



Education

# Are SSDs Ready for Enterprise Storage Systems

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## ◆ Are SSDs Ready for Enterprise Storage Systems

Computer architects dream of storage devices for their applications/workloads which can provide very high IOPs at minimal cost (IOPS/\$/GB) and fast access (low latency). “Enterprise-Ready SSDs”<sup>®IMEX</sup> have started to fulfill that promise as they segment into SATA and PCIe based Storage products. A major factor for their quick adoption has been the advent of new controllers and firmware which have allowed them to transparently mitigate early issues related to reliability, endurance, data retention, performance, ease of management and interoperability with exiting storage interfaces. But their real success in enterprise adoption comes from Automated Storage Tiering activated by monitoring workload I/O access signatures and behavior over time and then non-disruptive migration of hot data to SSDs, resulting in over 200% improvement in IOPS and 80% improvement in response time at peak loads.

### Learning Objectives:

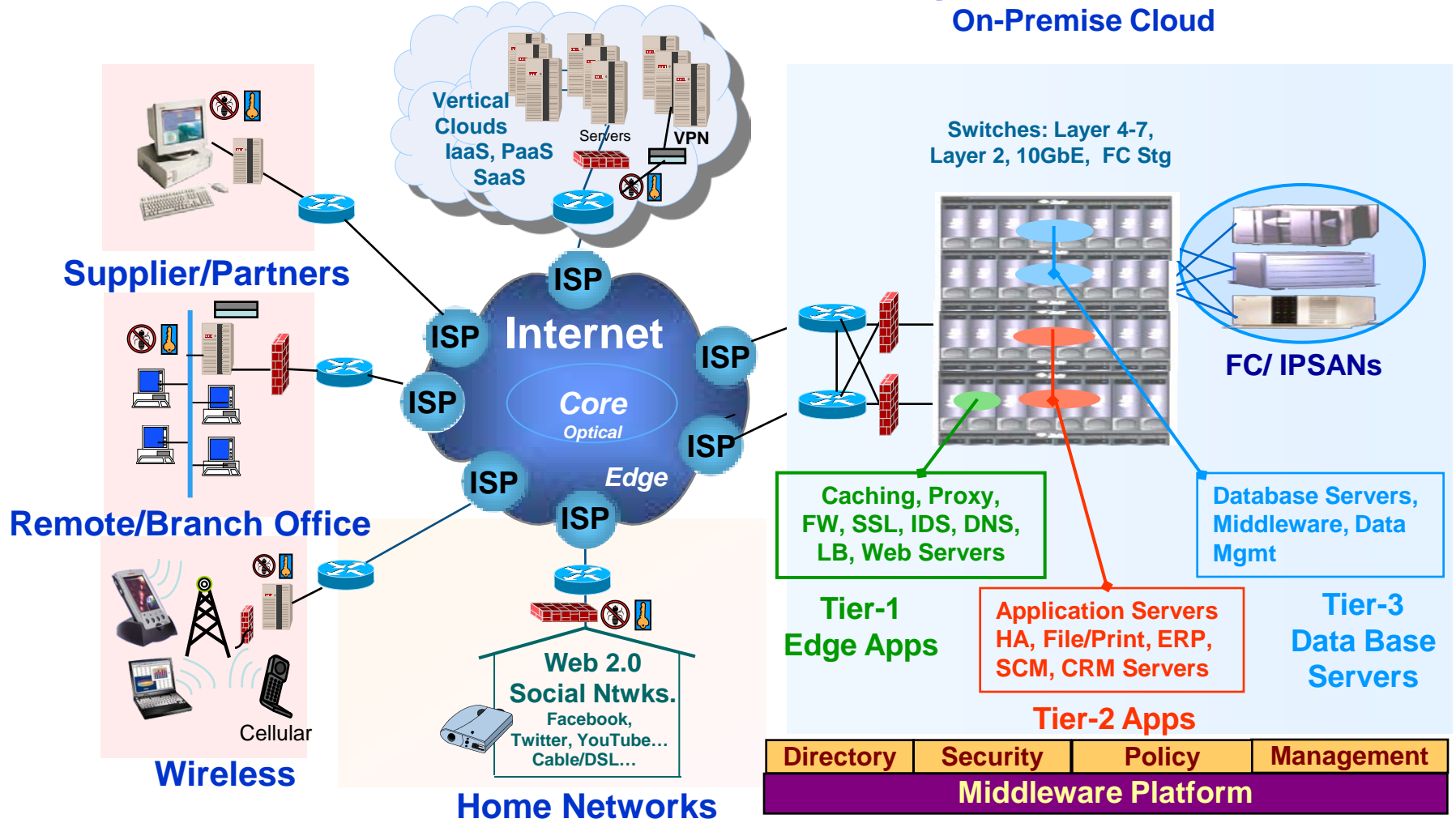
- The presentation provides an overview of SSD technology, storage characteristics and applications that benefit the most from its usage. It also provides techniques for workloads optimization using automated smart-tiering and system implementation in enterprise storage systems together with economics of SSDs usage in real life.
- The presentation illustrates how optimally selected hybrid storage of SSDs and HDDs can achieve 65% lower TCO, 475% higher IOPS and 165% lower footprint while achieving a whopping 800% in \$/IOPs in SANs and other storage systems under different scenarios.

