THE CAPACITY ERA

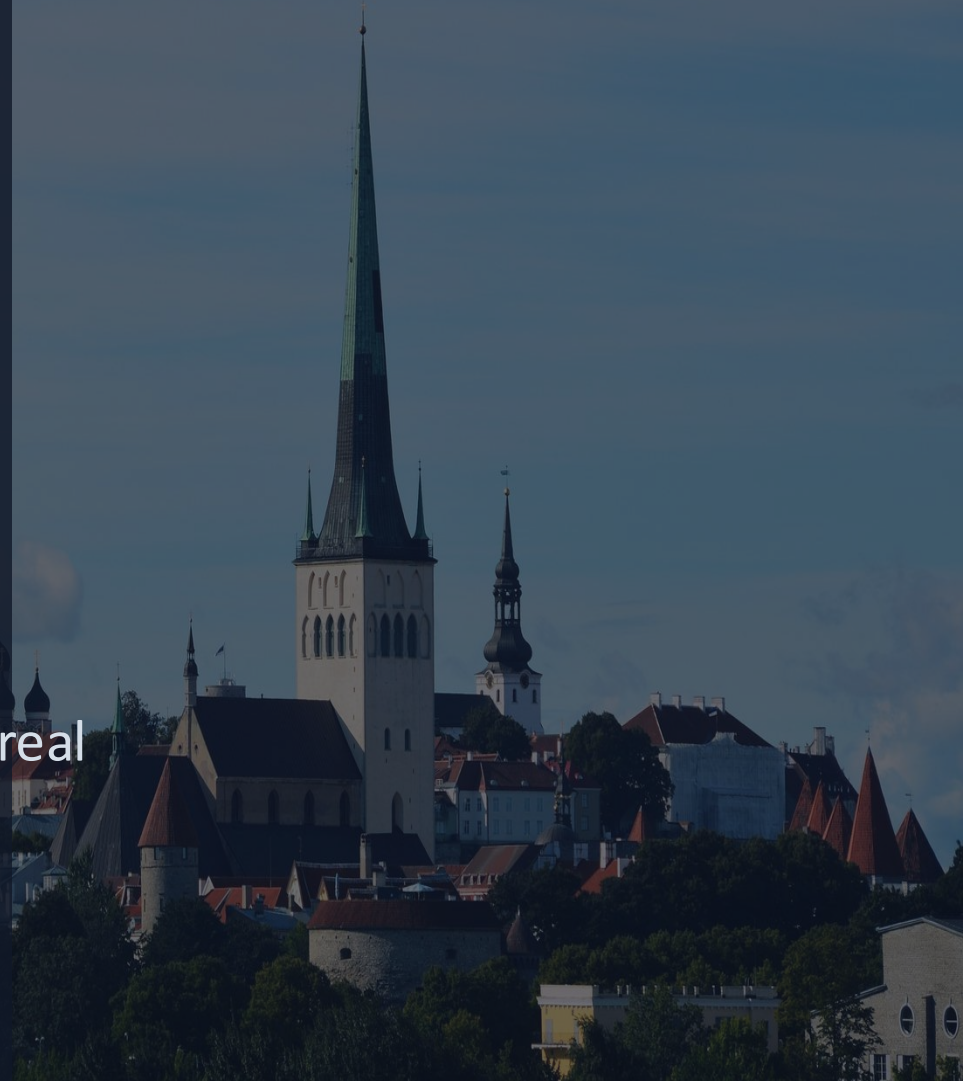
Storage Days Tallinn

31 August – 1 September 2026

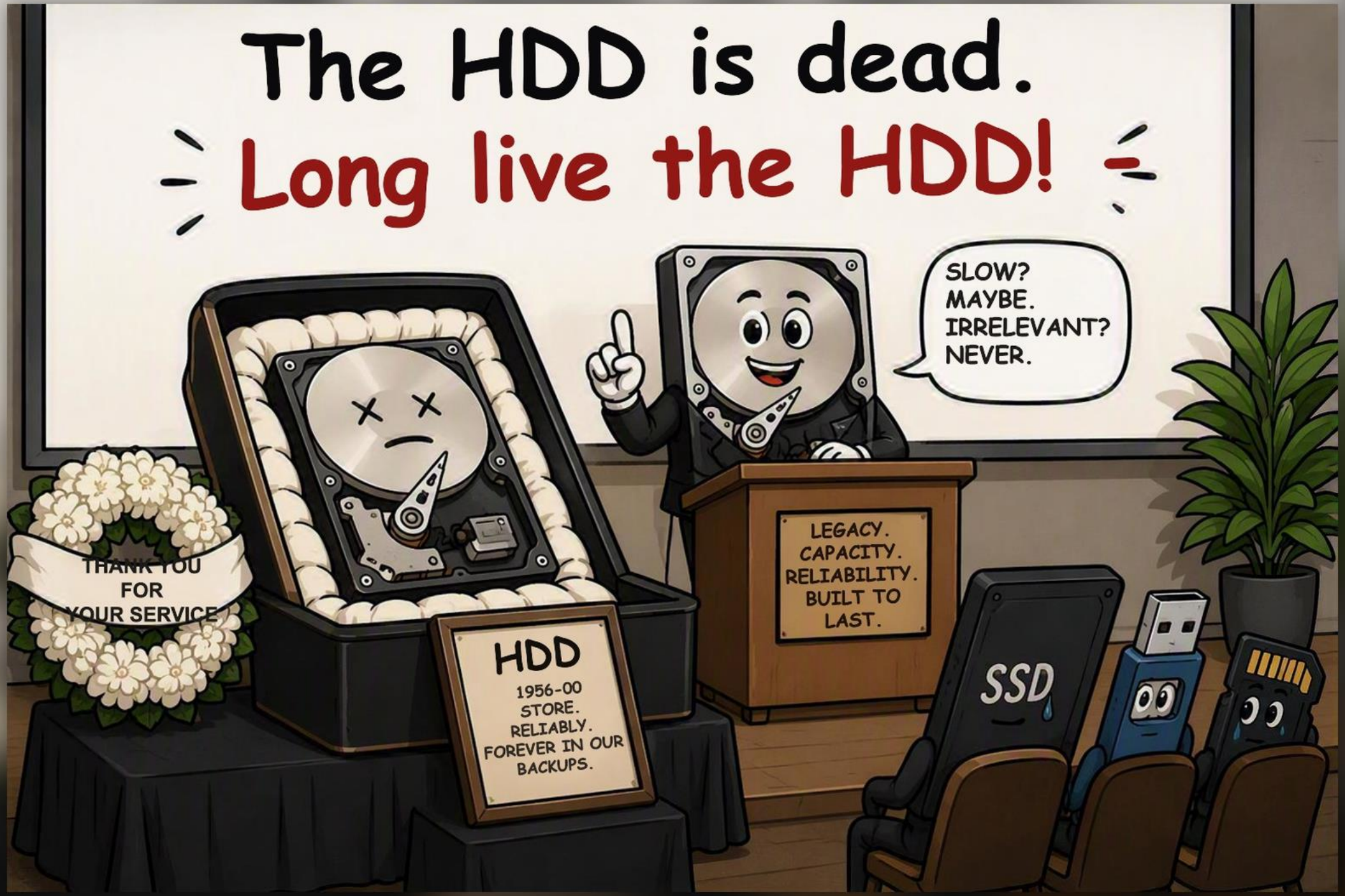
TALLINN, ESTONIA

Data Growth Meets Physics

The Race to 100 TB HDD Capacity – Innovations that make it real



Uwe Kemmer Director EMEAI Field Engineering


The HDD is dead.
Long live the HDD!
SLOW?
MAYBE.
IRRELEVANT?
NEVER.
LEGACY.
CAPACITY.
RELIABILITY.
BUILT TO
LAST.
THANK YOU
FOR
YOUR SERVICE
HDD
1956-00
STORE.
RELIABLY.
FOREVER IN OUR
BACKUPS.
SSD

Agenda

01 HDDs in the AI area

02 Future Technology for
- Higher capacity
- Better performance
- Lower power consumption

03 New HDD Features
- Head Depop
