintain additional HDDs to meet storage capacity needs. It also reduces the costs of the energy that would be required to power the additional lower capacity HDDs and to remove the heat generated by those additional lower capacity HDDs.

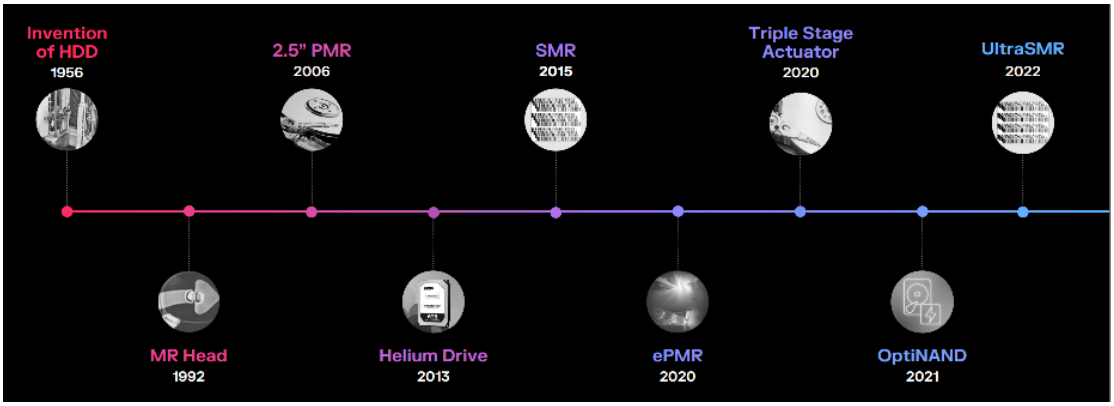
With higher capacity HDDs, a given amount of rack space can support more storage capacity and the extra networking and server equipment required to support the additional lower capacity HDDs is not required, lowering the total costs of the storage system. These various factors lower costs for a given amount of storage i.e., more storage capacity in a smaller data center space, reduced heat generated per TB of data, reduced maintenance of HDDs for a given storage capacity and less networking and server equipment costs. All of this favors a lower TCO when using higher capacity HDDs.

However, some applications may not need large data sets and smaller HDDs may work just fine, although they won’t scale like higher capacity HDDs. Also, some storage systems may include a lot more parallel access between the HDDs to create higher overall aggregate performance with some additional costs to provide that parallelism. Many other users will use more expensive SSD storage for the more active data with HDD storage in the background to retain less active data at lower costs. Thus, the actual TCO for a user’s storage system includes a lot of variables and trade-offs, making it difficult to do a precise calculation.

Western Digital recently made a comparison between storage systems using the company’s 16TB HDDs versus its new 22TB HDDs. The storage system using 22TB HDDs required 27% fewer servers and had 26% lower energy consumption, in Watts/TB, to store the same amount of data.

Western Digital innovations that address TCO factors

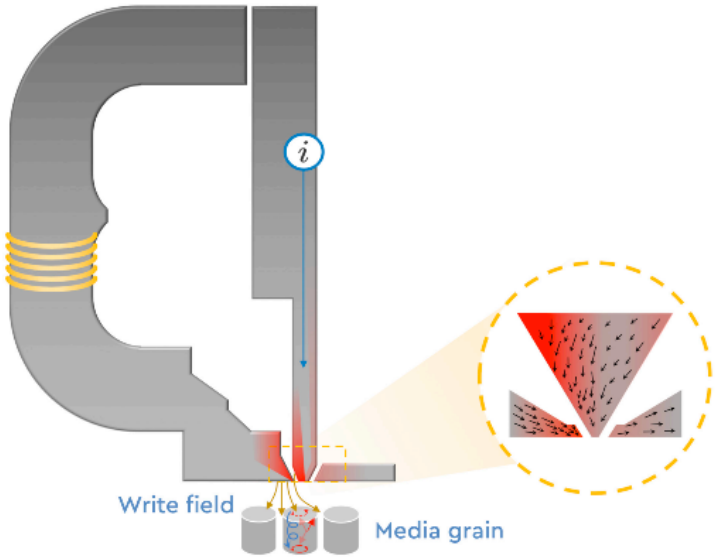
Western Digital can trace its HDD business history back to 1956 (through its acquisition of HGST in 2013) with the introduction of the first digital hard disk drive by IBM for its 305 RAMAC computer. The figure below shows a timeline for some of the HDD advances made by Western Digital and its predecessor companies.



