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Education

The Benefits of Solid State in Enterprise Storage Systems

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Abstract

- Solid State in Enterprise Storage Systems
  - Targeted primarily at an IT audience, this session presents a brief overview of the solid state technologies which are being integrated into Enterprise Storage Systems today, including technologies, benefits, and price/performance.
  - It then goes on to describe where they fit into typical Enterprise Storage architectures today, with descriptions of specific use cases.
  - Finally the presentation speculates briefly on what the future will bring.

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Agenda

- Why flash in the datacenter? Why now?
- Memory, cache and storage
- Flash in enterprise storage today
  - SSD storage tier
  - Storage controller-based cache
  - Host-based flash
  - Network cache
- What's next
- Conclusion

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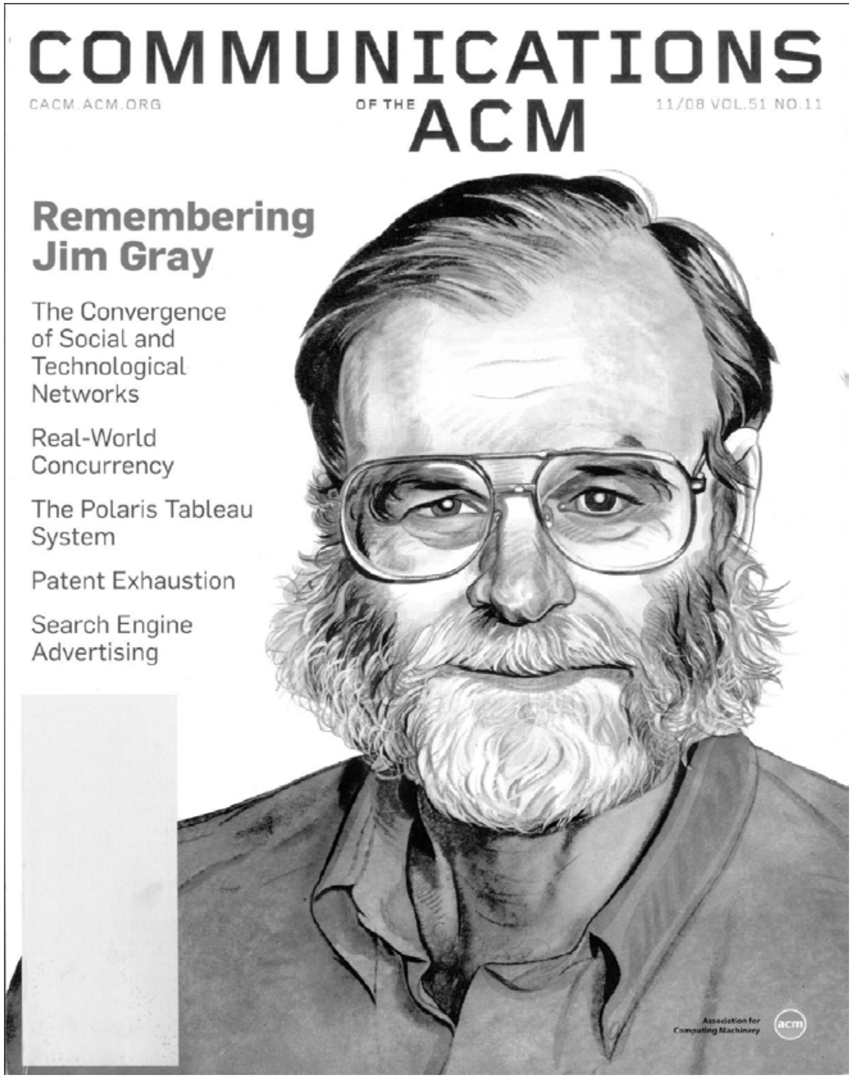
Remembering Jim Gray



Database and systems design pioneer, and co-creator of the Five Minute Rule (1987)

"Flash is a better disk …, and disk is a better tape" ~2006

Lost at sea January 2007

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Why Flash in the Data Center Now?

- 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

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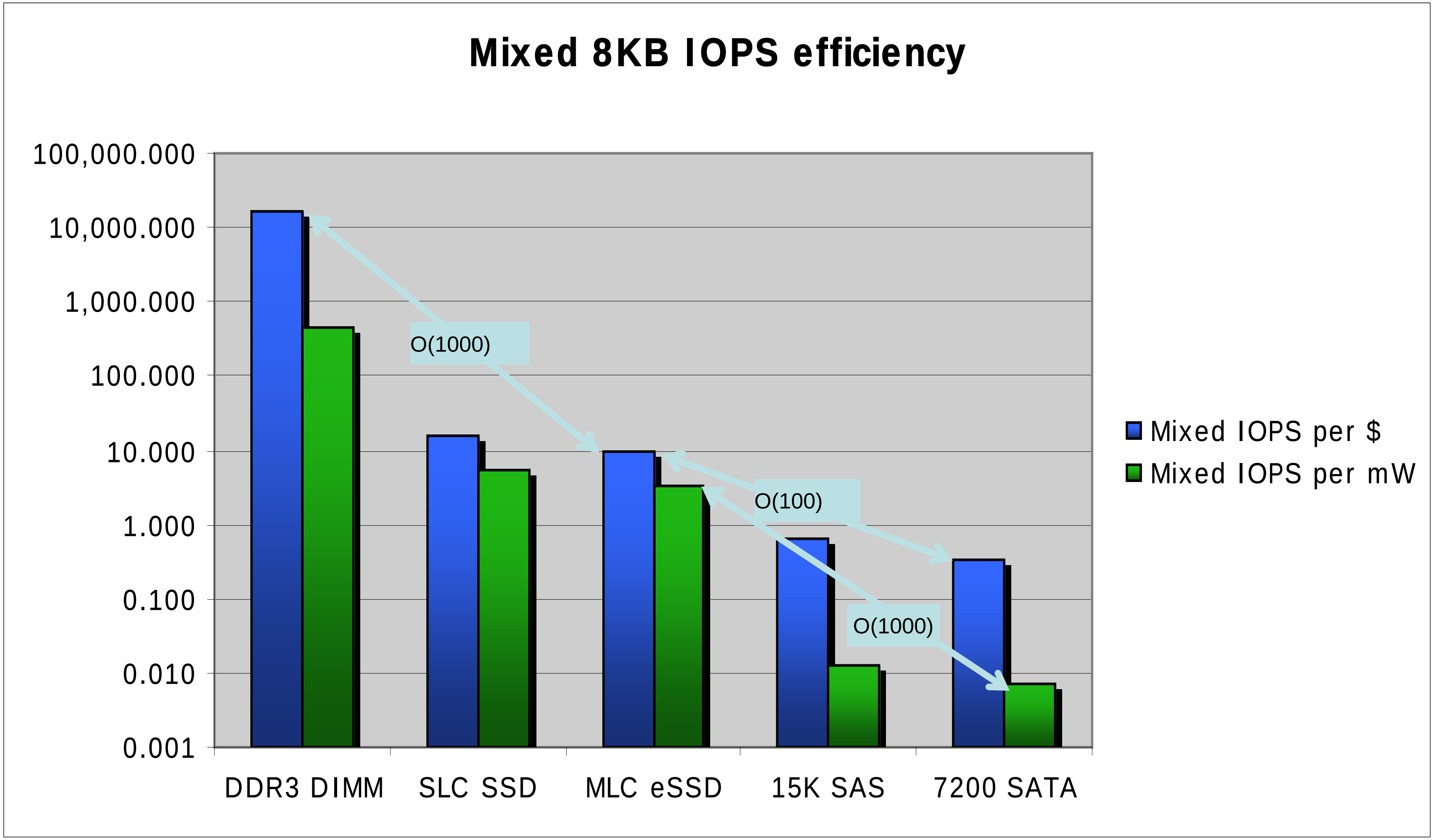
Why Flash? IOPS Efficiency