- Variable Capacity

Optimize Capacity, Performance, and Power

Capacity-Optimized

Store more data, same footprint

Performance-Optimized

Increase throughput, same interfaces

Power-Optimized

Reduce power consumption, same chassis

AI is Changing Storage Requirements

WHAT AI SYSTEMS NEED

- Data at Scale
- Reliability & Durability
- Cost Efficiency
- Performance
- Power Efficiency

THE RIGHT ARCHITECTURE BALANCES

- Performance
- Capacity
- Economics

Increase Capacity Without Expanding Your Footprint

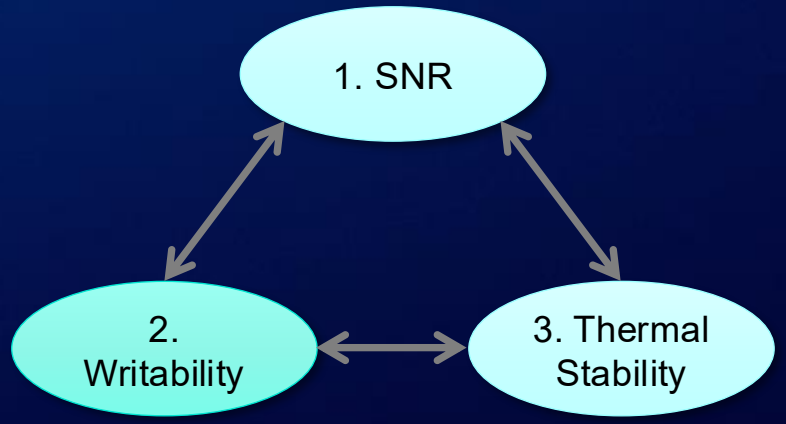
ePMR → 60TB

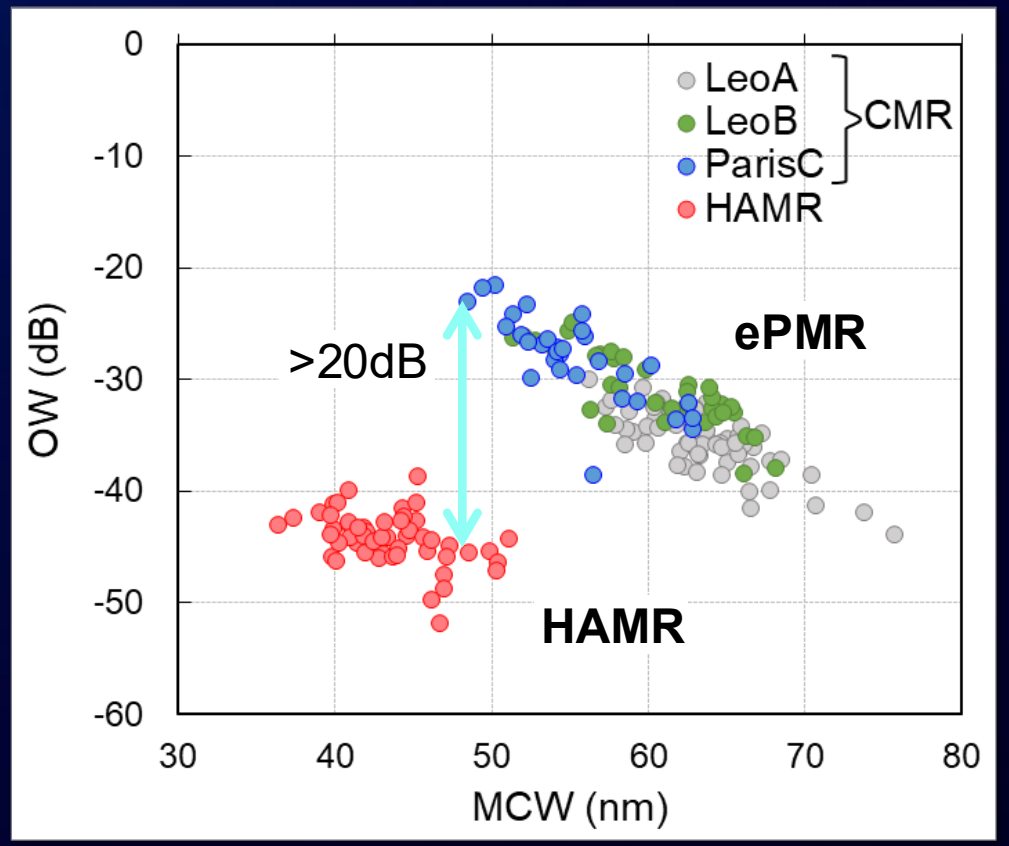
HAMR → 100TB → Beyond

The Bottleneck: Areal Density Limits

Trilemma:

