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The Benefits of Flash in Enterprise Storage Systems

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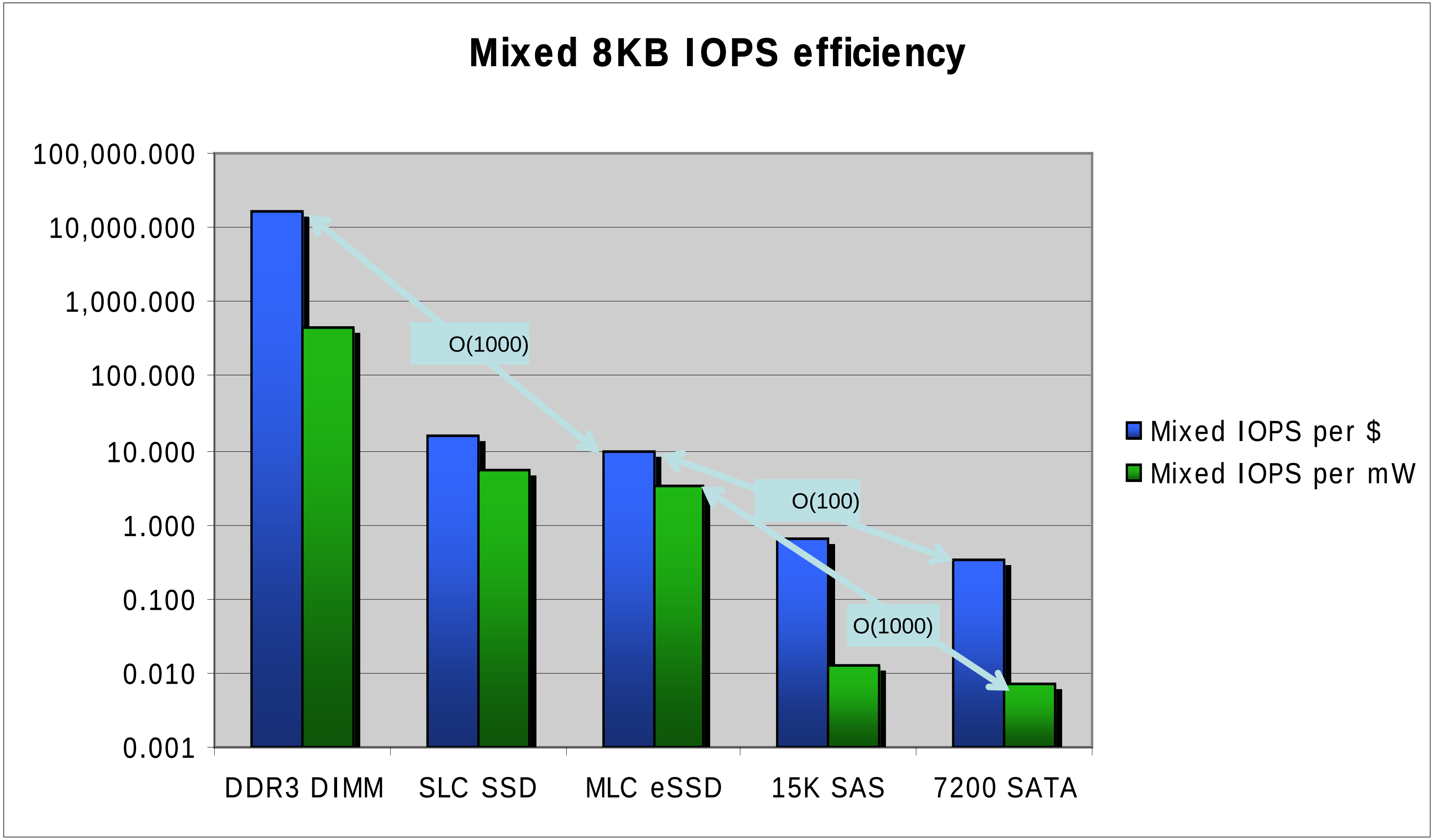
Agenda

- Why flash in the datacenter? Why now?
- Memory, cache and storage
- Flash in enterprise storage today
  - Hybrid arrays; SSD storage tier
  - Storage controller-based cache
  - Flash in host systems
  - All-flash arrays
- What's next
- Conclusion

