Flash: The Great Disruptor

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Flash Memory Summit, August 11, 2015
Forward Looking Statements

This presentation contains certain forward-looking statements.

Any statement that refers to expectations, projections or other characterizations of future events or circumstances is a forward-looking statement, including those relating to market growth for flash and SSD, industry trends including the increased adoption of and demand for flash and SSD in various devices and pricing trends, enterprise applications and data centers, future memory technology, technology transitions and future products, including 3D NAND and its capacities, capabilities, scalability, performance, cost and timing of commercial availability, as well as increased SSD capacities and emerging storage class memory. This presentation also contains information from third parties, which reflect their projections as of the date of issuance of those statements.

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Waves of Disruption

Flash has changed application media repeatedly by reaching new levels of cost for utility

Outpacing Moore’s Law

OVER 50,000X Cumulative cost reduction over 20 years*

Note: Images are not to scale
*Based on historical SanDisk NAND pricing 1992*
3D NAND Flash: Tall is the New Small

Proximity Effect (V)

No lateral coupling

Small vertical coupling

FG

2D NAND

BiCS
Overcoming 2D Scaling Challenge

3D NAND Flash

- Core Dielectric
- Body Silicon
- Control Gate
Flash in Mobile Devices

Putting the power of business in phones and tablets
Flash in the PC

Changing form factor, user experience, cost and speed of business
Disruptive to the CPU-DRAM paradigm

Flash in the PC

- **i5-4GB-SSD**: 80 seconds, $90
- **i7-4GB-HDD**: 198 seconds, $200

Adding 4GB DRAM helps marginally on performance but adds even more cost and both of these upgrades degrade battery performance.

Source: Lenovo T450, May 2015
HDD’s $40 Problem

Inflection point reached when cost of utility drops below HDD

Driving an increased rate of SSD adoption into PCs

Source: Gartner, April 2015
Data Center: The Next Wave
Flash Meets Key Data Center Requirements

- Low Power
- Extreme Performance
- Reliable
- Scalable
- Breakthrough Economics
SanDisk Enterprise SSDs continue to deliver density growth while mission critical HDD density hits a wall
Flash Solutions Already Cost Less than HDDs

Example: 50TB minimum of database storage needed

More power and more space needed

51K IOPS

288 HDDs @ 300GB
(12) 24 drive enclosures 51.8 TB usable

20X Performance same cost per GB

1 M IOPS

24 SSDs @ 3.84TB
(1) Enclosure 6 drives per enclosure 55 TB usable capacity

23% Lower TCA • 27% Lower TCO • 66% reduction in HW footprint

Source: Assumes 5 drive RAID 6 arrays. 100% reads at 4k transfer size. 75k IOPS per SSD and 300 IOPS per HDD. Assumes 4 enclosures needed for SSD access density and not for capacity housing. TCO based on 15.8 cents per KWh and 17% media maintenance costs per year.
Traditional IT Virtualization

Traditional IT

- Rack
- Server
- SAN Fabric
- SAN
- Mostly SAS HDD → Flash
- Typically ~30 Attached nodes
- Fixed Workload
  Or heavy VM Load

Private Cloud

- Rack
- Ethernet Switch
- Server
- Server
- Server
- Server
- SDS
  → easy deployment
  Mostly SATA
  iSCSI = SAN Perf
- iSCSI
- SAN
- High Performance
- Containers
- VMs
- SDS = easy deployment
- Mostly SATA

Flash Memory Summit | Santa Clara, California | August 2015
Hyperscalers Move to Disaggregated Storage

**Webscale Architectures**

- Rack
- Ethernet Switch
- DAS
- Cool = HDD HDD → Flash
- Warm = SSD SATA → NVMe
- Hot = PCIe Flash

**Disaggregated RSA**

- Rack
- HBA/NIC
- PCIe Switch
- CPU
- GPU
- AFA
- Large Pools Of Flash
Today’s Datacenter Infrastructure is Changing

SDx (Software Defined Datacenter & Storage)

Problems (Performance, Agility)

Datacenter Solutions

RSA (Rack Scale Architecture)

Problems (Management, Bandwidth)

Needs at Scale

Enterprise Development

Web/Cloud Development
Changing Shape of Flash Storage

SSDs
- SATA
- SAS
- Reliability & Performance

Fusion ioMemory™
- PCIe cards
- In-Server
- Highest App Performance
- High Capacity 6.4TB

InfiniFlash™
- Block or File/Object
- 500TB
- Lowest $/GB Storage

Server & Storage Solution

Highest Performance Database & Log

Ultra-Dense Low Cost Solution
In Summary...

- **3D NAND** is upon us but **2D** still has legs

- Flash has achieved new **utility cost** enabling deployment at scale in today’s data centers

- DC disaggregation will drive high **PB storage demand for EB class deployments**
Thank You

Expanding The Possibilities of Storage

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