1. High Signal-to-Noise-Ratio (SNR) requires small grains
2. Small grains can be made easy to write (good writability)
3. BUT small thermally stable grains are very difficult to write

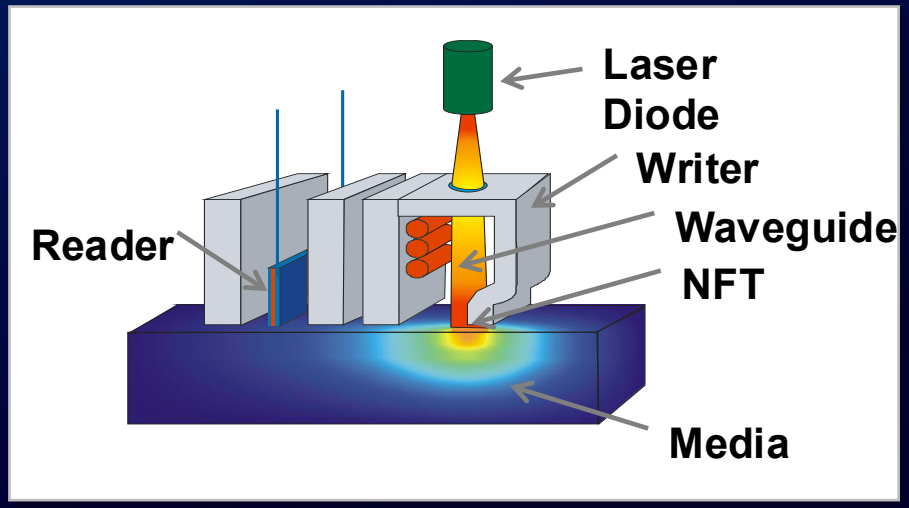




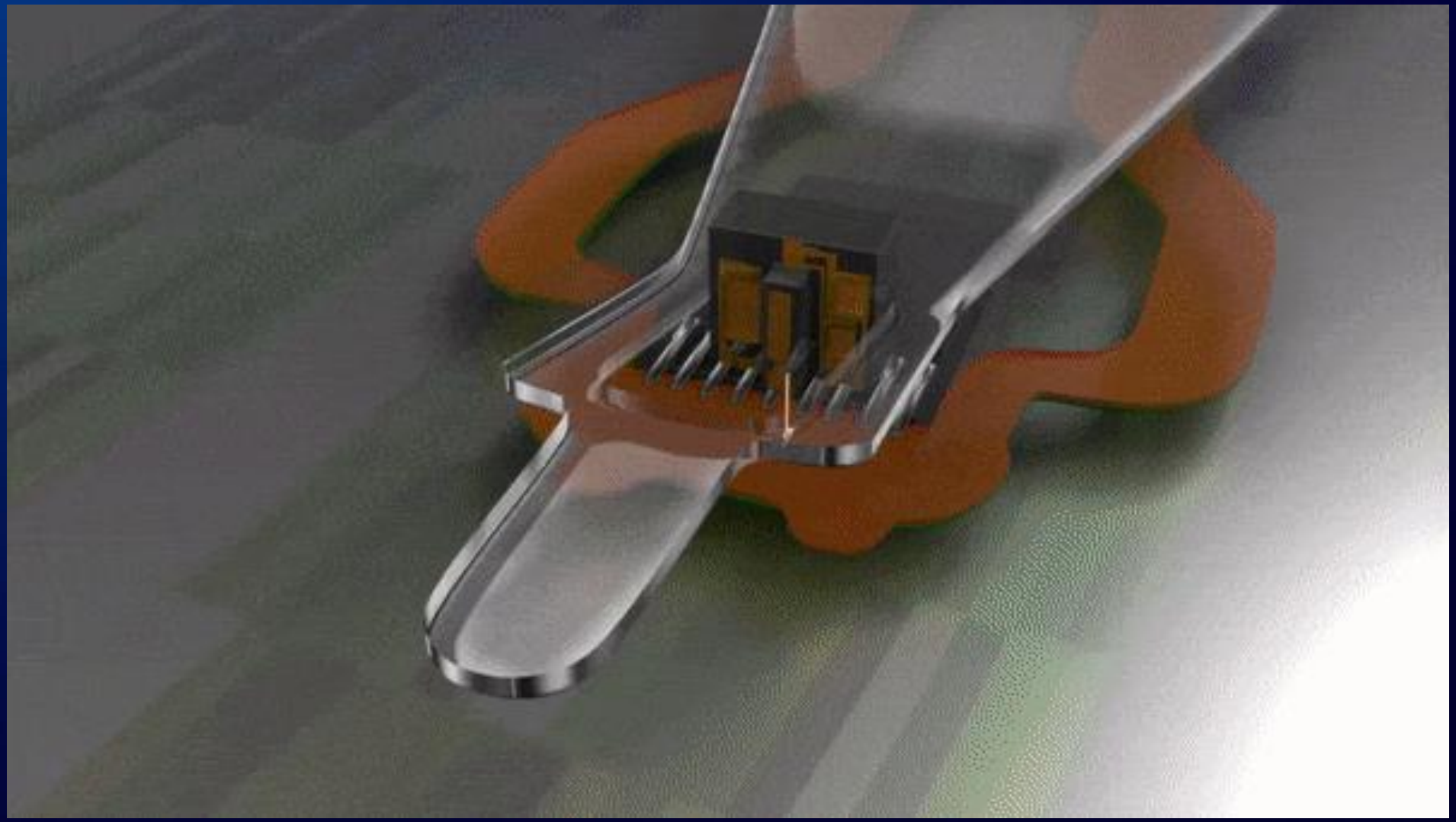
Solution: HAMR breaks the trilemma

The Breakthrough: HAMR

1. Laser-light travels through the waveguide
2. Waveguide delivers to light to the Near-Field-Transducer (NFT)
3. NFT converts the light to plasmons
4. These plasmons excite the HAMR media to very briefly heat it up
5. While hot, the magnetic writer can magnetize the media (→ writing)
6. Media quickly cools so the data is ‘frozen’ in place at extremely high density