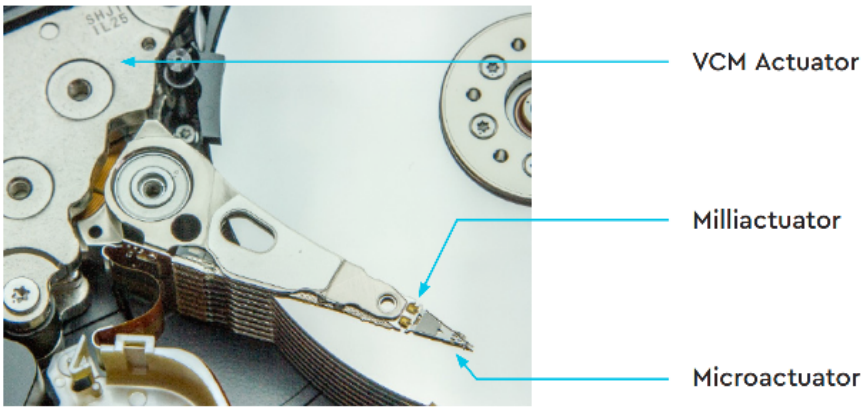
In 2013, Western Digital was the first company to introduce hermetically sealed HDDs that were filled with helium (He) gas, the company's Helioseal® technology. Helium is much less dense than air, and as a consequence, sealed He-filled HDDs create less turbulence and drag on the rotating disks in the HDD. This reduces the energy required to rotate these disks and allows the use of thinner disks so more disks and heads can be used in a given form factor HDD. More disks mean higher capacity per HDD. At the time of the announcement, the company said that the there was a 23% power reduction for the He-filled HDD compared to conventional air-filled HDDs and when the additional two disks in the He-filled HDD were taken into account the improvement in watts-per-TB was 45%. He-filled HDDs also run cooler, 4 degrees C cooler for the Helium-filled drives, requiring less energy to remove the heat they generate from a data center. The combination of more storage capacity per drive and lower energy consumption mean that He-filled HDDs provide a better TCO and their use results in a more sustainable data center. Let's look at other ways that Western Digital is increasing their HDD storage capacity and thus lowering the TCO of HDD storage.

In 2020, Western Digital introduced its initial version of energy assisted magnetic recording (ePMR) in its HDDs. As the size of the magnetic recorded bits get smaller, the natural thermal fluctuations in the environment can cause pieces of these bits to spontaneously reverse. Over time, these reversals degrade the recorded magnetic information. To combat this thermal decay, HDDs must use magnetic media that requires a much higher magnetic field to record on them (higher coercivity media). The write element in HDD heads is not capable of generating these fields and so cannot write on this media without help. Energy assisted magnetic recording will be needed to write on this high coercivity media.

Western Digital will eventually use heat-assisted magnetic recording (HAMR) to achieve the highest recording areal densities, but its initial energy-assisted products, starting in 2020, used a bias current during writing to stabilize the transitions during the magnetic recording in order to achieve higher storage areal densities. Western Digital calls this technology energy-assisted perpendicular magnetic recording, or ePMR. ePMR increases storage density and reliability by reducing jitter in the write element of the head and allowing for more accurate and consistent data placement, thereby increasing tracks per inch (TPI) and bits per inch (BPI). The image below shows the write bias current applied to enable Western Digital's ePMR. ePMR provides a bridge between conventional PMR and HAMR.



Also in 2020, Western Digital introduced its triple stage actuator for more accurately positioning the read/write head elements over the recording track on the rotating disks. The triple stage actuation starts with the movement of the heads across the disk surface using the voice coil motor (VCM), a milliactuator close to where the head suspension is attached to the actuator arm. This provides finer motion control and a microactuator located under the ceramic "slider" that contains the head read and write elements, which provides the most precise motion control. The positions of these three actuators are shown below.



Triple actuation with optimized firmware enables faster access to data and also helps in achieving higher track densities and thus greater storage capacity per disk.

In 2021, Western Digital introduced its OptiNAND™ technology, leveraging the company's NAND flash in the HDD PCBA to enhance the drive functionality. OptiNAND integrates an iNAND® Universal Flash Storage (UFS) Embedded Flash Drive (EFD) with traditional spinning disk media, and incorporates innovative changes to the firmware algorithm and system-on-a-chip (SoC). This reimagined storage architecture will enable new innovations, forming the basis for future capacity, performance and reliability gains.