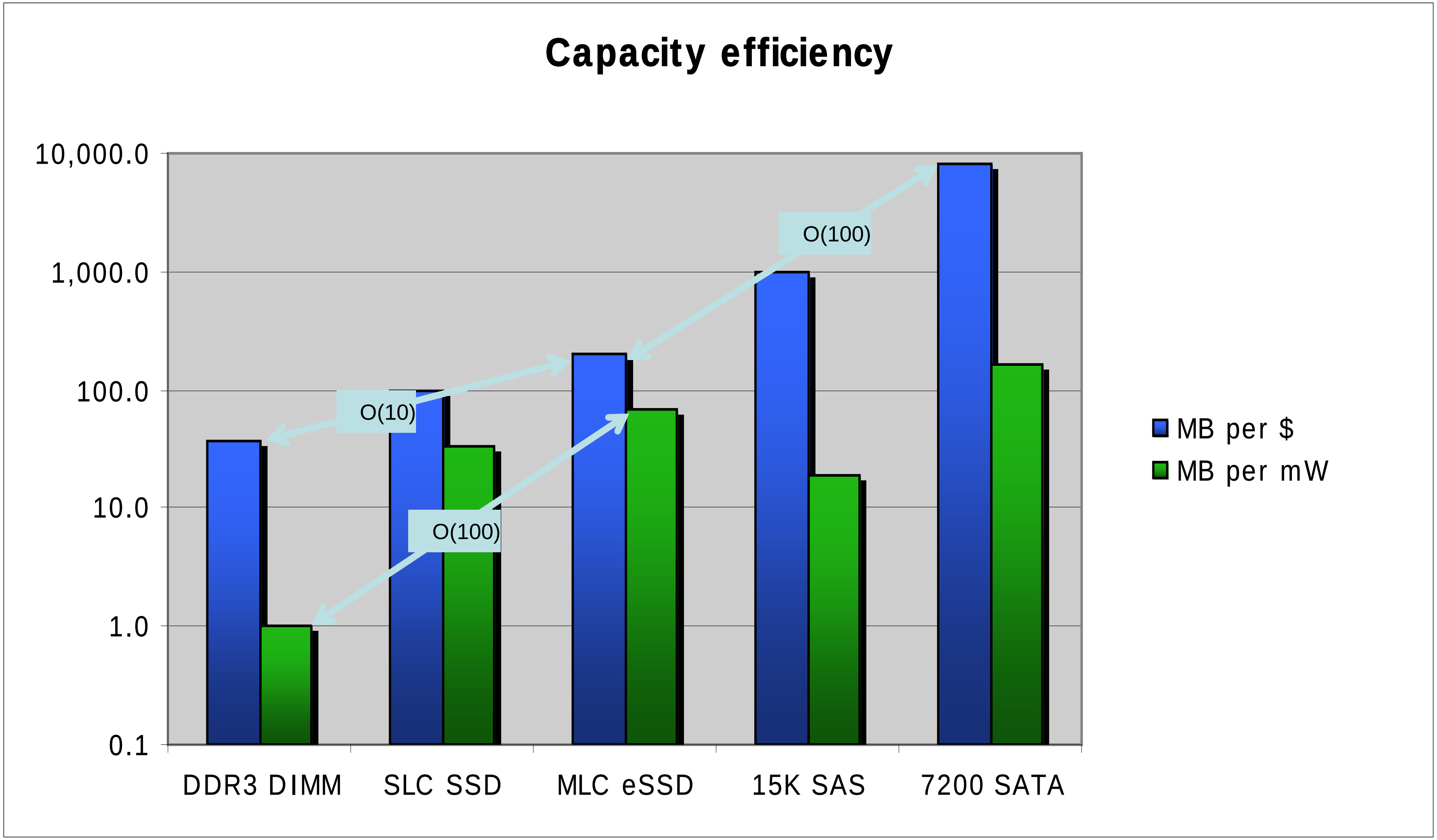
Why Flash in the Data Center?

- **Why flash?**
  - Capacity efficiency versus DRAM
    - ~5x better $ per GB
    - ~40x better power per GB
  - IOPS efficiency versus HDDs
    - ~40x better $ per IOPS
    - ~600x better power per IOPS
- **Why now?**
  - Period of rapid density advancements led to HDD-like bit density at lower $/GB than DRAM
  - Innovations in SSD and tiering technology