HAMR (Animation)



The Unique Anatomy of WD's HAMR Drive

4TB
per Platter

44TB
per Drive

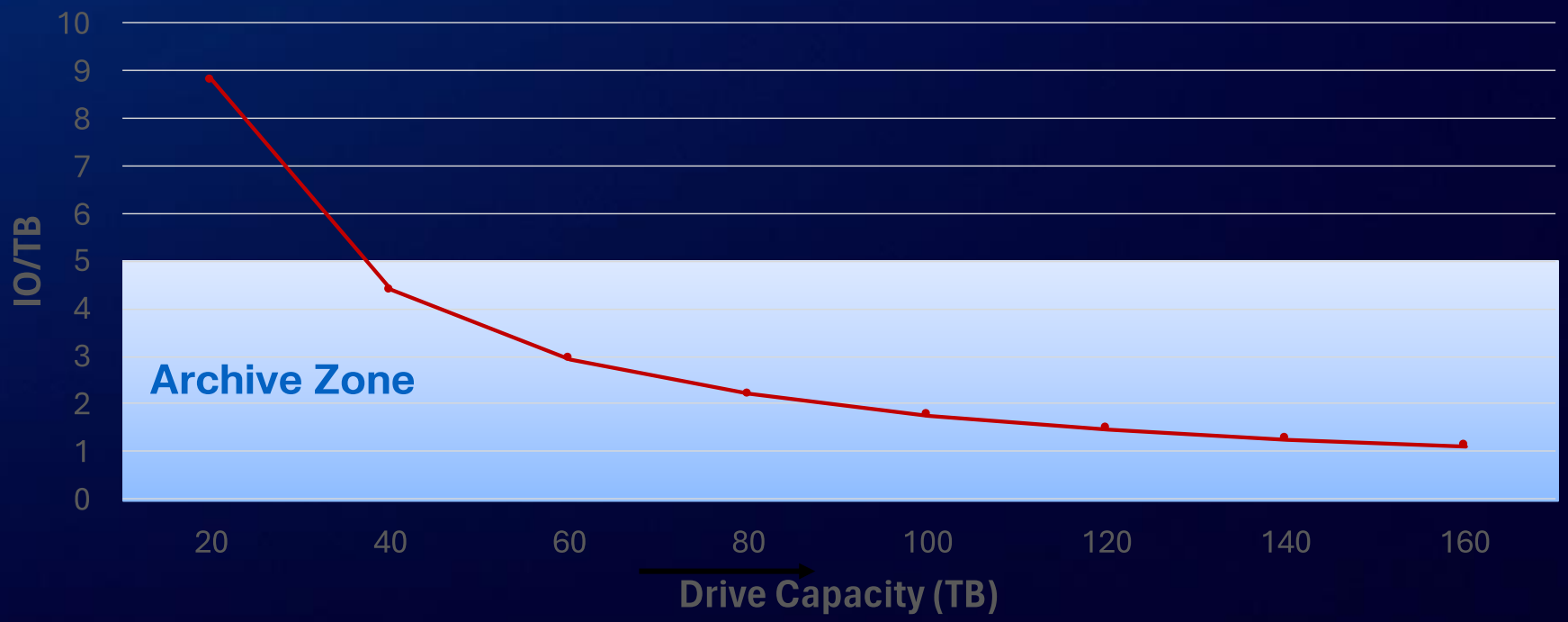
Same architecture,
increased areal density

Performance Drives

Delivering throughput advances while preserving HDD economics

Performance Drives

- Declining IO/TB is unstoppable
  - How to achieve customer acceptance?
- SMR will be the first casualty due to garbage collection performance loss