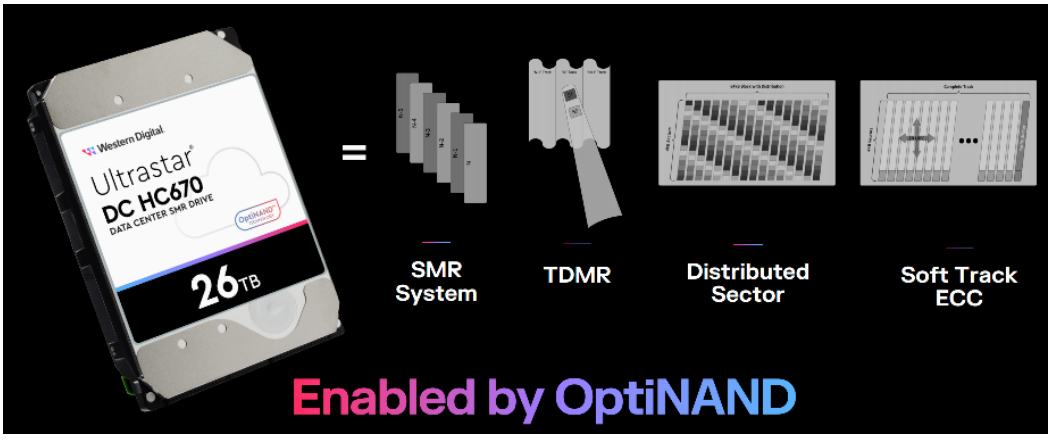
OptiNAND uses the drive system on chip (SoC) to control communication with the iNAND flash drive. Key drive housekeeping functions take advantage of the higher flash memory capacity to store more metadata

than is feasible on convential HDDs. HDDs can generate gigabytes of metadata that can be stored on the OptiNAND. This metadata can be accessed faster than if it was stored on the HDD and is used to enhance the performance and storage capacity of the HDD. Also, storing the metadata in the NAND flash frees up additional capacity on the HDD for storing user data. Faster metadata access allows faster HDD performance.

ArmorCache™ technology, enabled by OptiNAND, provides enterprise power loss protection in write cache enabled (WCE) mode for the first time in HDD history. In addition, it boosts write cache disabled (WCD) mode performance to be equal to WCE mode, which allows systems that previously required WCD mode for power-safe operation to no longer pay a performance penalty for choosing WCD mode. The capacity and performance improvements of OptiNAND and ArmorCache improve HDD TCO.

Western Digital introduced its first shingled magnetic recording (SMR) HDDs in 2015. Shingled magnetic recording partially overwrites a previously written track of data with a new data track. This allows a higher track density (number of tracks per length of the disk radius) and thus a higher HDD capacity that non-SMR (often called conventional magnetic recording or CMR) HDDs. The figure below illustrates an implementation of zones of SMR tracks in an SMR HDD compared to the isolated tracks in a CMR HDD.

Normally SMR drives using the same configuration as a CMR drive can get about 10% higher track density, and thus a 10% higher drive storage capacity. As shown in the figure below, using OptiNAND and advanced signal processing algorithms with special data sector placement, a 22TB CMR drive can be turned into an SMR drive with 26TB (18% higher than the CMR HDD). Western Digital calls this SMR technology UltraSMR.



Conclusions

HDDs store the majority of the world's data, particularly in data centers. Continuing advances in HDD technology by Western Digital will enable this continued TCO advantage, helping to store the coming data tsunami and enable business growth.

Using the combination of helium-sealed HDDs with CMR energy assisted magnetic recording (ePMR) and OptiNAND technology, Western Digital started shipping a 10-disk 22TB nearline HDD in July 2022, available for various markets but with enterprise and big data centers as a major market. Using its UltraSMR technology, the company increased that capacity by 18% to 26TB on its SMR HDD version.

Using these technologies and eventually, new types of energy assisted magnetic recording, much higher storage areal density HDDs are possible, resulting in HDD capacities over the next few years that could store up to 50TB of data. These high-capacity HDDs will supply the capacity needed to enable organizational digital transformations and emerging business models with a lower TCO and more sustainable data centers.

About the Author

Tom Coughlin, President, Coughlin Associates is a digital storage analyst as well as a business and technology consultant. He has over 40 years in the data storage industry with engineering and management positions at several companies.

Dr. Coughlin has many publications and six patents. Tom is also the author of Digital Storage in Consumer Electronics: The Essential Guide, which is now in its second edition with Springer. Tom publishes the *Digital Storage Technology Newsletter, the Media and Entertainment Storage Report*, the *Emerging Non-Volatile Memory Report* and other industry reports. Tom is also a regular contributor on digital storage for Forbes.com and other blogs.

Tom is active with SMPTE, SNIA and the IEEE, (he is Past Director for IEEE Region 6, Past President of IEEE USA, Past Chair of the IEEE New Initiatives and Public Visibility Committees and active in the Consumer Electronics Society) and other professional organizations. Tom was the founder and organizer of the Storage Visions Conference (www.storagevisions.com as well as the Creative Storage Conference (www.creativestorage.org). He was the general chairman of the annual Flash Memory Summit for 10 years and is currently Program Chair. He is a Fellow of the IEEE and is Chair of the Consultants Network of Silicon Valley (CNSV). For more information on Tom Coughlin and his publications and activities go to www.tomcoughlin.com.

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