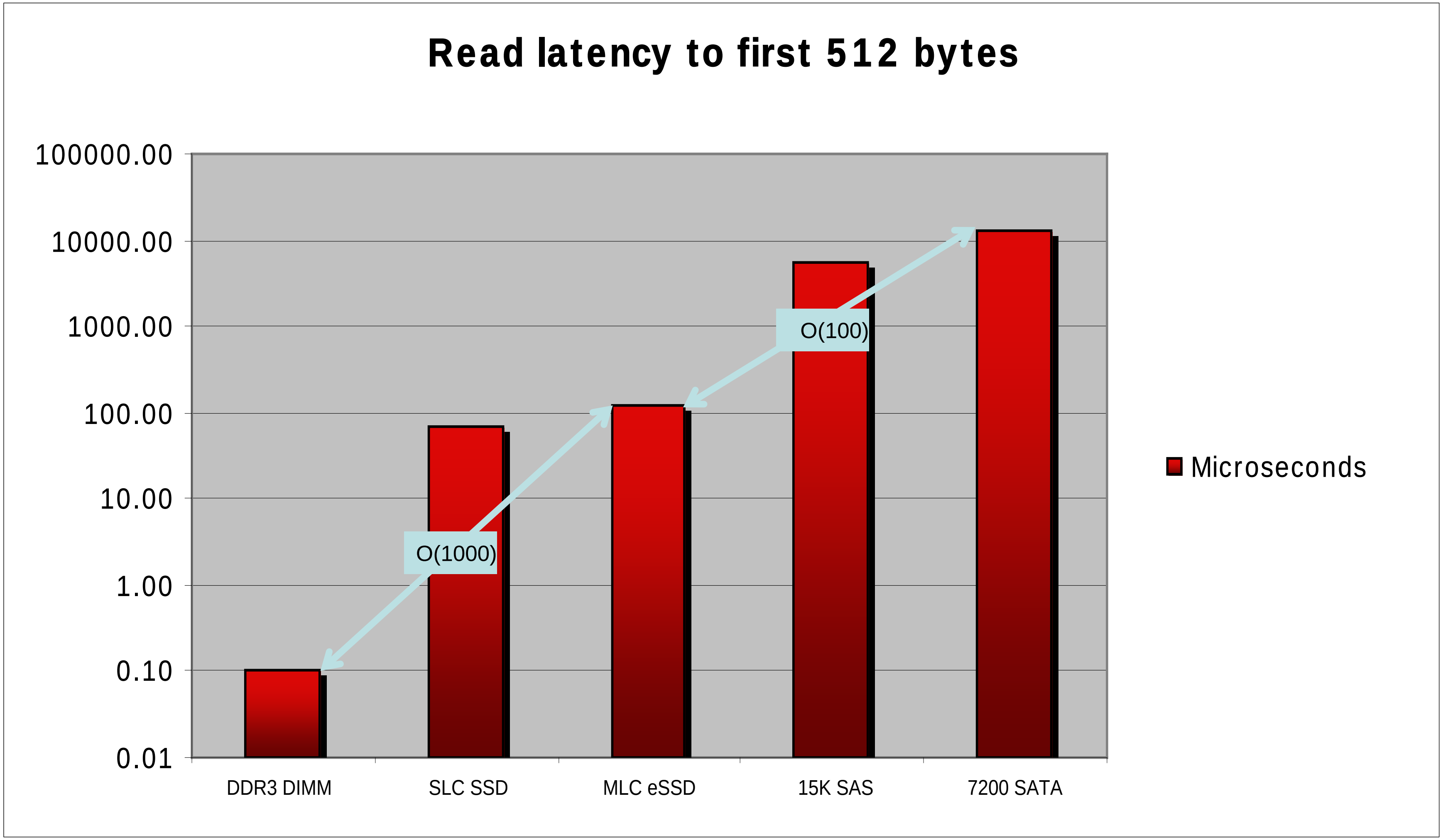
IOPS Efficiency



Capacity Efficiency



Read Latency



Five Minute Rule, 1987 (Jim Gray)

- Assuming that the cost of a cache is dominated by its capacity, and the cost of a backing store is dominated by its access cost (cost per IOPS), then the breakeven interval for accessing a page of data in cache is given by:

  Break-Even-Interval =
  Backing-Store-Cost-Per-IOPS /
  Cache-Cost-Per-Page

- 1987: Disk $2,000 / IOPS; RAM $5 / KB → 1 KB breakeven = 400 seconds ~= 5 minutes

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Five Minute Rule, 2010: DRAM & HDD

- Disk $1 / IOPS (2,000x reduction)
- DRAM $25 / GB (200,000x reduction)

→ 100 KB breakeven ~= 5 minutes
→ 8 KB breakeven ~= 1 *hour*
→ 1 KB breakeven ~= 10 hours *as Gray predicted*

- 200,000x / 2,000x = 100-fold decrease in breakeven access rate for a DRAM cache page backed by disk → much bigger DRAM caches

Five Minute Rule, 2010: DRAM & Flash

- MLC eSSD ~$0.10 / mixed 8 KB IOPS
- DRAM $25 / GB

➔8 KB breakeven ~= 8 minutes (1/10th DRAM)

Adding flash between DRAM and HDD reduces the breakeven access interval for DRAM by 10x, indicating that DRAM capacity could be reduced to hold working sets for data accessed 1/10th as often