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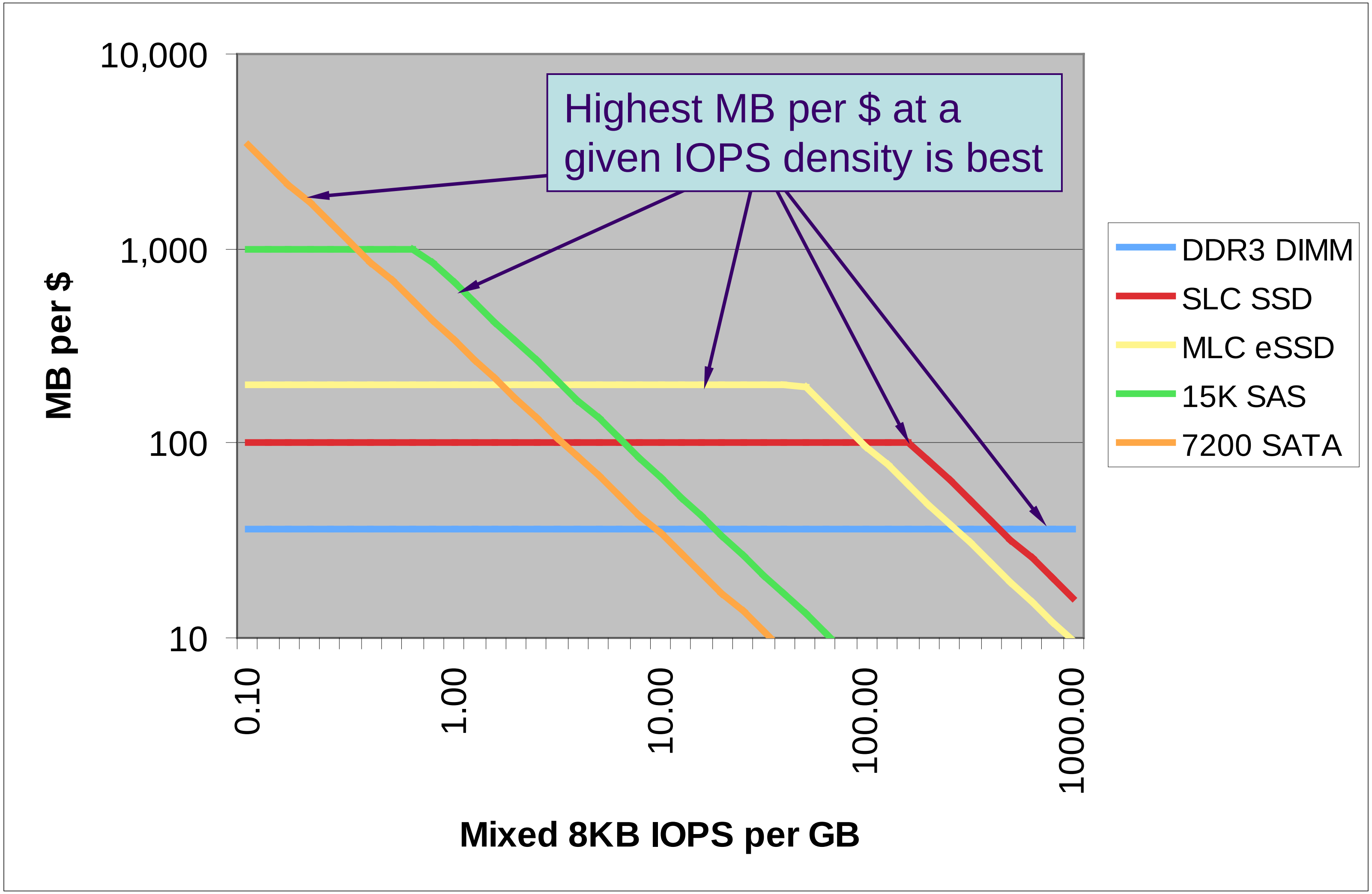
Why Flash? An IOPS Density View