- IT DataCenter & Cloud Infrastructure Roadmap
- Storage Usage Patterns – Issues & Requirements
- NextGen SSDs for Enterprise Storage Systems
- Enterprise SSD Market/Product Segments by Interfaces
- SSD vs. HDDs vs. Hybrids - Price/Perf/Availability
- SLC vs. MLC SSDs – Technologies, Drivers & Challenges
- New Intelligent Controllers – Key for SSD Adoption
- AutoSmart Storage-Tiering Software – Usage & Impact
- Applications best suited for SSDs
- Key Takeaways

# IT DataCenters & Cloud Infrastructure SNIA

## Public CloudCenter<sup>®</sup>

## Enterprise VZ Data Center On-Premise Cloud





## Cloudization

**On-Premises > Private Clouds > Public Clouds**

DC to Cloud-Aware Infrast. & Apps. Cascade migration to SPs/Public Clouds.

## Automation

**Automatically Maintains Application SLAs**

(Self-Configuration, Self-Healing<sup>©IMEX</sup>, Self-Acctg. Charges etc)

## Virtualization

**Pools Resources. Provisions, Optimizes, Monitors**

Shuffles Resources to optimize Delivery of various Business Services

## Integration/Consolidation

**Integrate Physical Infrast./Blades to meet CAPSIMS<sup>©IMEX</sup>**

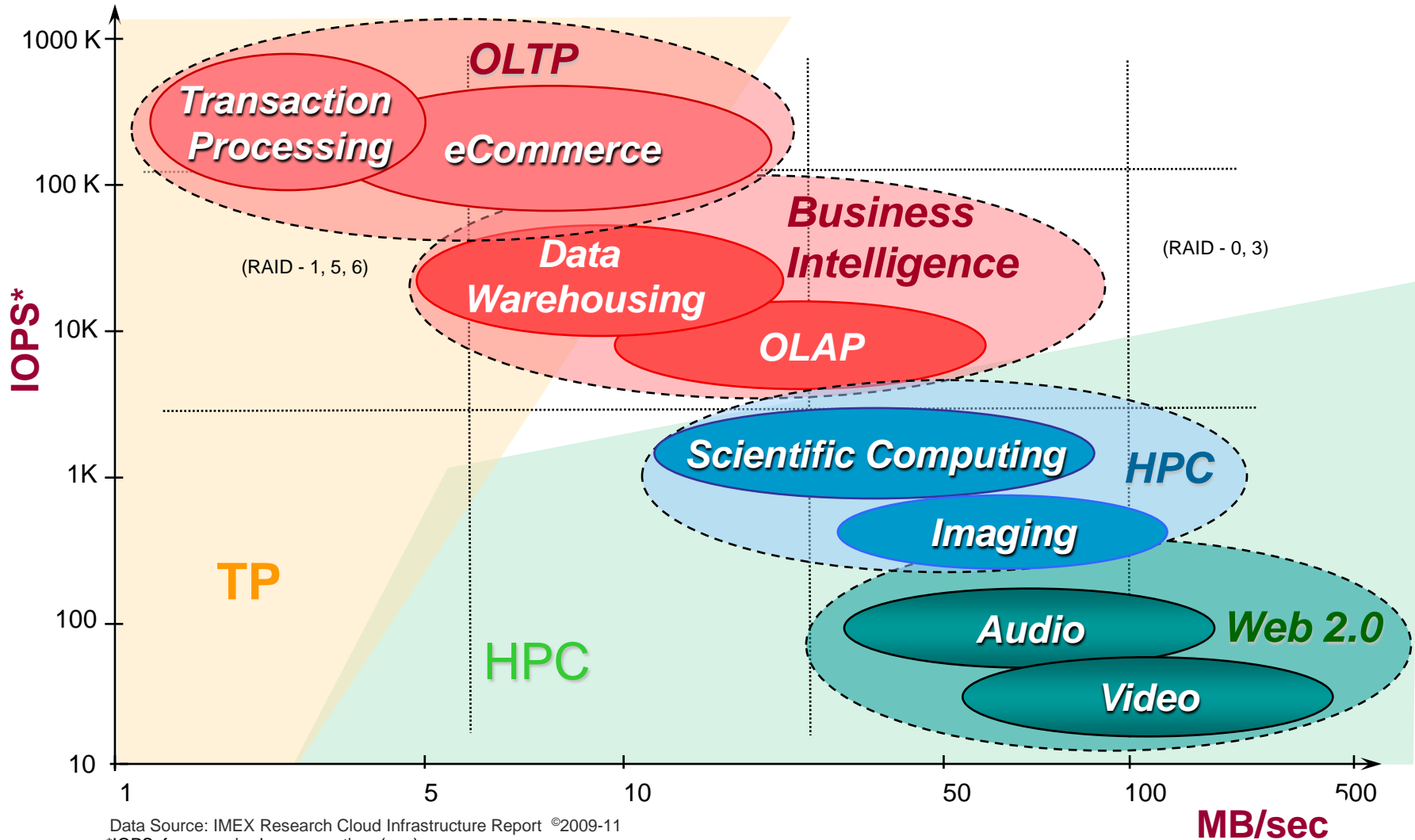
Cost, Availability, Performance, Scalability, Inter-operability, Manageability & Security