INDUSTRY FIRST

Dual Pivot Technology

Doubles the number of transactions per second

Dual Pivot: More Performance Without Re-Architecting

01

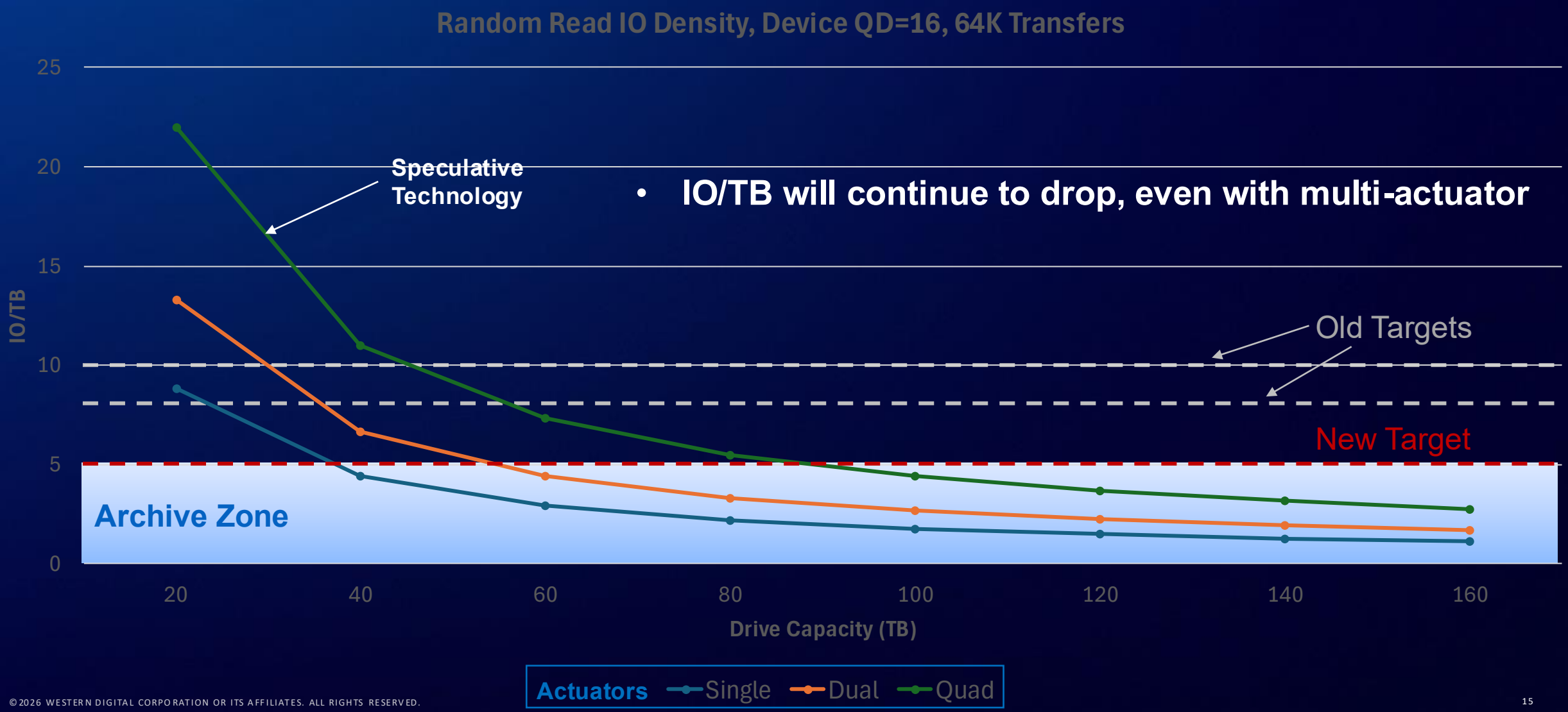
No changes to

- Power infrastructure
- Software stack
- Enclosures

02 **Improve performance**

03 **Maintain operation stability**

IO/TB Downward Trajectory is Unstoppable



INDUSTRY FIRST

High Bandwidth Drive Technology

2x Bandwidth already demonstrated

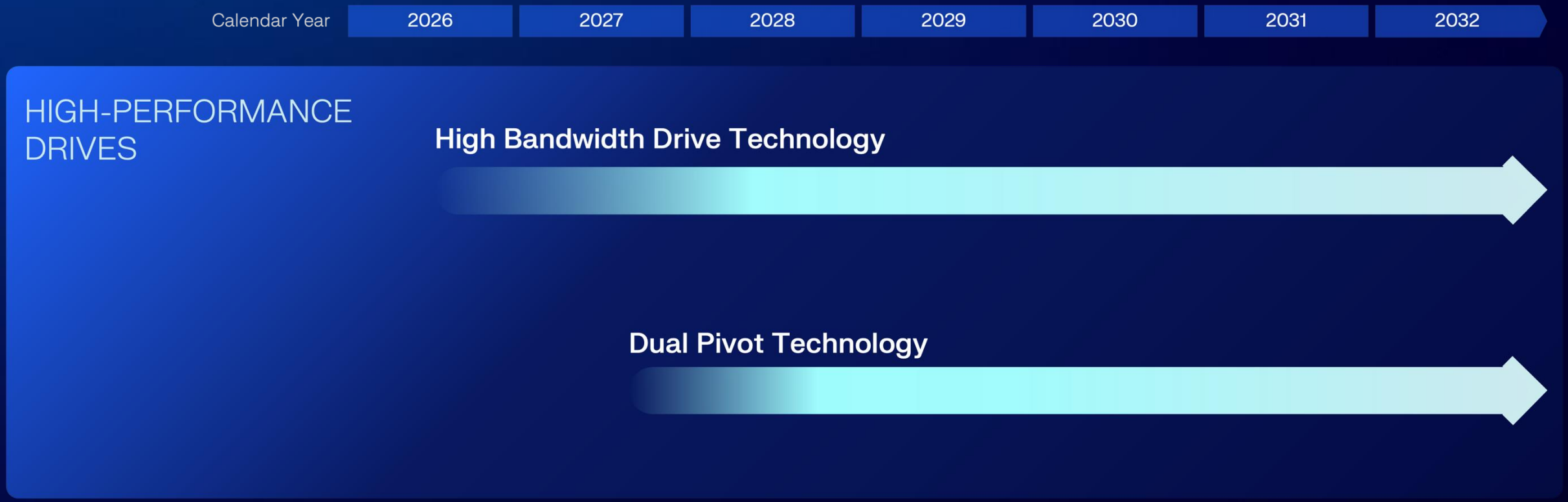
8x Bandwidth planned by 2030

High Bandwidth Drive: Performance For AI Workloads

01	Better TCO
02	Optimized for AI pipelines
03	High throughput for AI Data
04	Reduce reliance on Flash
05	Balance performance with cost efficiency vs QLC

Performance Drives

Combining Our New Technologies to Maintain 6–10x Cost Advantages vs. QLC as Capacities Grow



Power Optimized Drives: Lower the Cost of Storing and Retaining AI Data

- 20% Power savings
- 10% Increased capacity
- Improved TCO
- Ideal for long term data retention and archive