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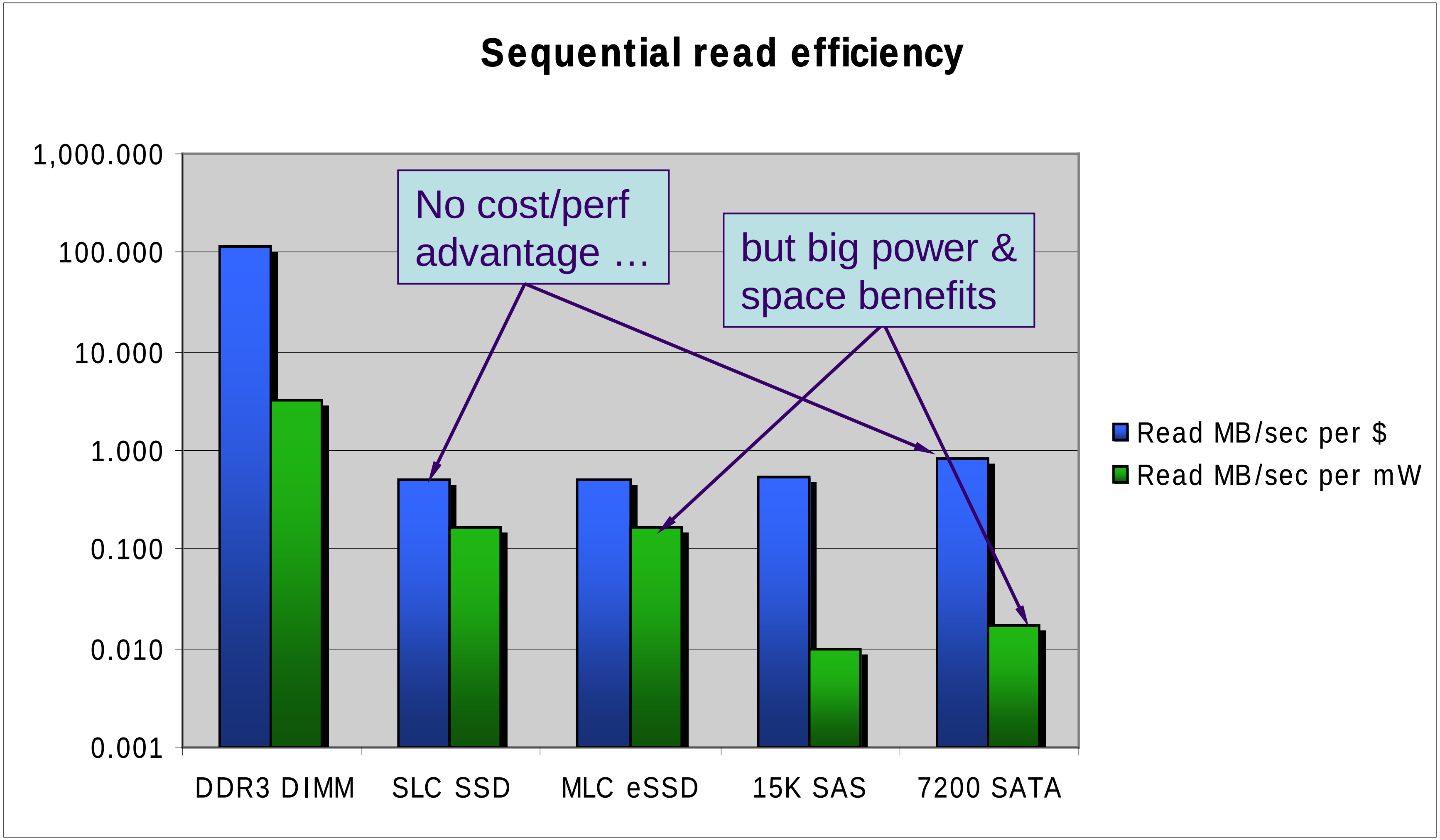
Why Flash? Read Throughput per Watt



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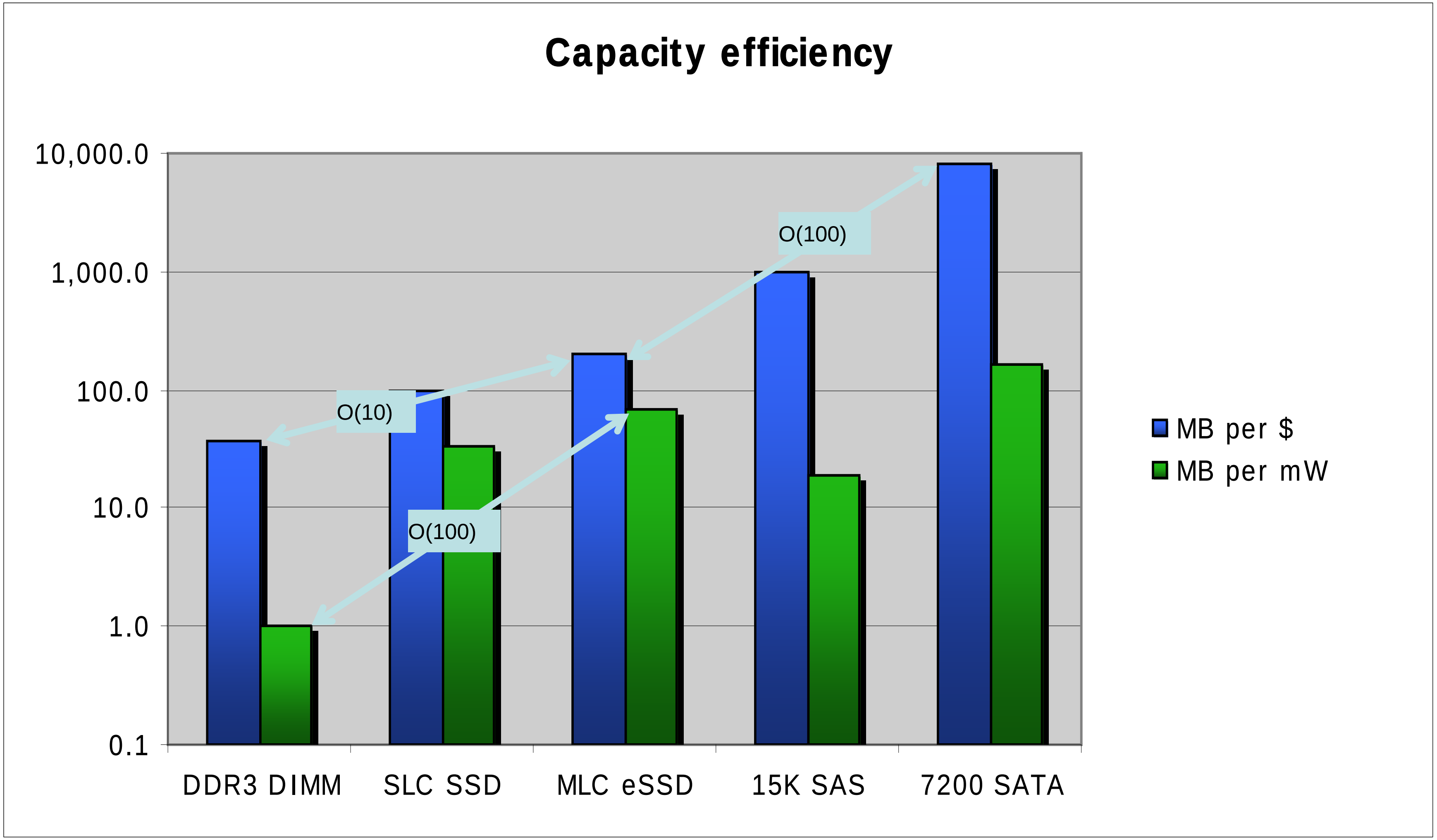
Why Flash? Capacity Efficiency