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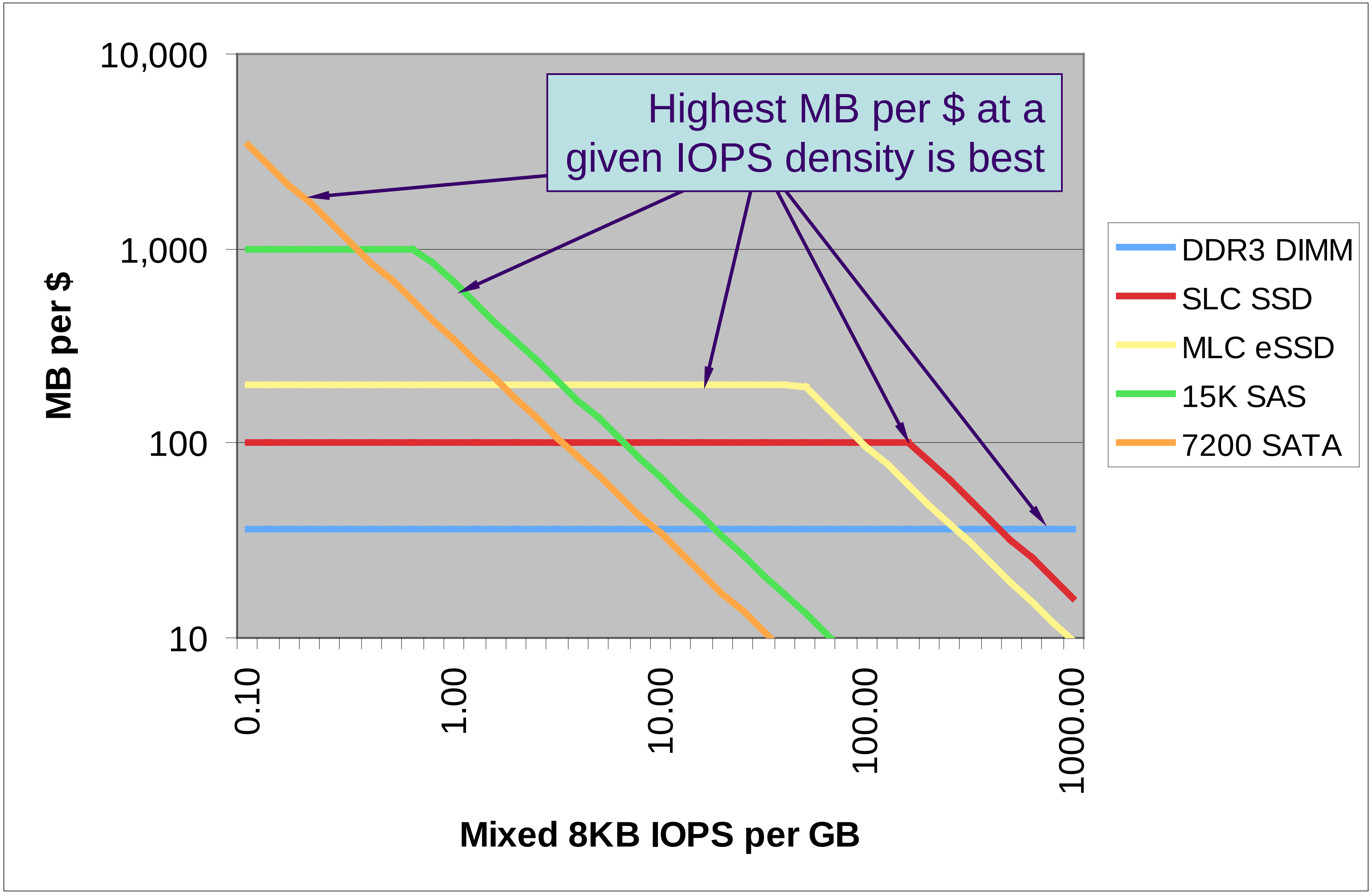
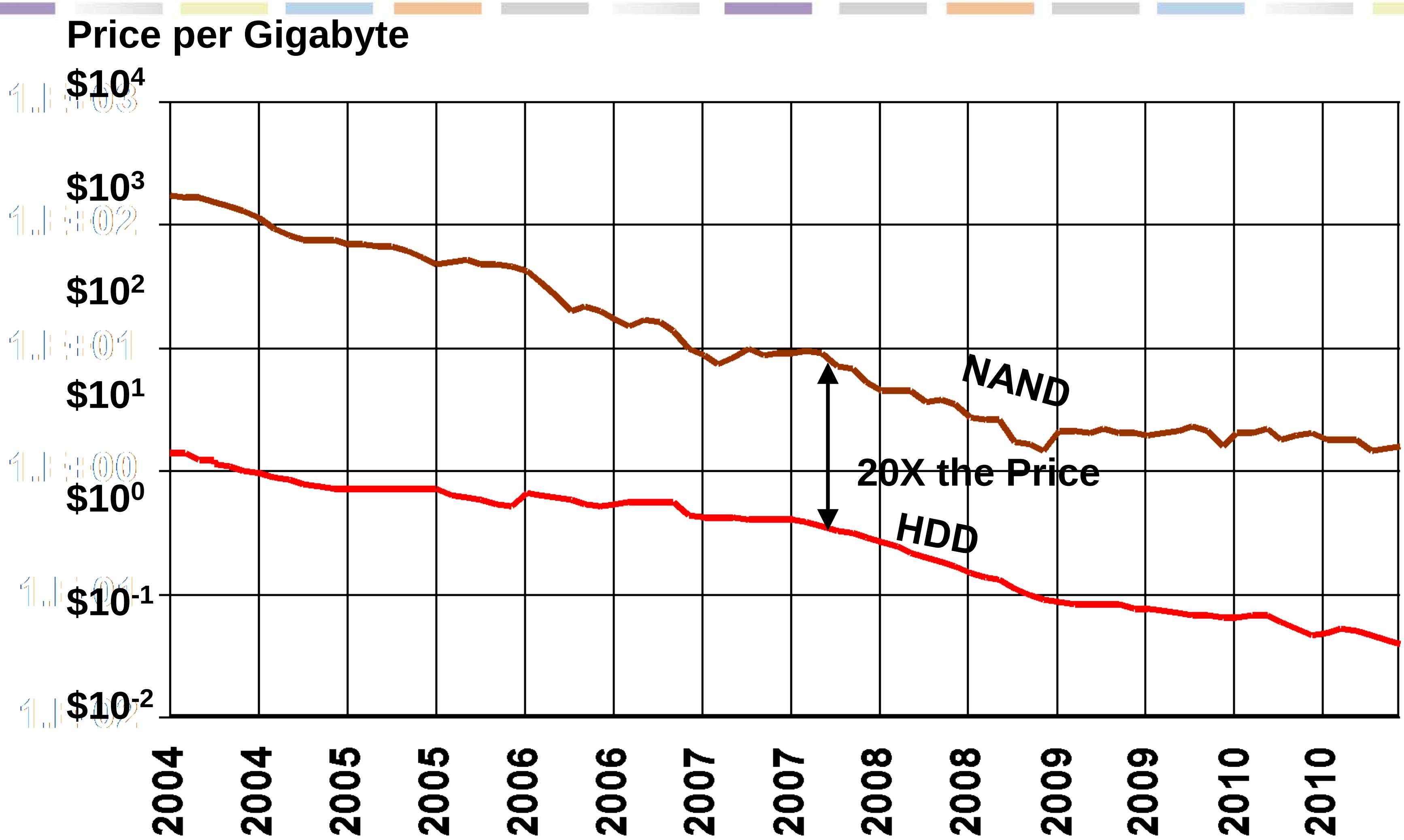
An IOPS Density View