The Roadmap to 100TB+

Logical Depop: Keeping Drives Online

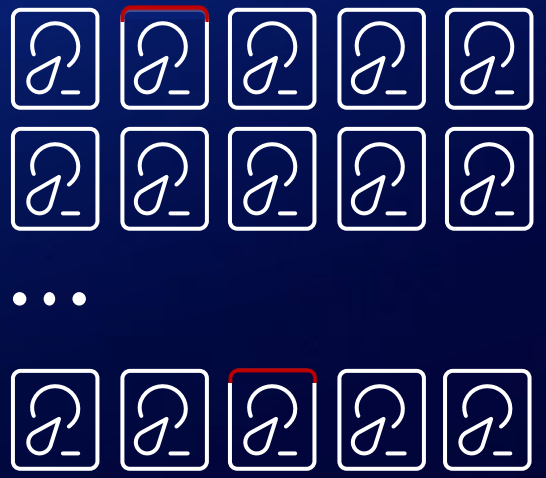
STANDARD DRIVES

100% of drive capacity lost

- 0% of each broken drive's capacity remains online
- Drive data is lost
- Time to replace a broken drive is days / weeks
- Increased cost of labor, handling risk, and downtime cost

LOGICAL DEPOP

~5% of drive capacity lost*



- ~95% of a broken drive's capacity could remain online
- Drive data is lost
- Time to resolution is a day for CMR and a couple of hours for SMR
- Capacity is restored automatically, no human required
- Reduce operational costs for logistics, technicians, and replacements

*Assumes a 20-head drive

CMR: Remove Element And Truncate (Repurposing Depop)

Remove Element (=Head) And Truncate is commonly referred to as RDP (repurposing depop).

REAT is the destructive member of the Repurposing-Depopulation (RDP) command family that removes one physical storage element (head) and then shrinks the drive's customer-addressable capacity.

EFFECTIVELY, IT DOES 3 OPERATIONS

01

Moves any reserved area files off the head being removed

02

Removes the head from the logical head map

03

Re-formats the drive (using a normal Format process)

SMR: Remove Element And Modify Zones (Data Preserving Depop)

Remove Element and Modify Zones is commonly referred to as DPDP (data preserving depop).

Unlike REAT, REMZ is not a data-destructive capacity-reducing operation for the surviving heads: it logically depopulates one head/element from a 100 % SMR drive, marks the affected zones offline and commits the predicted-error information for the media cache on that head — but the rest of the drive keeps its data. No internal Format Unit is enqueued.

EFFECTIVELY, IT DOES 4 OPERATIONS

01

Moves any reserved area files off the head being removed

02

Updates any zones on the affected head to “Offline”

03

Mark Zones that us Media cache on depoped head with Predict error information

04

Removes the head from the logical head map

Restore Elements And Rebuild (Repurposing Repop)

Restore Elements And Rebuild is commonly referred to as Repop (repurposing repopulation).

REAR is the counterpart to REAT and REMZ: it repopulates (“rebuilds”) storage elements that were previously logically depopulated by an RDP and DPDP operations and triggers a full (or fast) format so the drive can operate again at full / a larger capacity. It is customer-data destructive.

EFFECTIVELY, IT DOES 3 OPERATIONS

01

Restores all the heads previously removed by in-field Depop or DPDP in the logical head map

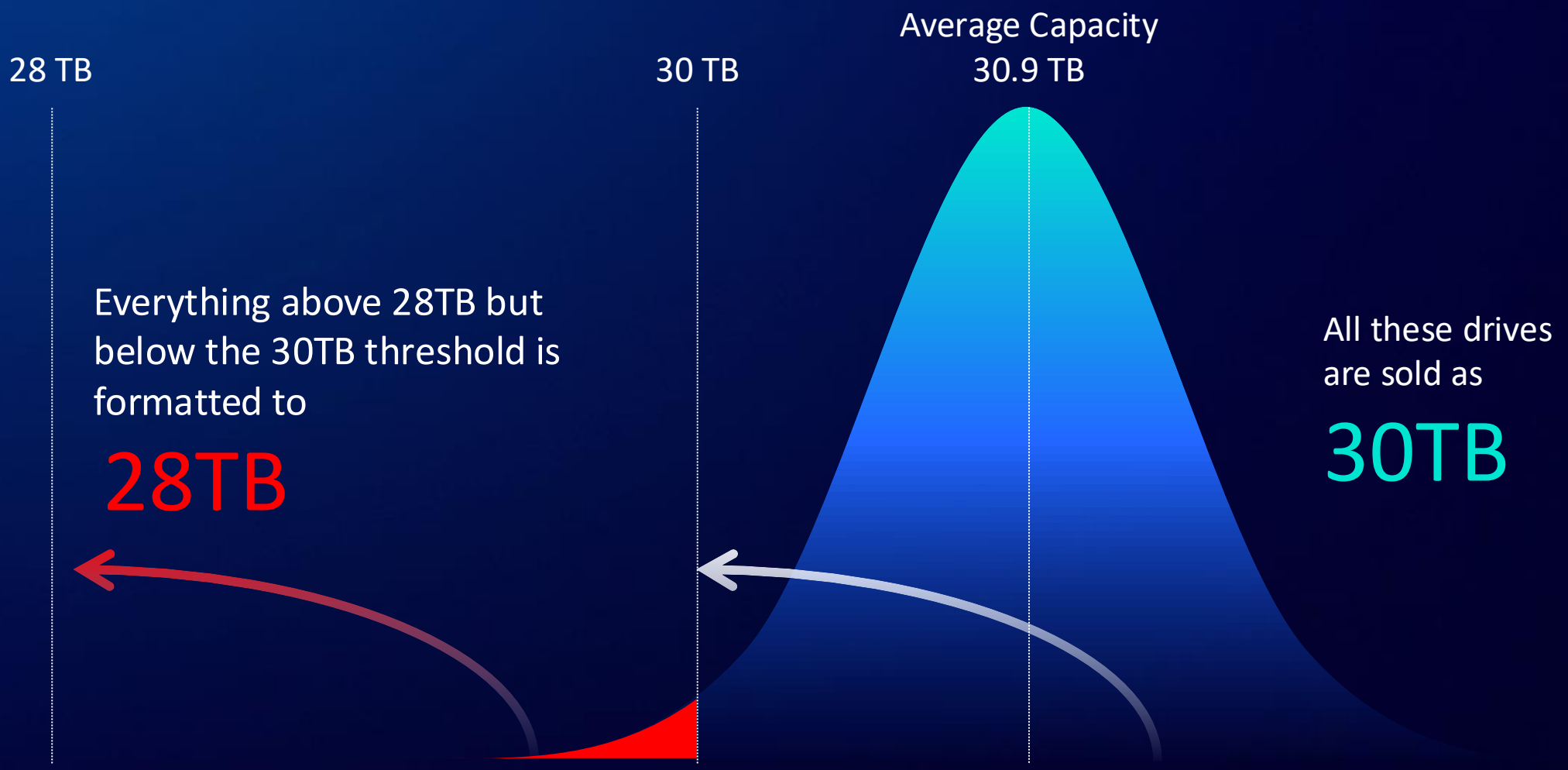
02

Moves any reserved area files back to the head they were removed from.

