HDD Is The Backbone Of The Data Center

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An Explosion Of Data And Storage

- Worldwide data creation[1] 132.4ZB in 2023 to 393.9 in 2028
- Installed data storage capacity[2] 9.3ZB in 2023 to 19.2ZB in 2028

- Large but currently unsized tailwind of AI likely

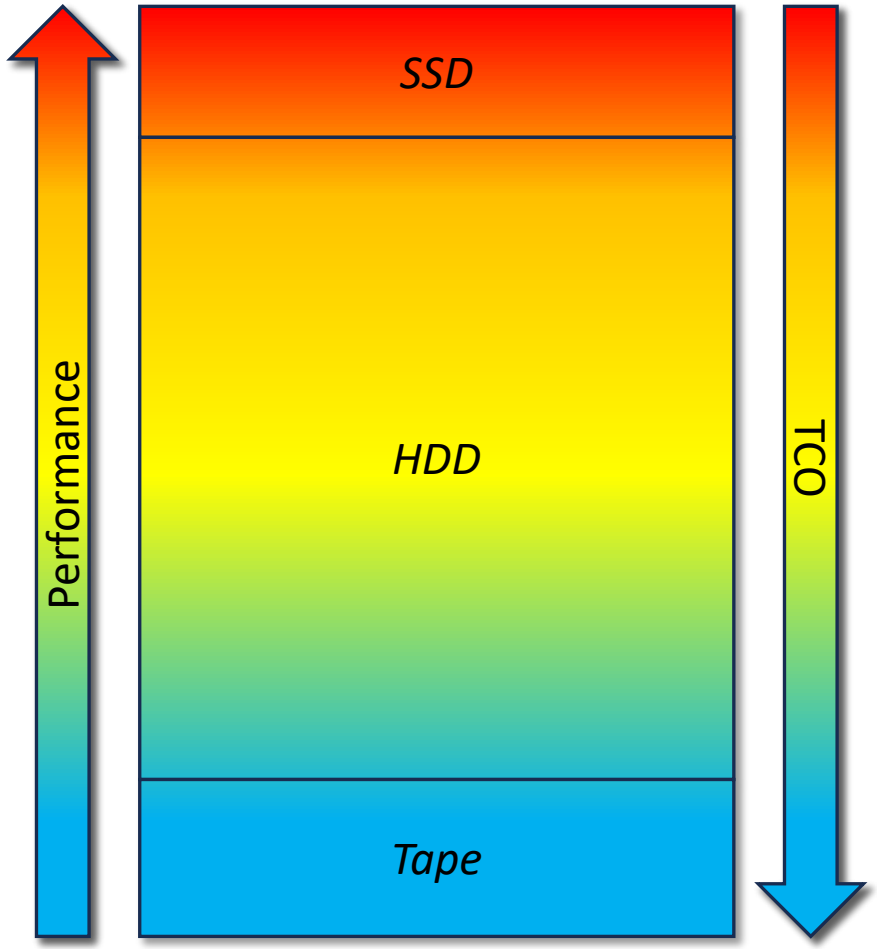
- Dominant storage tech (HDD/SSD/Tape) will each comprise a slice of this storage pie…

  …but the pie is growing!

1. Source: IDC Global Datasphere Forecast, 2024-2028, May 2024, US52076424
2. Source: IDC Worldwide Global StorageSphere Forecast, 2024-2028, June 2024, US52312824

Different Needs Depending On Workload

- Modern datacenter will have multiple coexisting storage tech based on performance and TCO needs:
  - SSD: Blazing performance, high $/TB
  - HDD: High performance, moderate $/TB
  - Tape: High latency, low $/TB
- Largest tier is the “warm” middle suitable for HDD; HDDs comprise nearly 80% of WW installed DC capacity[1]
- Within tier, storage decisions made based on TCO



1. IDC Revelations in the Global Storagesphere Aug 2023

Typical Workloads

- SSD: Transactional, hot, small payload, high IOPS, <<latency
  - “Data Warehouse”—structured data requiring high random read/write
  - Cache tier for oft-retrieved data
  - Data requiring machine-level latency
- HDD: Throughput, warm, large payload, sustained
  - “Data Lake”—unstructured, raw data
  - Sequentialized data
  - Data requiring human-level latency
- Tape: Cold/archival data not needing fast retrieval
  - Archival, regulatory data
  - Air-gapped immutable storage

TCO Basics

- TCO is dominated by the storage devices, as measured by $/TB
  - Assuming modern software-defined storage deployment
  - Compute, networking, power consumption, storage density, maintenance all order-of-magnitude smaller factors than $/TB[1]
- $/TB of HDD is highly advantageous; capacity enterprise HDD vs enterprise SSD >6x gap
  - System-level TCO gap can be 3x or higher[1]
  - System-level CapEx gap can be 4x or higher[1]

- *Question: What is the history and future of HDD $/TB?*

1. WD Internal TCO Model

A Trip Down “Memory” Lane

- HDD capacities increased 530% and $/TB fell 81%[1] from 2014->2024

Product	Ultrastar 7K6000	Ultrastar He10	Ultrastar HC690	Change
Year Introduced	2014	2016	2024	
Capacity	6TB[2]	10TB	32TB	530%
Internal Fill	Air	Helium	Helium	
# Disks	5	7	11	220%
TB/Disk	1.2	1.4	2.9	240%
Recording Tech/Format	PMR/CMR	PMR/CMR	ePMR/UltraSMR	

1. WDC historical data, Capacity Enterprise HDD Segment, inflation adjusted
2. One terabyte (TB) is equal to one trillion bytes. Actual user capacity may be less due to operating environment.

The Future Of HDD Storage

- Traditional PMR recording approaching limits of the “superparamagnetic limit”, aka the “trilemma”
  - Limitations of materials used in head/media construction; particularly a limit to the writer maximum magnetic field strength
- HDD industry on the cusp of mainstreaming heat-assisted magnetic recording (HAMR)
  - HAMR avoids the trilemma by heating media past its Curie temperature, allowing it to be written with conventional field strength while resisting bit flip once cooled
- Advanced Storage Research Council (ASRC) projecting[1] HAMR enables 20% CAGR areal density capability (ADC) past 2030
  - Roadmap towards technologies like HDRC, HIMR, and BPM
- Comparison: NAND GB/wafer projected[2] to increase 19.4% CAGR, similar to HDD annual ADC gain

1. A new Advanced Storage Research Consortium HDD Technology Roadmap, 2022
2. TechInsights NAND Market Report Q3 2024

The Final Word

- A rising tide lifts all boats, and the size of the storage pie is growing.
  - Need to deploy multiple ZB/year for data storage installed capacity growth and replacement of decommissioned capacity
  - The future for SSD is very bright. The future for HDD is *also* very bright. Heck, even the future of tape is bright!
- The goal is to align the right storage technology with the optimal performance and TCO for each workload
- HDD has a significant (and expected to be persistent) TCO advantage compared to SSD. Thus the nearly 80% of data center workloads currently adequately supported by HDD can continue to be so in the future.
  - This mix may change as workloads change, but warm storage tier isn't going away
- In short: *Customers will use HDD where they **can**; SSD where they **must**.*

Thank You