NAND vs HDD History



Source: Objective Analysis

Understanding the NAND Market

Categories of Flash Systems

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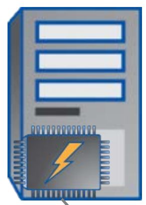
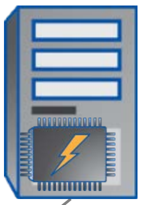
Host-based Flash

- Flash hardware, stores persistent data
- May be combined with s/w to form cache
- May act as internal DAS



Host-side Flash S/W

- Software only, may be tied to particular flash hardware



Flash-based Virtual Storage Appliance

- Software

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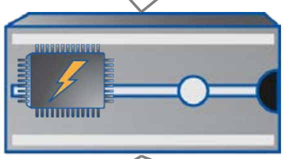
Flash in Storage Controller

- Flash hardware and s/w
- “Behind wire”
- E.g. Flash Cache



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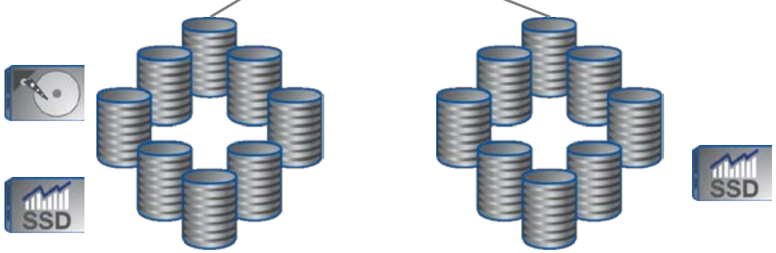
Hybrid (Flash/HDD) Array

- Mixed flash / HDD
- Automated Storage Tiering
- Traditional HDD arrays w/SSDs
- Custom-designed Flash/HDD systems



All-Flash Array

D

- Traditional arrays configured only w/ SSDs
- Flash only designed specifically for SSDs

(A) Hybrid Arrays

- **Mixing SSD and HDD for a particular workload will probably be the most cost-efficient use of SSDs in over the next few years**
- **SSD and HDD tiers accommodated in storage shelves**
- **Issue is to dynamically map workload to appropriate media**
- **Automated data placement and movement is essential**
  - Automated storage tiering (AST)
  - Policy-based
  - No administrator overhead imposed
  - Some vendors refer to this as tier-less storage

AST Considerations

- **Media configurability**
  - Virtual pool to LUN/aggregate mapping
- **Management granularity**
  - Automatic or Policy-engine based? Per LUN?
- **Operational flexibility**
  - Dynamic or batch migration? Predictable?
- **Management granularity**
  - Block size (smaller, better)? Dedupe? RAID limitations?
- **Workload sizing**
  - Predictive cache? Online workload tool? Best guess? Spreadsheet?