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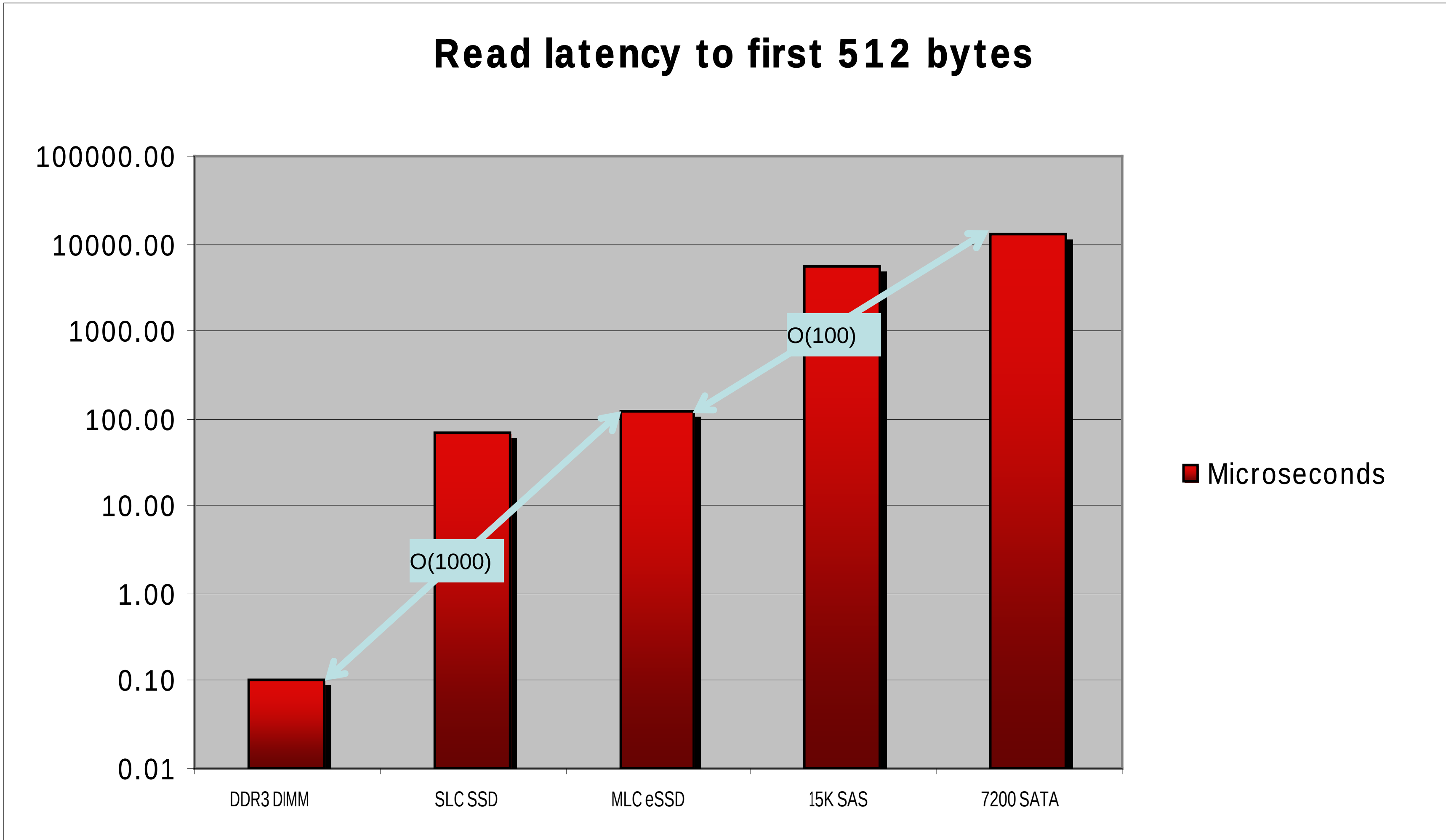
Why Flash? Read Latency



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Five Minute Rule, 1987

- 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

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- 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

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Five Minute Rule, 2010: Flash & HDD

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- Disk $1 / IOPS

- MLC eSSD ~$5 / GB

→ SSD 100 KB breakeven ~= 30 minutes
→ SSD 8 KB breakeven ~= 7 hours (5x DRAM)

Flash economically caches working sets with 5x longer access intervals than DRAM.

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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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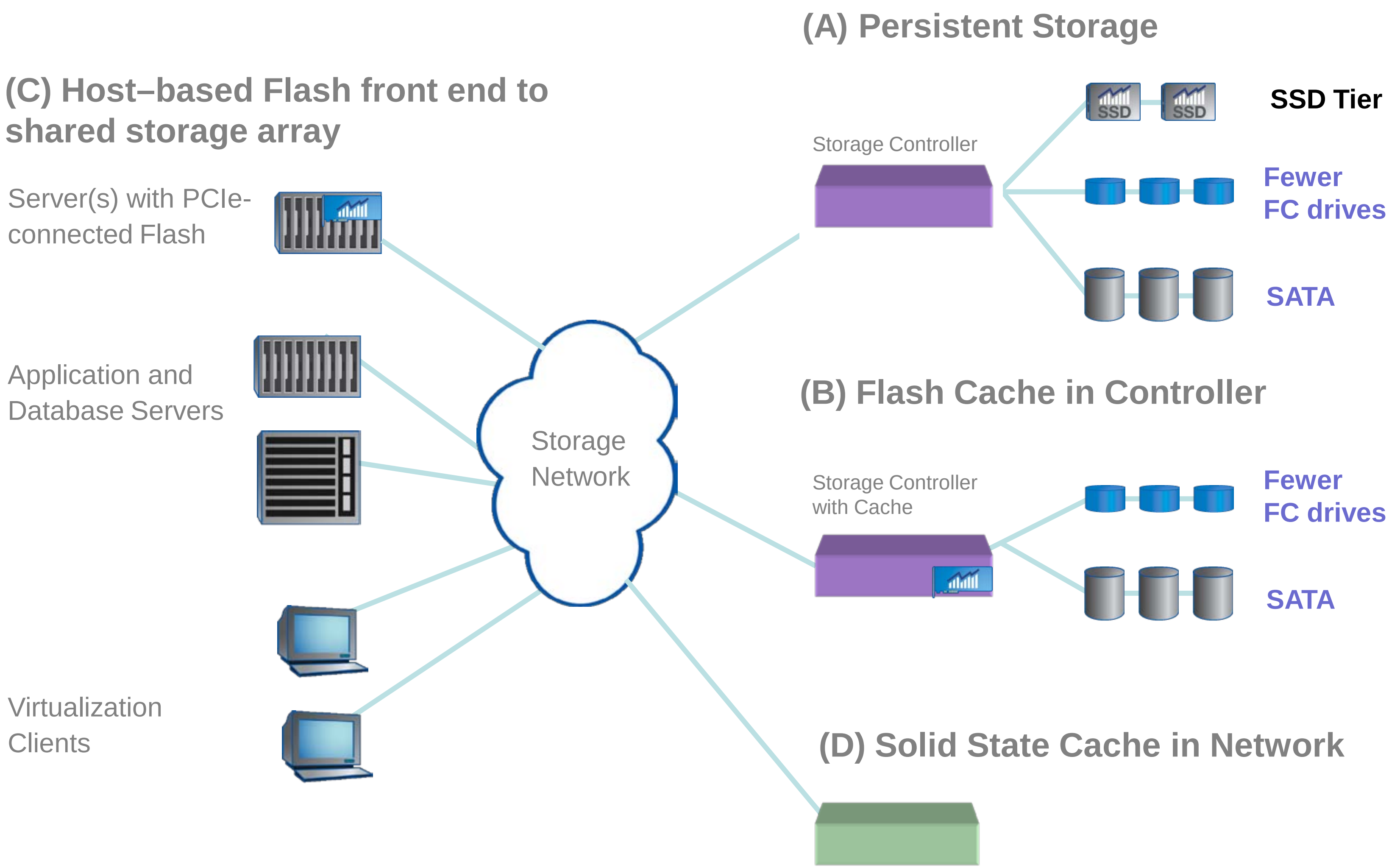
Storage Networking with Flash