## Standardization

**Standard IT Infrastructure- Volume Economics HW/Syst SW**

(Servers, Storage, Networking Devices, System Software (OS, MW & Data Mgmt SW))

# Market Segments by Applications



Data Source: IMEX Research Cloud Infrastructure Report ©2009-11

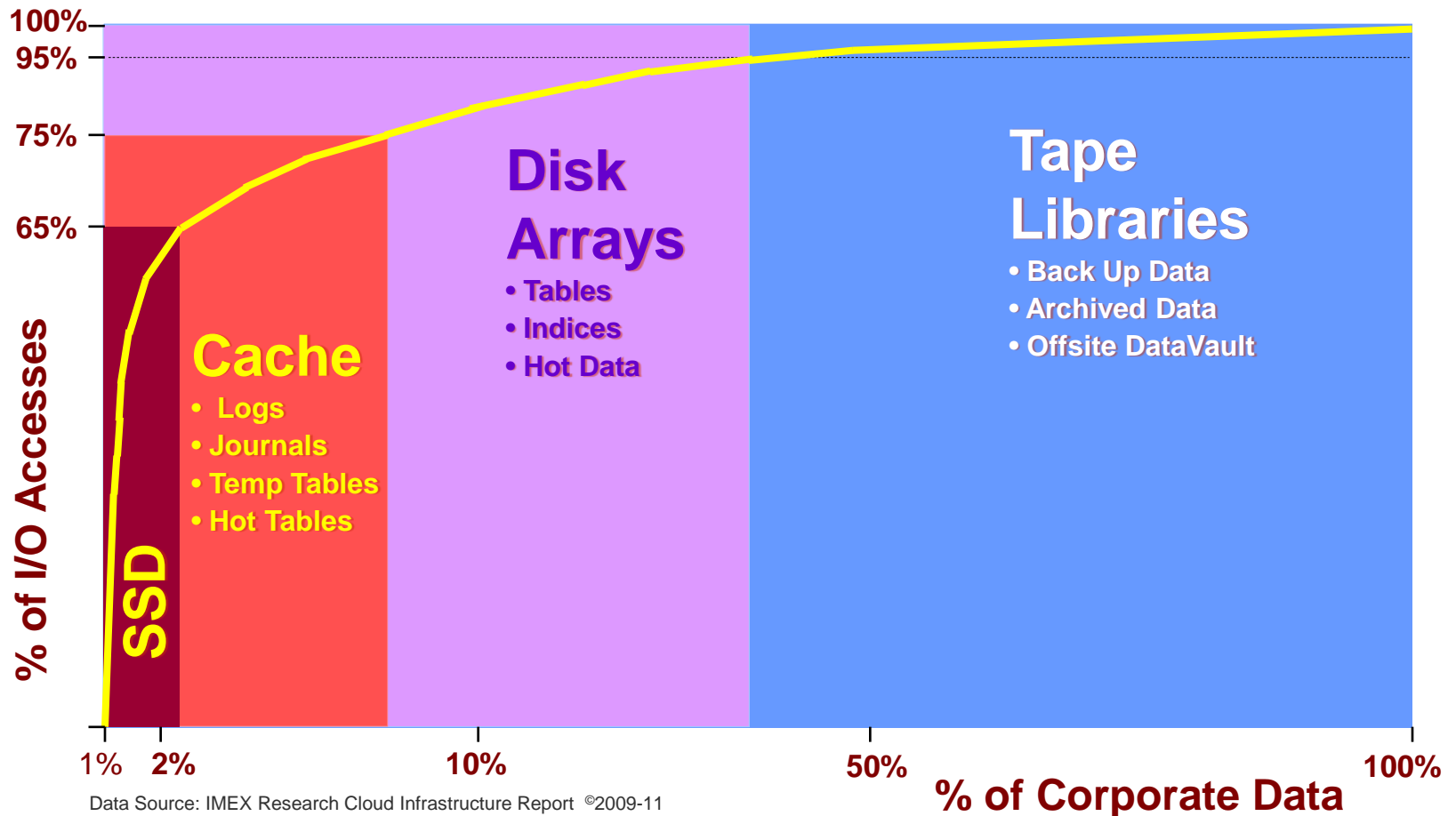
\*IOPS for a required response time (ms)