Practical Use Cases

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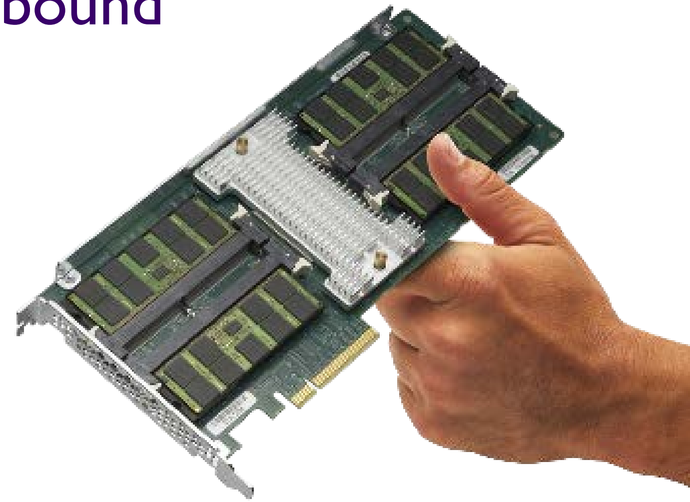
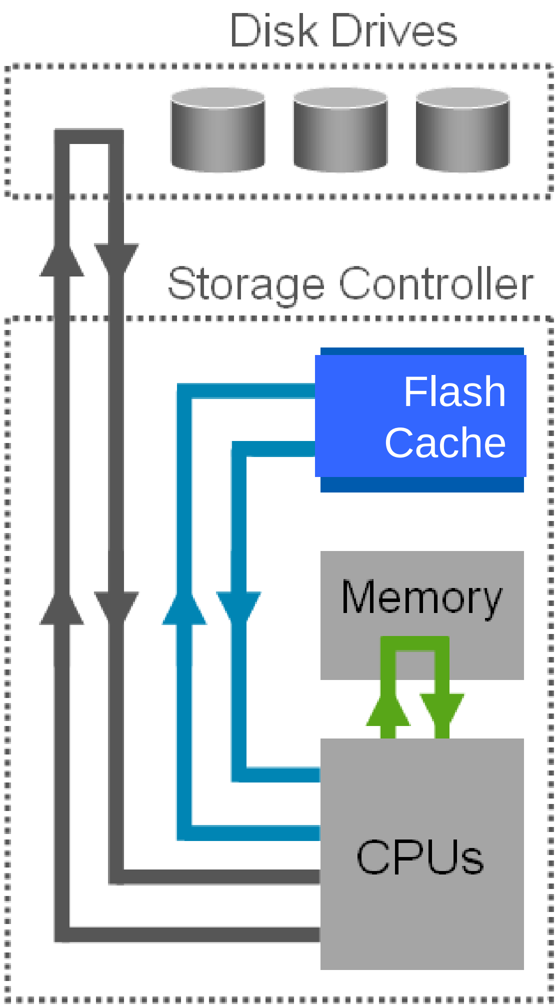
- **Database acceleration solution**
  - Entire database on SSD tier, or
  - Hot random access files on SSD and rest of database on standard disk
    - Indexes and temp space
- **Large scale virtual machine environments**
  - Solves "boot storm" problem for large numbers of virtual machines
  - Deduplication of VM data, e.g. virtual desktops
    - Reduces capacity requirements, increasing IOPS density, potentially making SSD economical

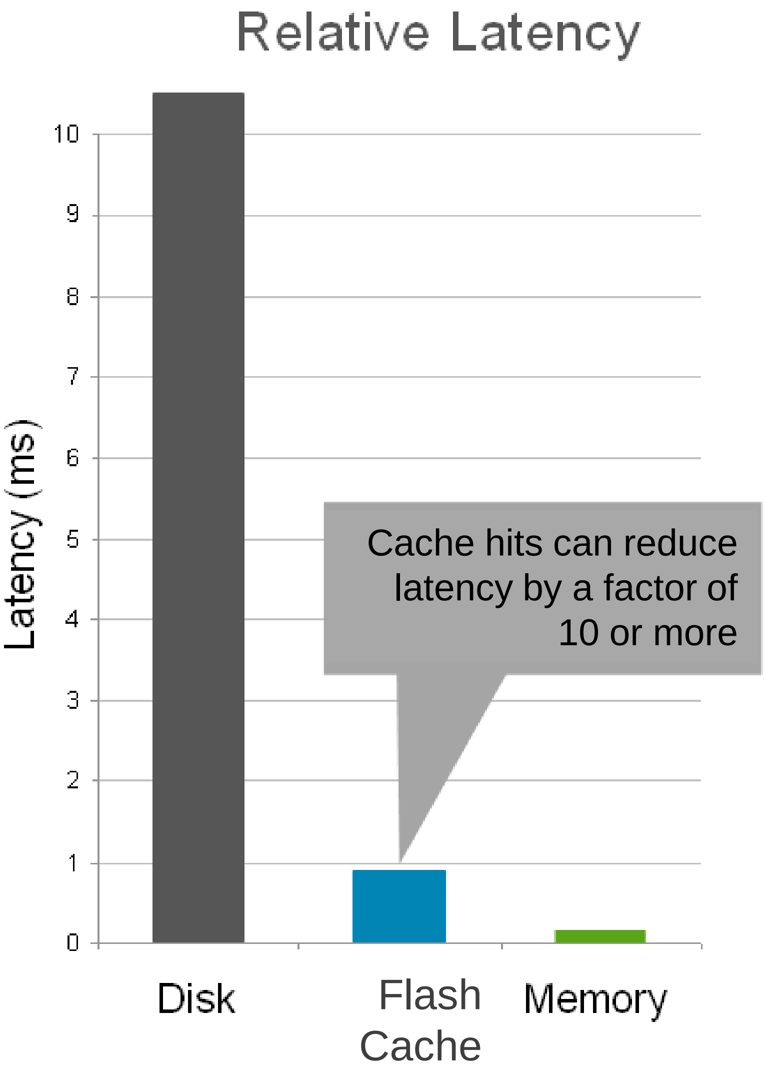
(B) Controller-based Flash Cache

- Functions as an intelligent read cache for data and metadata
- Automatically places active data where access can be fast
- Provides more I/O throughput without adding high-performance disk drives to a disk-bound storage system
- Effective for file services, OLTP databases, messaging, and virtual infrastructure