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Available Solutions Compared

	Pros	Cons
Solid State Drives	❒ Assured performance levels ❒ Low cost per IOPS ❒ Admin has direct control over data stored in SSD tier	❒ High cost per gigabyte ❒ Requires partitioning of hot data ❒ Limited practical applications at current SSD costs
Controller Cache	❒ Hot data automatically flows into cache – no admin required ❒ Deployment non-disruptive ❒ Viable for common enterprise applications	❒ Cache must be populated before it becomes effective ❒ Less predictable performance than static placement
Host-based Cache/tier	❒ IOPS tier of storage on host; capacity tier on shared storage ❒ Flash on host will become common ❒ Cache and AST implementations	❒ Big variations in implementation capabilities – block granularity ; AST software maturity; degree on admin required
Network Cache	❒ Hot data automatically flows into the caching tier ❒ Deployment relatively non-disruptive ❒ Scalable solution for HPC apps	❒ Cache must be populated before it becomes effective ❒ In-network placement may constrain protocols or use cases

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(A) Solid State Disk Tier

Advantages:

- Fast random I/O for small blocks
- Low read and write latency time
- Low power consumption
- Low noise
- Better mechanical reliability

Disadvantages:

- Very high price, typically 10-30X comparable fast HDDs
- Relatively limited capacities
- Less advantaged random write speeds (erase of blocks)
- Less advantaged sequential write (HDD strength)

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Practical Use Cases

- **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

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Automated Storage Tiering (AST)

- Utilizing both SSD and HDD for any workload will be the most cost-efficient use of SSDs in over the next few years
- Area of intense innovation among enterprise storage vendors
  - Media-spanning LUNs
  - Hybrid aggregates of volumes
  - Automated storage tiering software
- Issue is to automate data placement and movement
  - Automated tiering
  - Policy-based; no administrator overhead imposed
- Alternatively you can eliminate data movement
  - Caching implementations
  - Some vendors refer to this as tier-less storage

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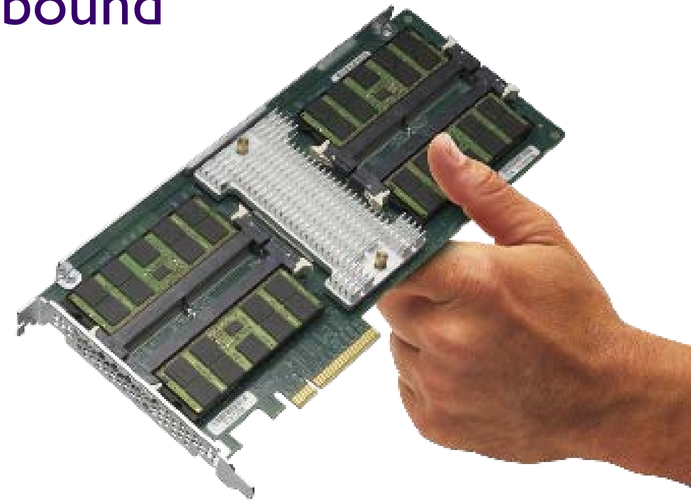
(B) Controller-based Flash Cache

- 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



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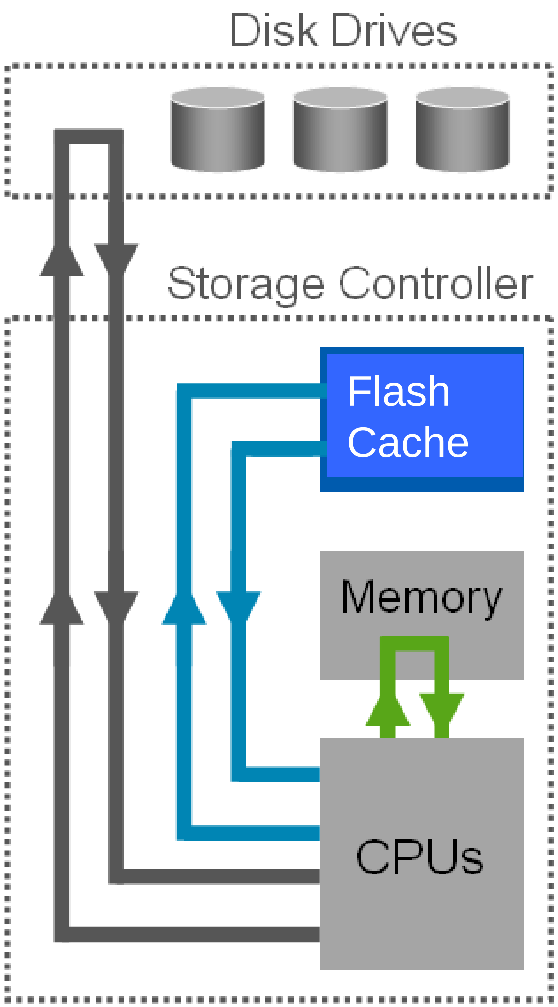
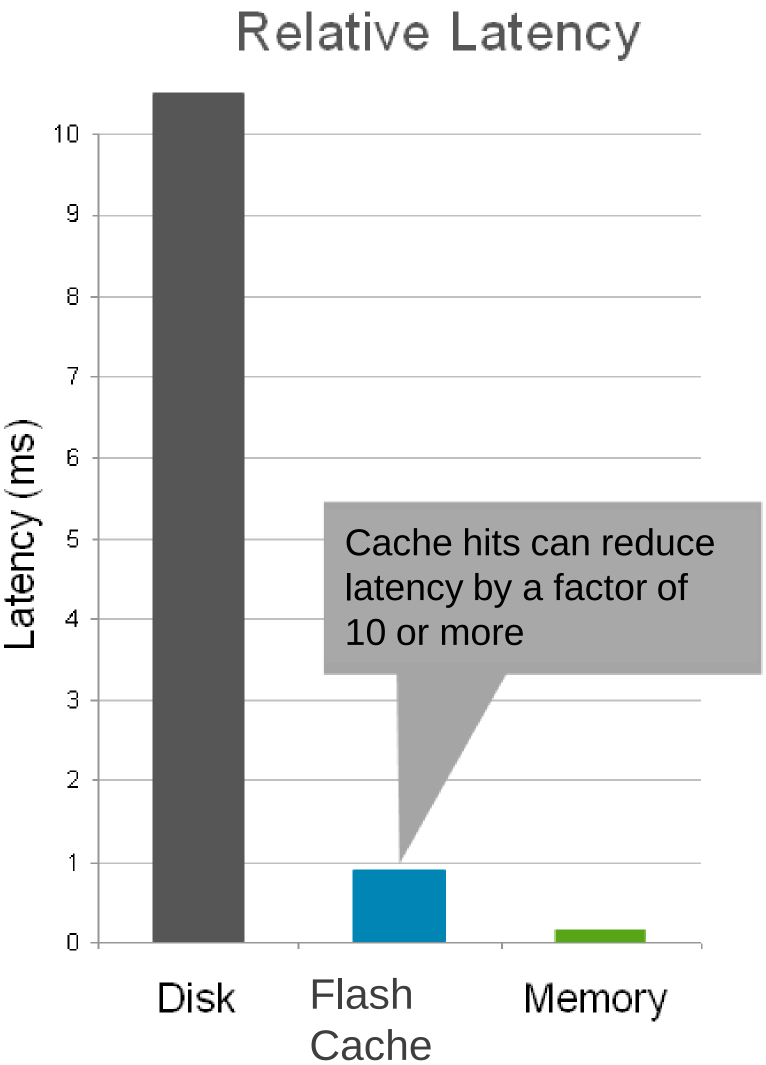
Reduce Latency with Flash Cache