\*=(#Channels\*Latency-1)

Are SSDs Ready for Enterprise Storage Systems?

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## I/O Access Frequency vs. Percent of Corporate Data

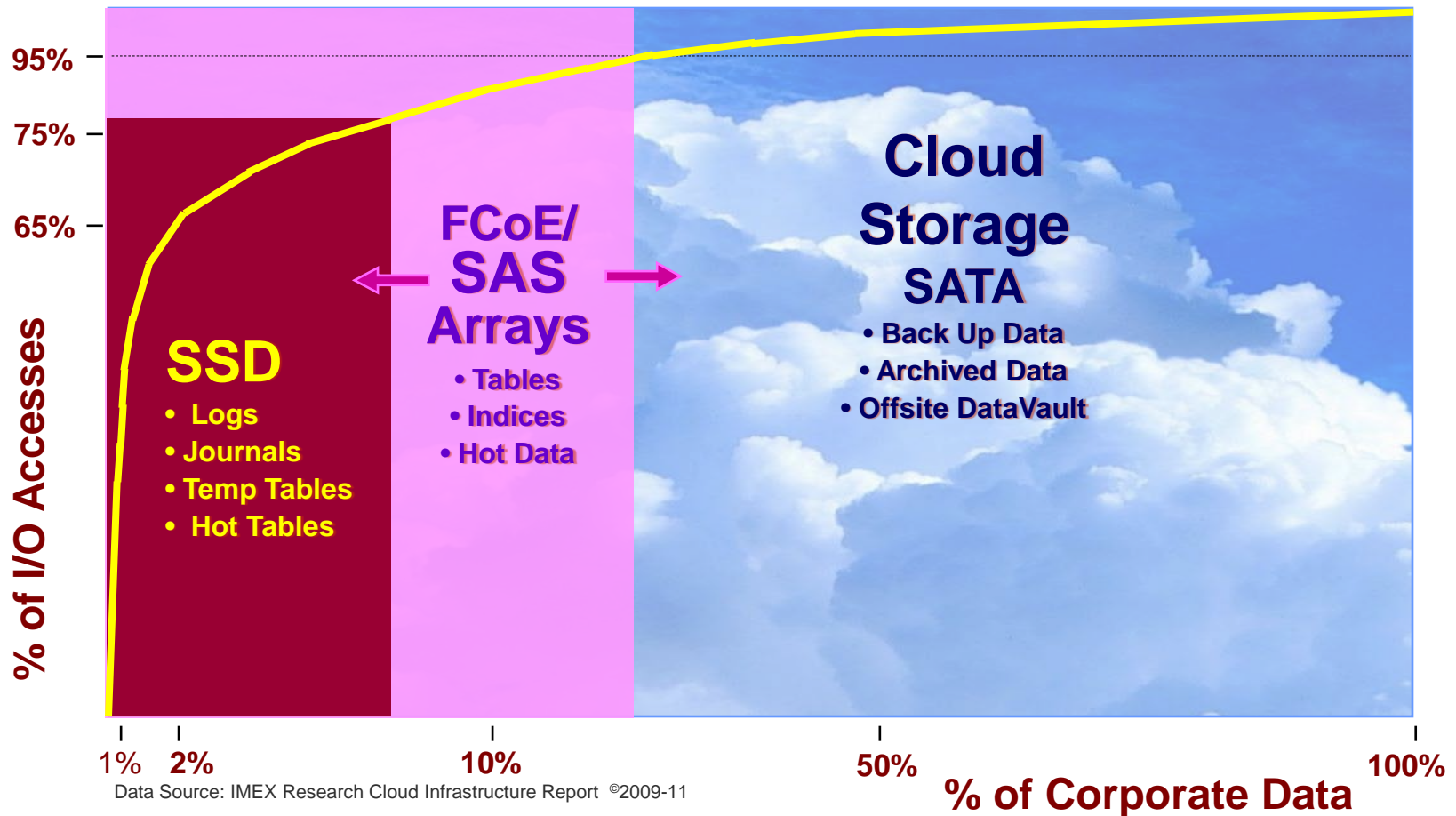


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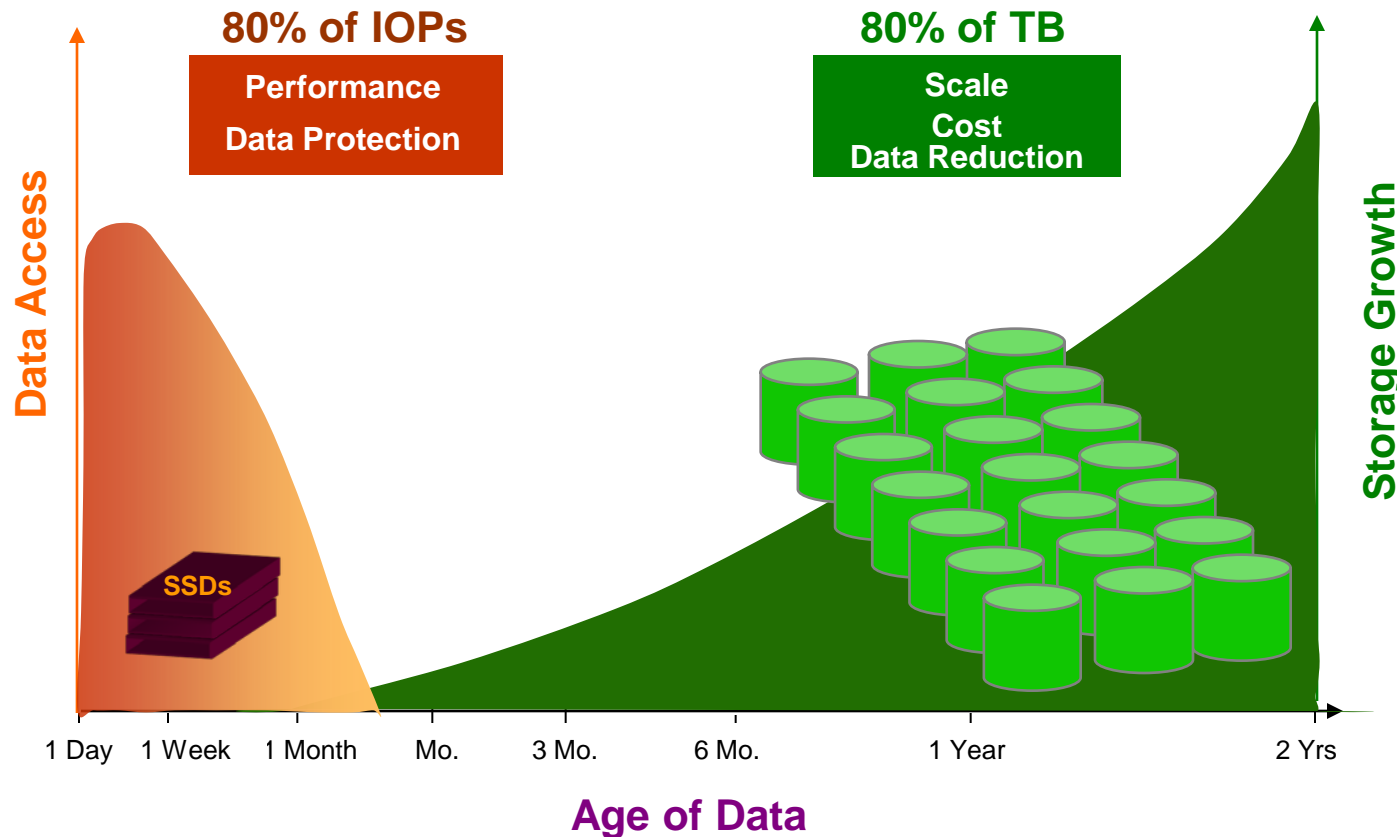
## I/O Access Frequency vs. Percent of Corporate Data