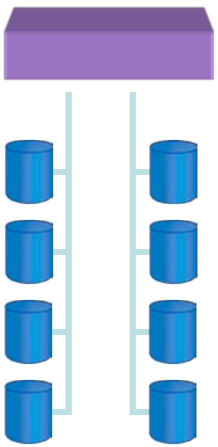


Reduce Latency with Flash Cache



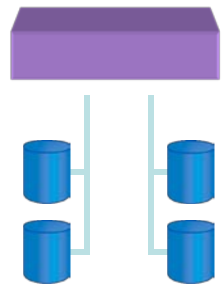


Use case: Scale Performance of Disk-bound Systems



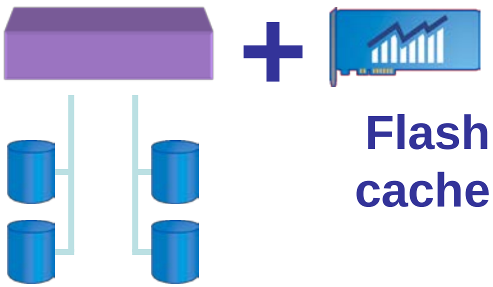
Add Spindles

- Use more disks to provide more IOPs
- May waste storage capacity
- Consumes more power and space



Starting Point: Need More IOPs

- Performance is disk-bound
- Have enough storage capacity
- Random read intensive workload



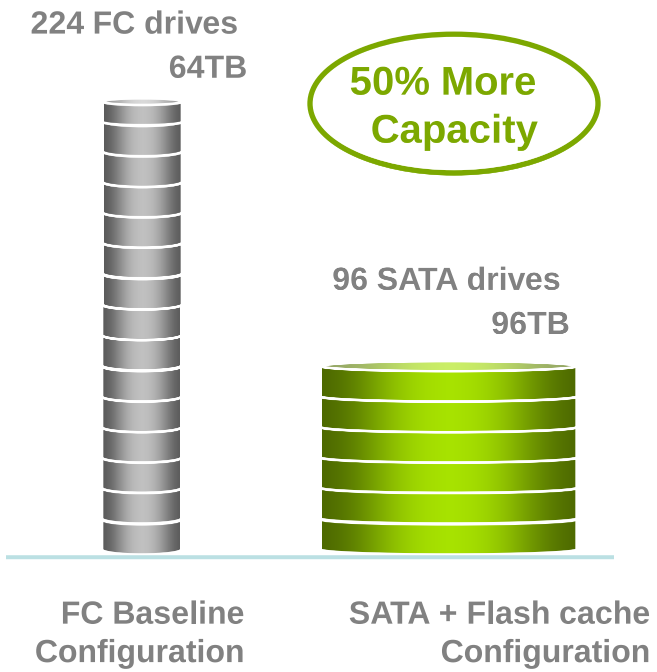
Flash cache

Add Flash Cache

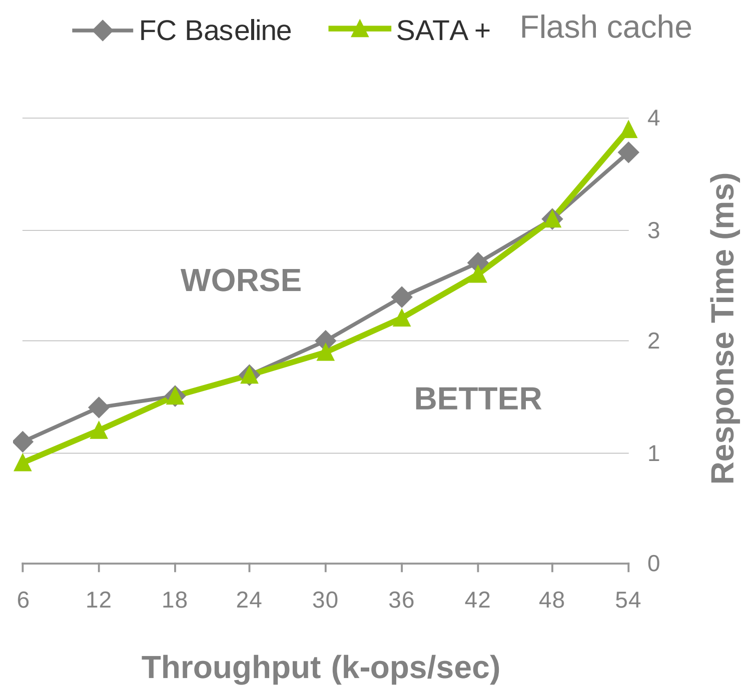
- Use cache to provide more IOPs
- Improves response times
- Uses storage efficiently
- Achieves cost savings for storage, power, and space

SATA HDD plus Flash Cache Example

Benchmarked Configurations



SPECsfs2008 Performance



- Purchase price is **39% lower** for SATA + Flash cache compared to FC baseline
- SATA + Flash cache yields **66% power savings** and **59% space savings**

For more information, visit http://spec.org/sfs2008/results/sfs2008nfs.html.
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(C) Host-based Flash

- Flash card on PCI bus in host system
  - Can support SCSI semantics or device driver model
- Acts as Tier 0 storage (IOPS tier) in front of networked storage (capacity tier)
  - Requiring no data movement (caching)
  - Requiring data movement (AST)
- Multiple implementations in development:
  - High performance DAS
  - Shared storage RAID subsystem in VM on host
  - Shared storage OS in VM on host
- Area of intense industry and standards activity