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Use case: Scale Performance of Disk-bound Systems

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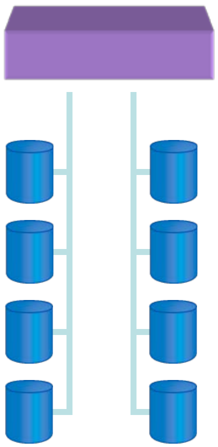
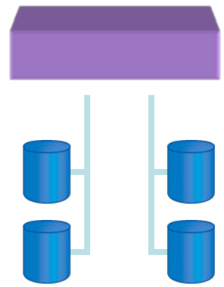


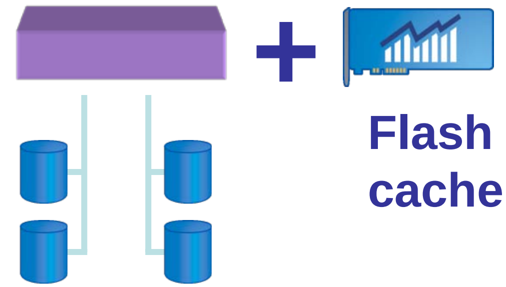
Add Spindles

- 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



Add Flash Cache

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

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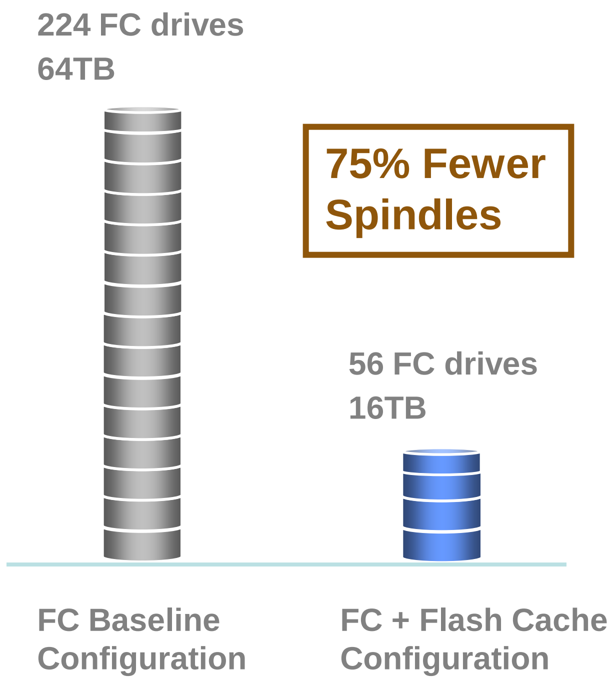
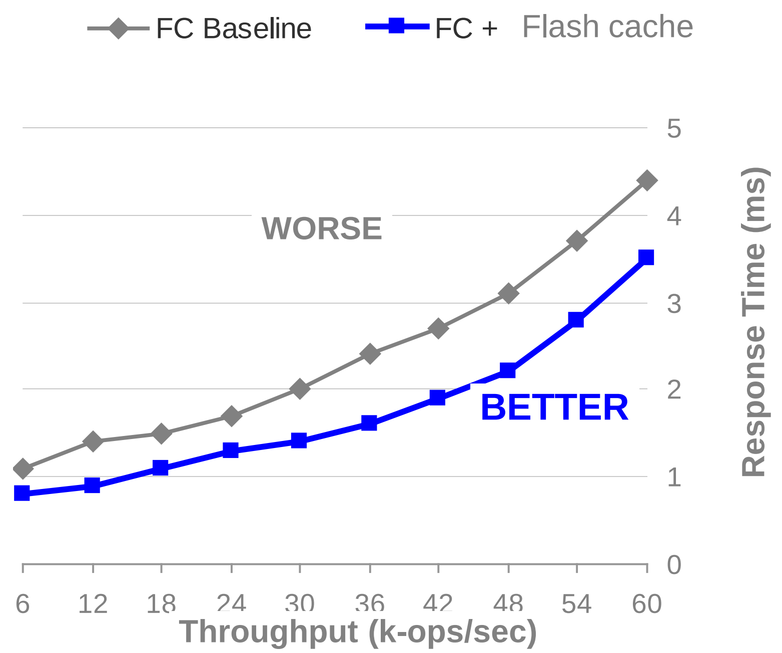
FC HDD plus Flash Cache Example

Benchmarked Configurations



SPECsfs2008 Performance



- Purchase price is **50% lower** for FC + Flash cache compared to Fibre Channel baseline
- FC + Flash cache yields **67% power savings** and **67% space savings**

For more information, visit http://spec.org/sfs2008/results/sfs2008nfs.html.
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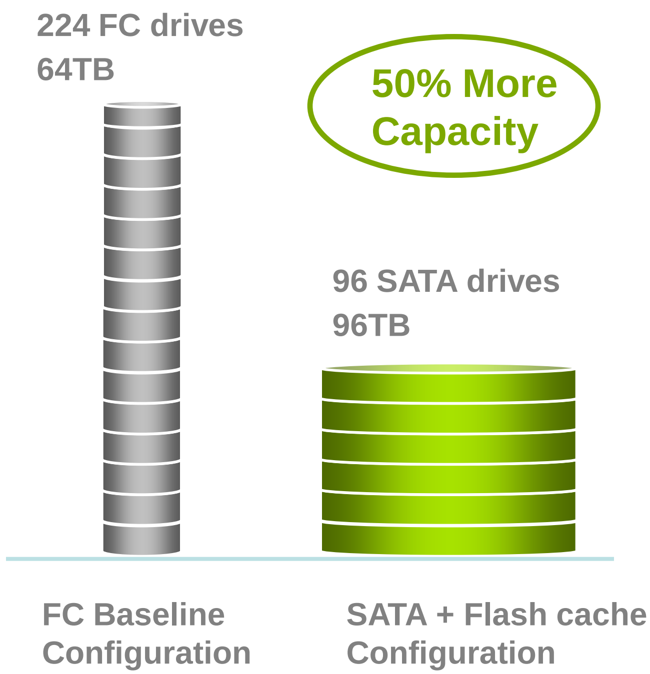
SATA HDD plus Flash Cache Example