03

Re-formats the drive (using a normal Format process)

Variable Capacity: Increase Usable Capacity



Variable Capacity

01

One part number, a range

Unlike fixed capacity which is 1 part number = 1 capacity, Variable Capacity is 1 PN = a range of capacities in 0.5TB increments.

02

What a 30TB-VC contains

30TB-VC, will be a mix of [30, 29.5, 29, 28.5, 28].

03

Less capacity left on the table

The key benefit to Variable Capacity is that more capacity per drive is available. Drive capacities are usually made in 2TB increments. Up to 1.999 TB can be wasted. By offering 0.5TB increments, WD can make available more capacity to customers.

04

When fixed capacity is right

Some use-cases (like RAID) may not be able to take advantage of Variable Capacity. For those customers and use-cases, traditional fixed capacity is the right choice.

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Thank you

Questions and discussion

Uwe Kemmer Director EMEAI Field Engineering

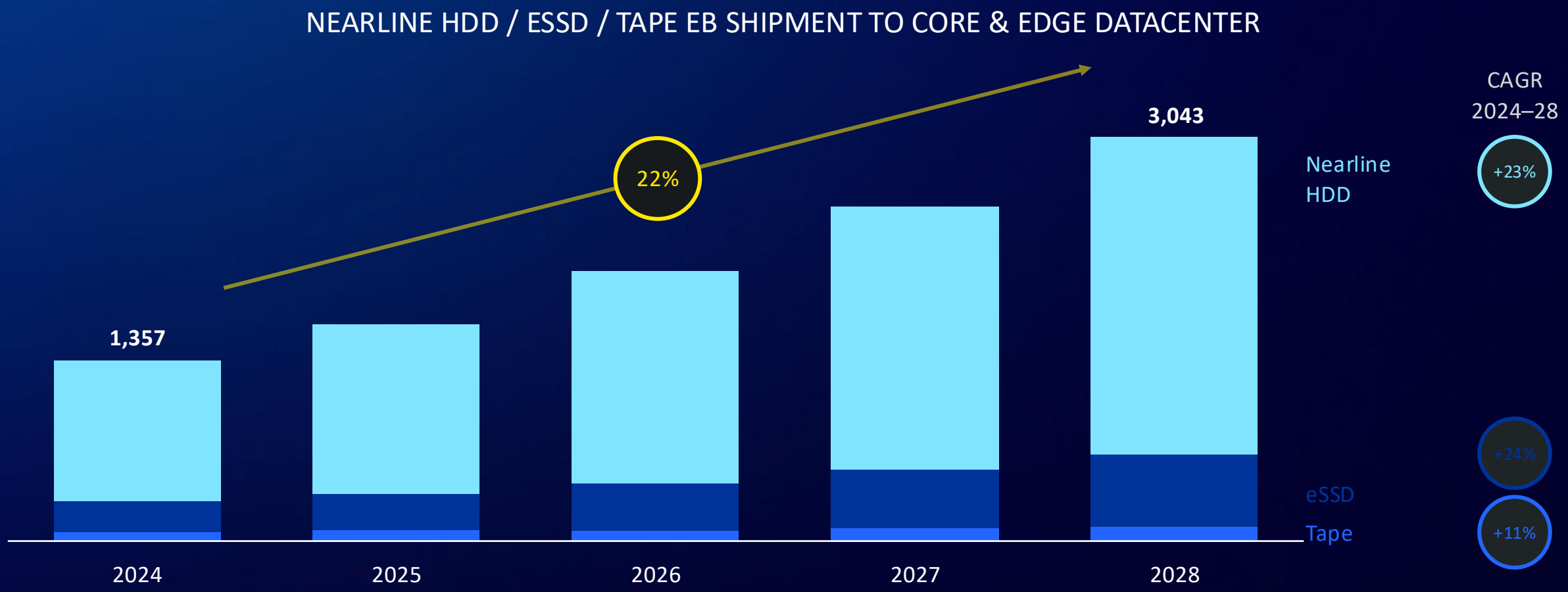
Uwe.Kemmer@wdc.com +49-170-2293628 · https://www.westerndigital.com