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# Data Storage Usage – Access & Longevity

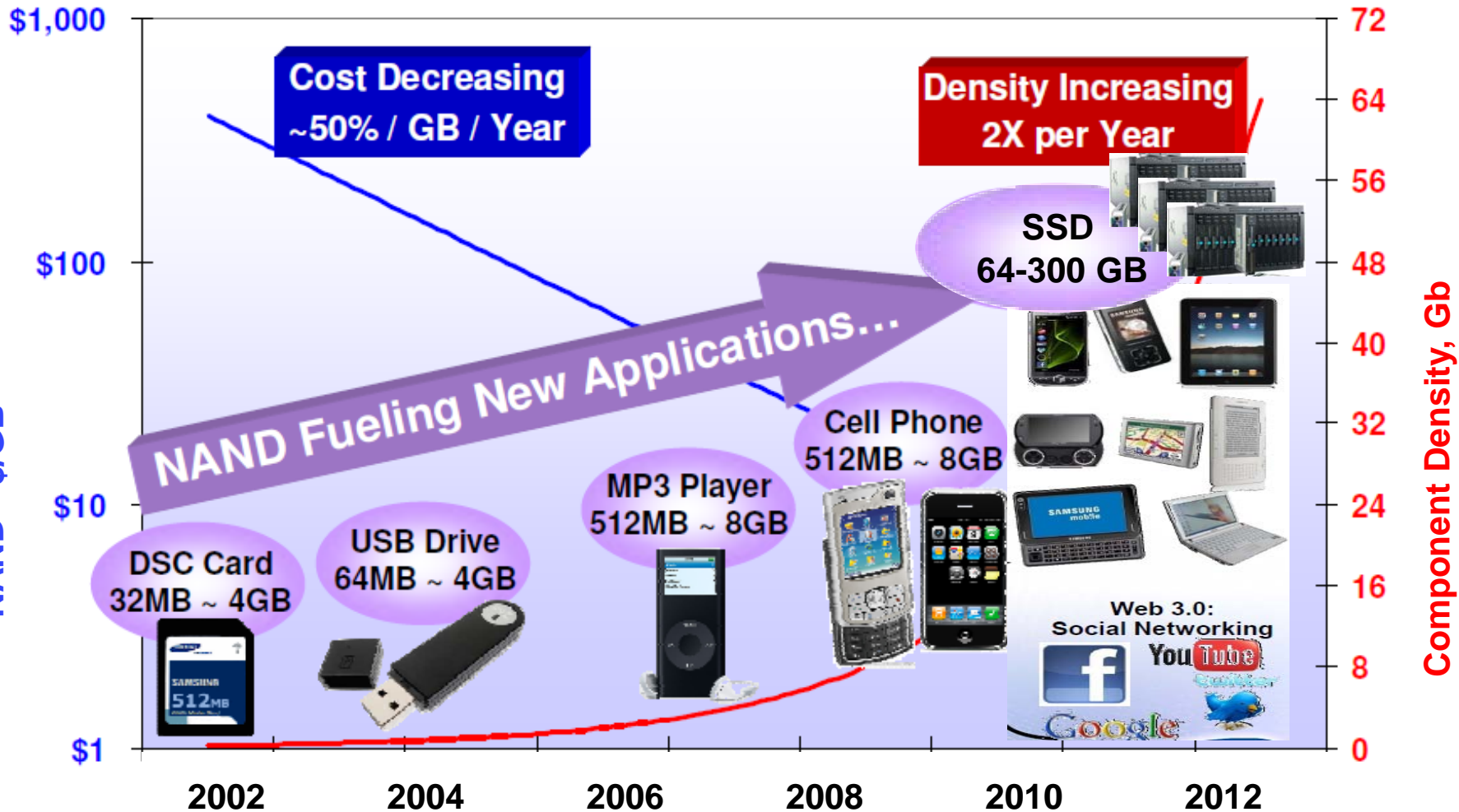


Data Source: IMEX Research Cloud Infrastructure Report ©2009-11



# NAND: Enabling Consumer to Enterprise Mkts

SNIA

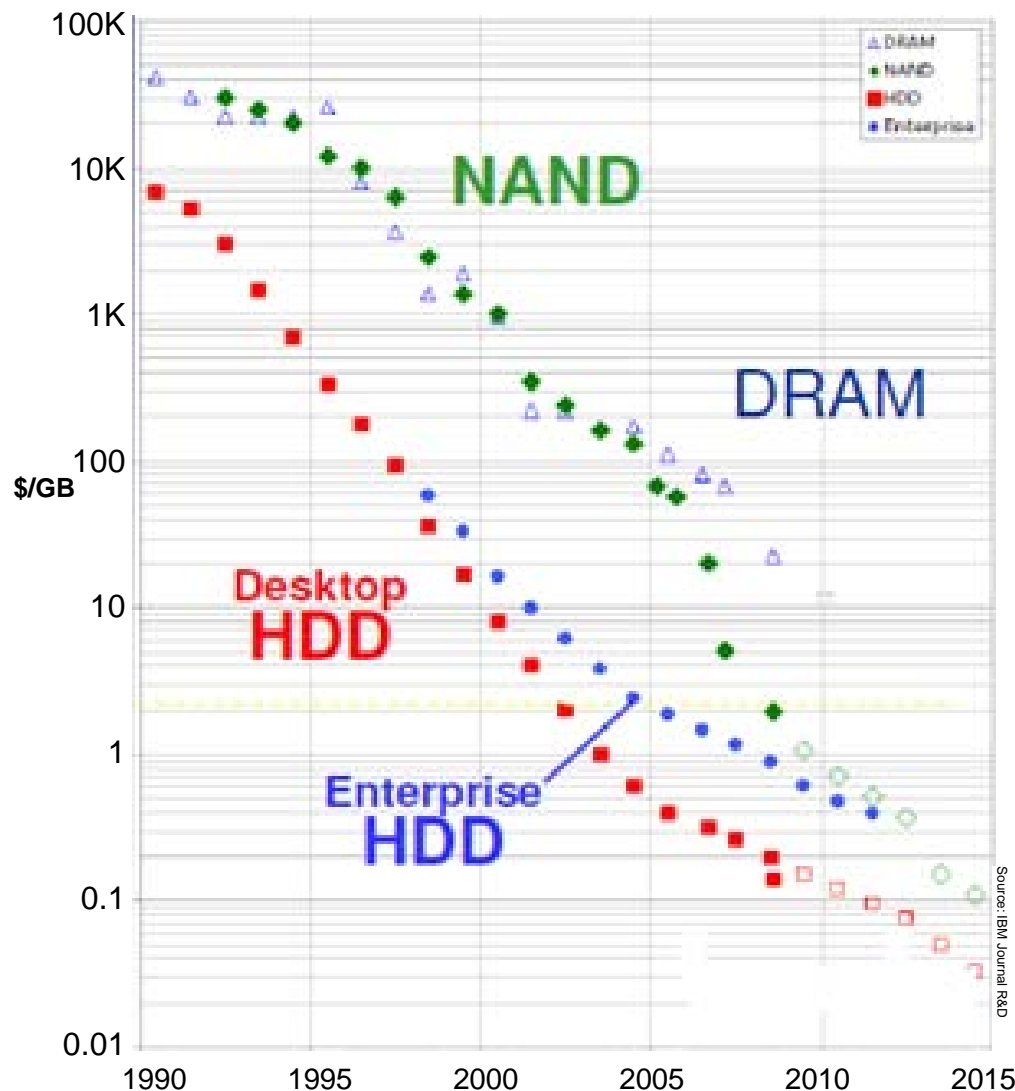