Benchmarked Configurations



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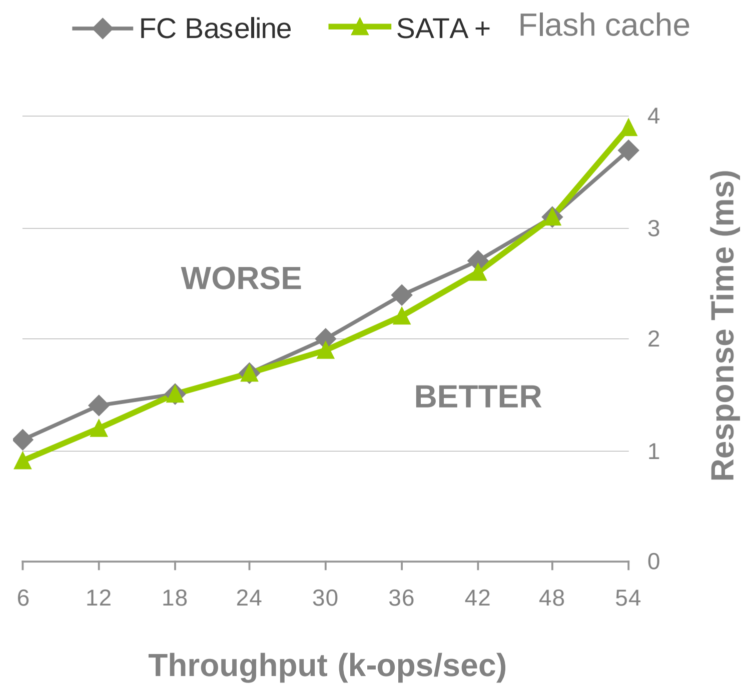

- Purchase price is **39% lower** for SATA + Flash cache compared to FC baseline
- SATA + Flash cache yields **66% power savings** and **59% space savings**

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(C) Host-based Flash

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

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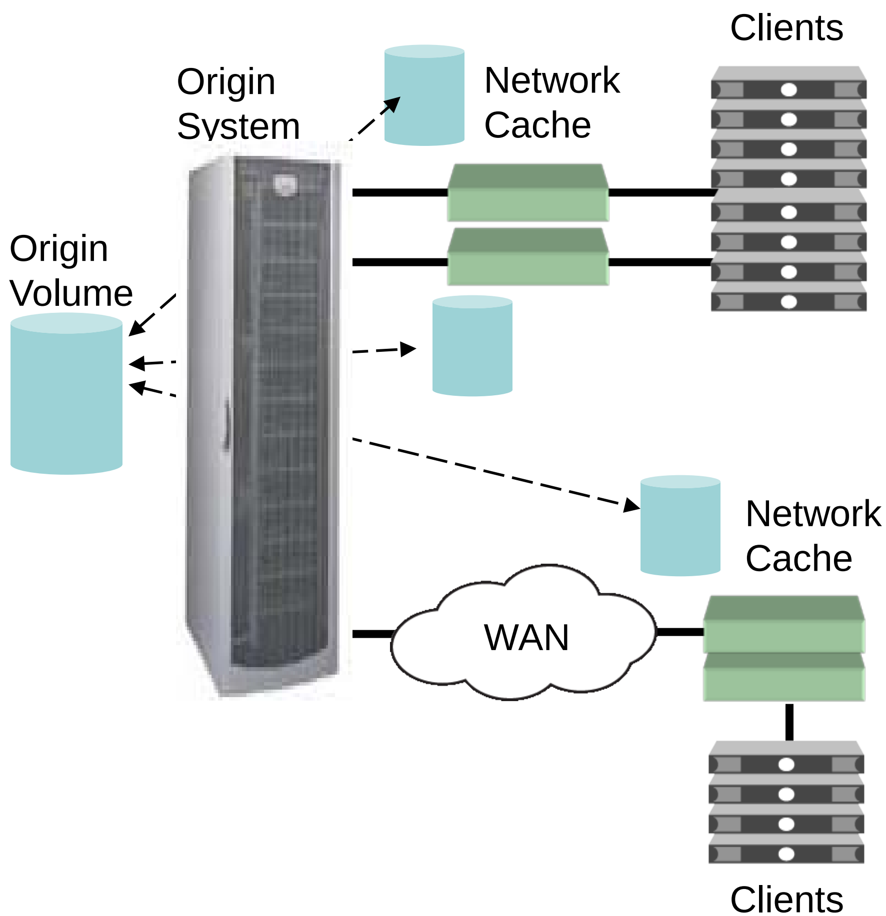
(D) Network Cache Topology



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Practical Use Cases

- **Network cache solutions**
  - All files on HDD in shared storage array
  - Accelerated by SSD-based network cache
  - Self–tuning write-through cache
- **Same pros and cons as SSD tier**
- **Typical applications**
  - Rendering
  - Seismic
  - Financial modeling
  - ASIC design

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Cost Structure of Memory/Storage Technologies

<u>Cost</u> determined by

- cost per wafer
  - # of dies/wafer
    - memory area per die [sq. µm]
      - memory density [bits per $4F^2$]
        - patterning density [sq. µm per $4F^2$]