HDDs Are the Foundation of AI / Cloud Data Storage

80% of storage within the cloud is based on HDDs

Source: IDC, Worldwide Global StorageSphere Forecast, 2025–2029

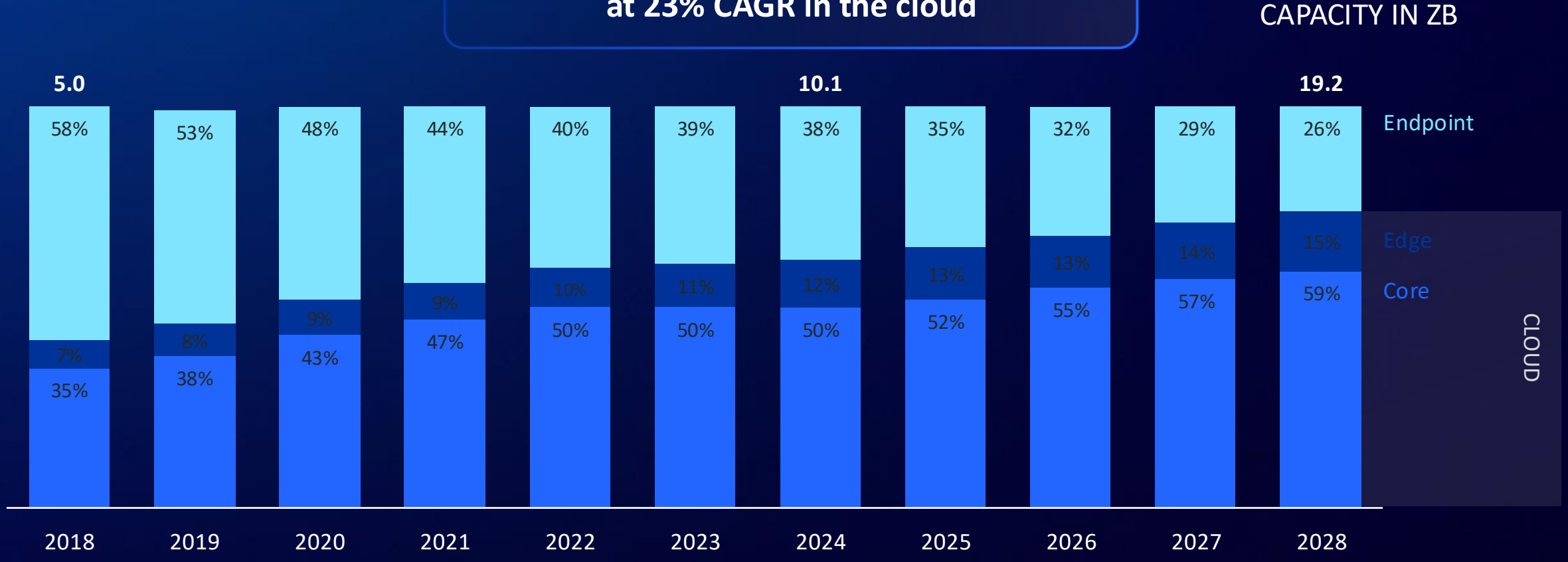
HDD Is the Undisputed Leader in Storage



Sources:
Worldwide IDC Hard Disk Drive Forecast, 2024–2028, doc #US52746924, December 2024
Worldwide IDC Solid State Drive Forecast Update, 2024-2028, doc #US51688124, December 2024
Trendfocus Tape & Archive Storage service, CQ3'24 Quarterly Update, December 2024

Installed Storage in the Cloud Will Continue to Grow

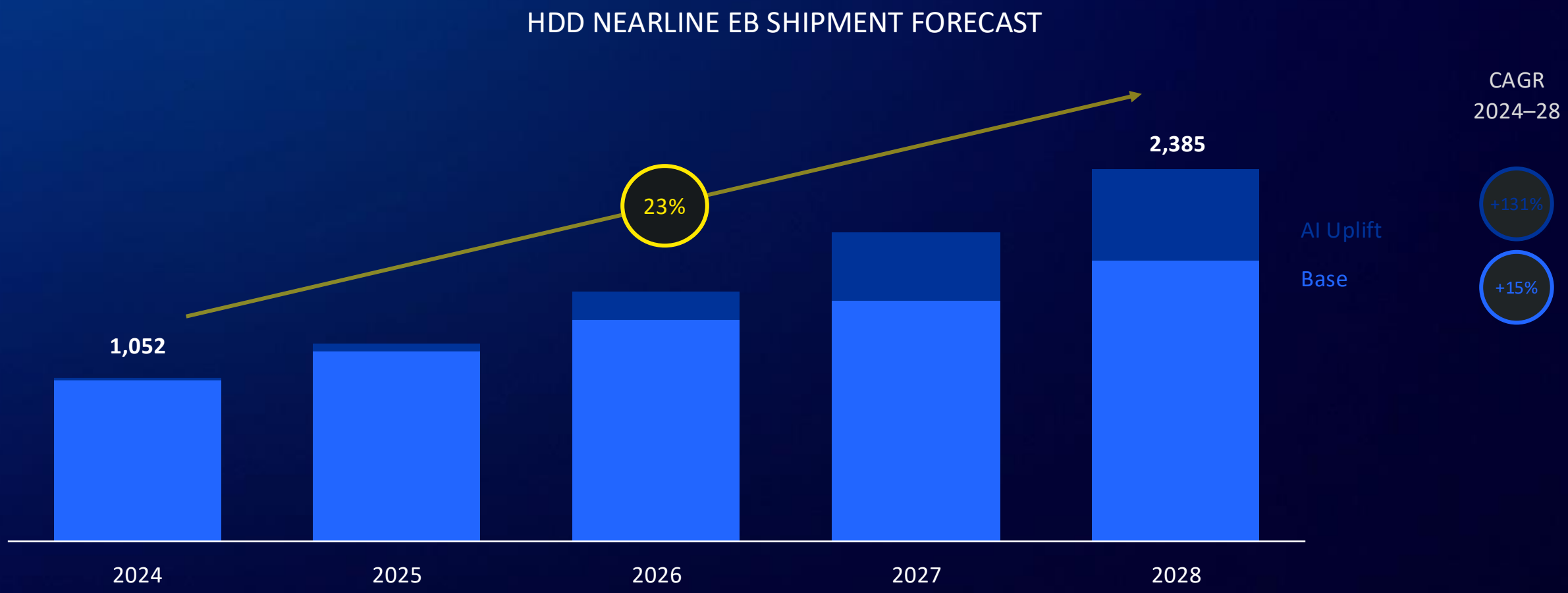
2024–2028 installed base storage will grow at 23% CAGR in the cloud



Source: Worldwide IDC Global StorageSphere Forecast, 2024-2028, doc #US52076424, May 2024

Examples: Core = Datacenter for large enterprise, hyperscale service providers and social media, Edge = in-store controllers, telecom substations, branch offices, enterprise gateways
Endpoint = client devices such as PC, smartphone and tablet, autonomous vehicles, video surveillance recorder

AI Will Boost HDD Nearline TAM



Sources:
For total EB Worldwide IDC Hard Disk Drive Forecast, 2024–2028, doc #US52746924, December 2024
For Base and Uplift, WDC internal estimates