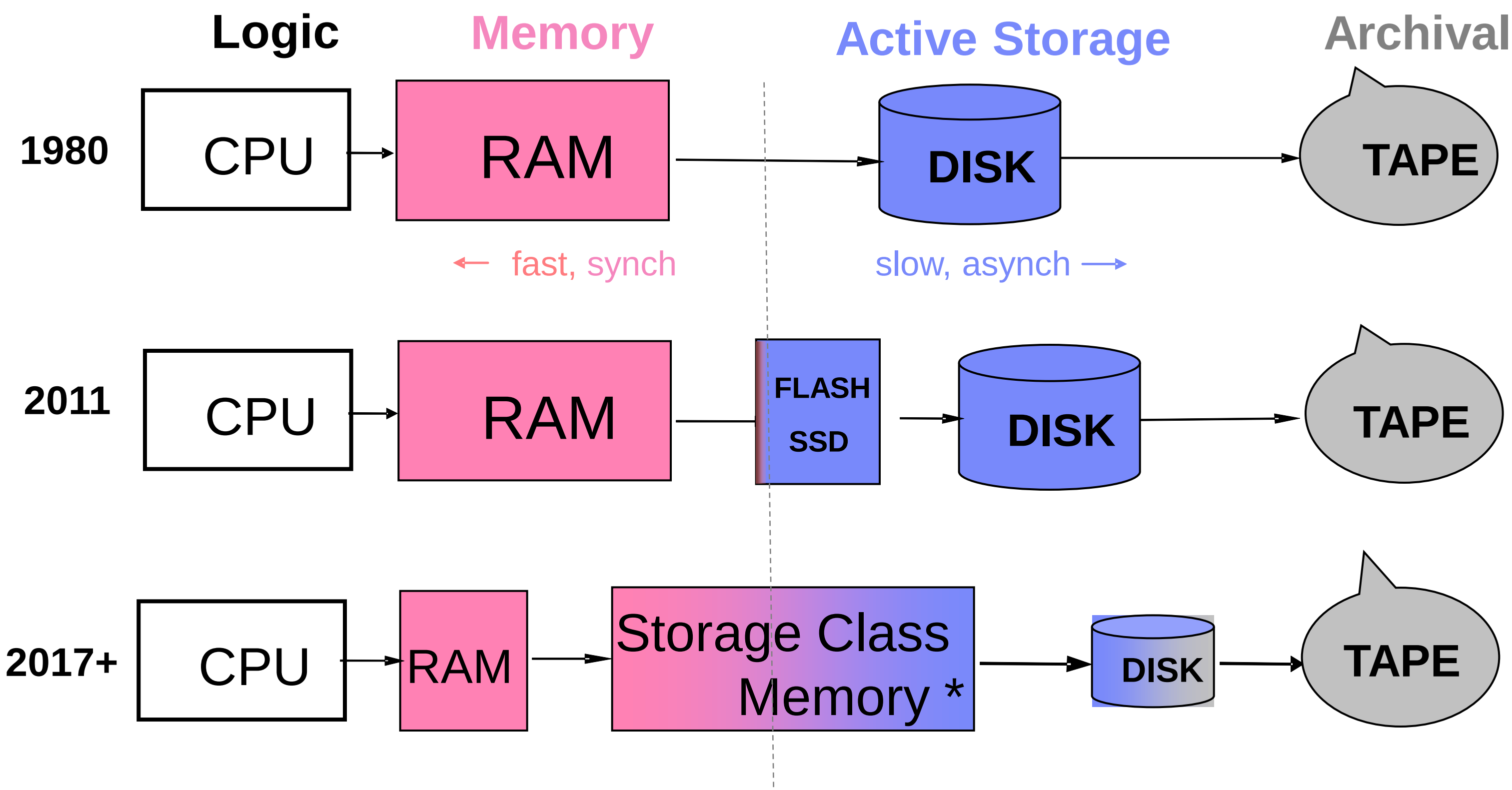
Typical Use Cases

- **High-performance DAS workloads** which entirely fit into host Flash (typically OLTP or hot virtual server applications)
  - **For data and workloads which need to take advantage of shared storage data protection**, use host flash with shared storage RAID subsystem in VM on host
  - **For data and workloads which need to take advantage of shared storage data protection, data management and/or deduplication** use host flash with shared storage operating system in VM (Virtual Storage Appliance) on host

(D) All-flash arrays

- Two categories today:
  - Hardware design center, focused on high performance and price/performance, lightweight data management, small footprint, low power usage, designed for scale-up
  - Software design center, balance of performance and features, robust data management with built-in efficiency and protection mechanisms, designed for scale-out
- Ultra high performance and sustained low latency for real-time OLTP, VDI, tech apps
- The next-generation tier 1 storage?

System Evolution



* e.g. Phase Change Memory
MRAM/STTMRAM
RRAM

Summary

- Solid state technologies are having a profound impact on enterprise storage
- It's not just about replacing mechanical media with solid state media
- The architectural balance of memory, cache and persistent storage is changing
- Today's solid state implementations in enterprise storage demonstrate these changes
- It's still early days in this discontinuity… with persistent non-volatile memory on the horizon

Attribution & Feedback

The SNIA Education Committee would like to thank the following individuals for their contributions to this Tutorial.

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