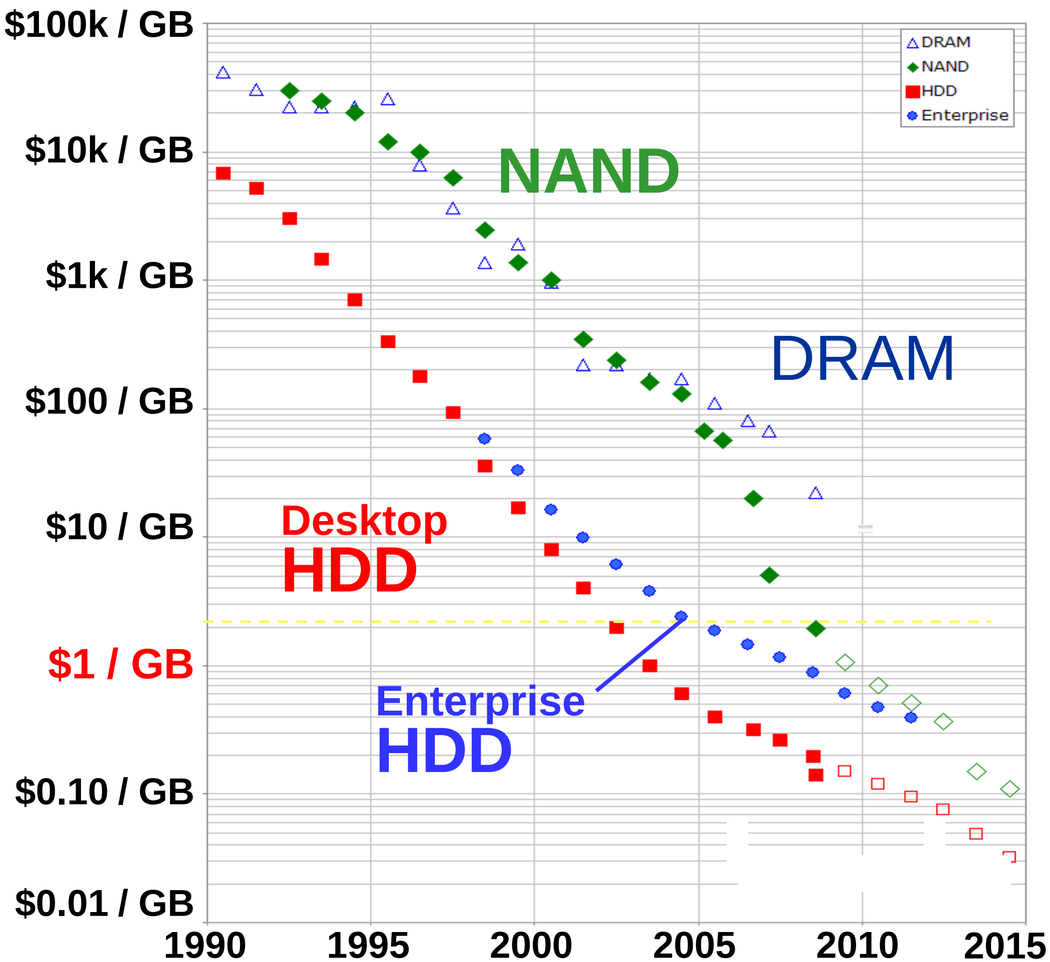

Chart courtesy of Dr. Chung Lam, IBM Research updated version of plot from 2008 *IBM Journal R&D* article

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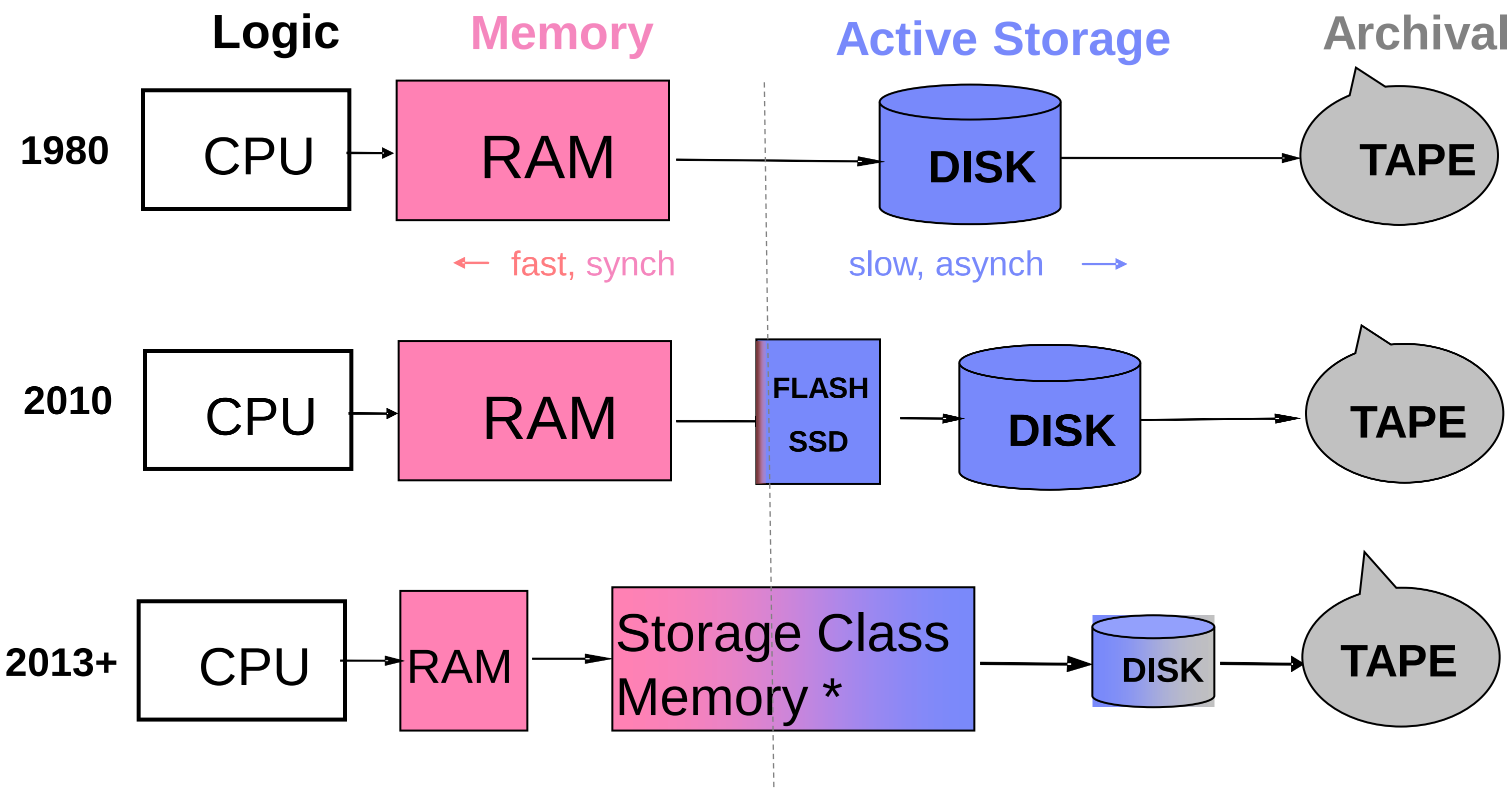
System Evolution



* e.g. Phase change memory
Memristor
Solid Electrolyte
Racetrack memory

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Summary

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- Over the next 5 years solid state technologies will have 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 will change
- Today's solid state implementations in enterprise storage demonstrate these changes
- It's still only the beginning…

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Q&A / Feedback

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- Please send any questions or comments on this presentation to SNIA: add your track reflector here

Many thanks to the following individuals for their contributions to this tutorial.

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Chris Lionetti	**Alan Yoder**
Phil Mills	

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