Source: Samsung & IMEX Research

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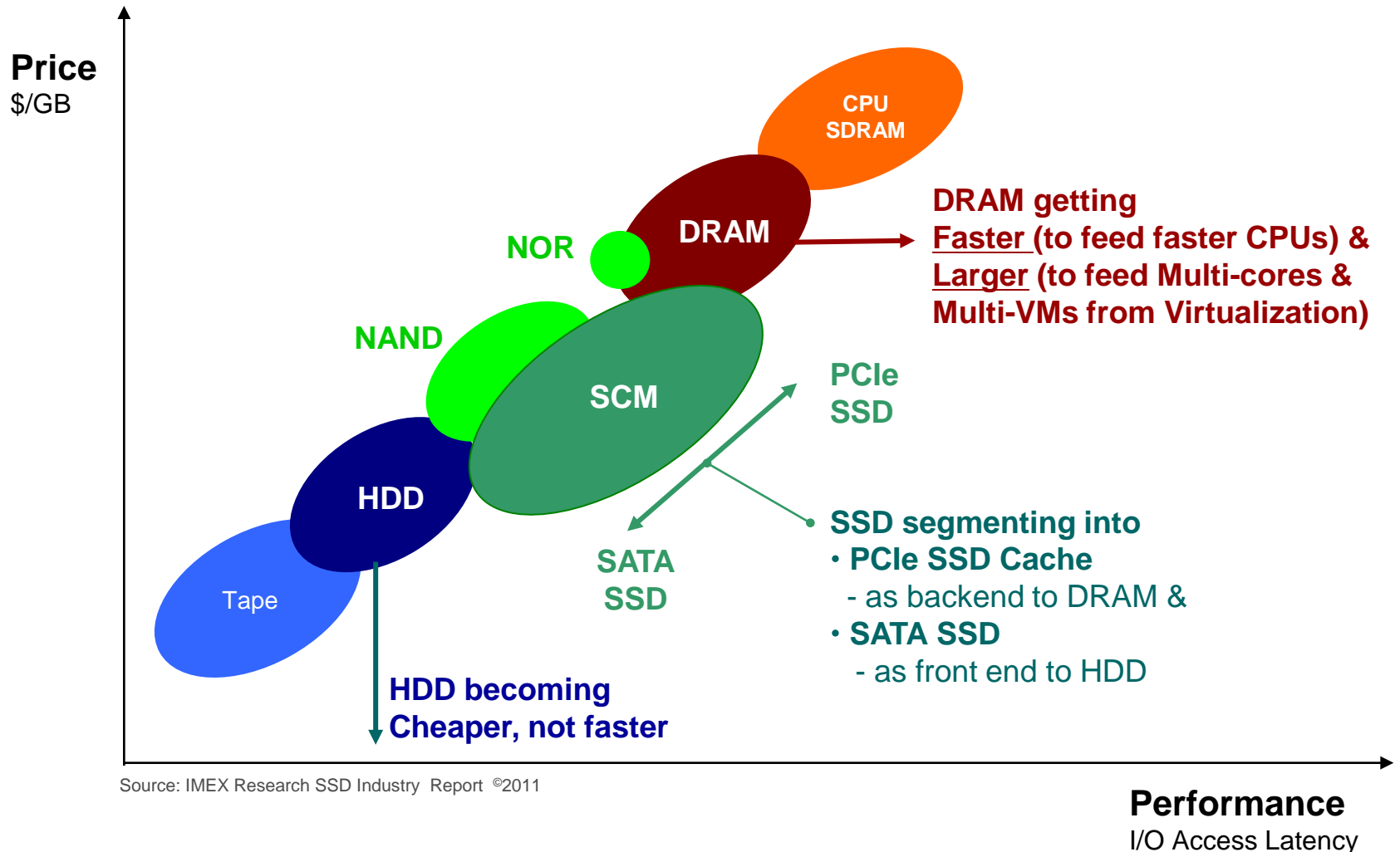
# Enterprise SSDs Trends - Cost



## ► Price Erosion Trends

- ◆ Driven by an explosion in the use of cost-sensitive handheld mobile devices, MLC NAND has seen an explosive growth.
- ◆ On enterprise side Clustered low cost servers used in multiple environments from DB to BI to HPC applications besides being driven by Cloud Service Providers are providing an overall growth of 107% cagr in Computing SSDs GB
- ◆ SSD units are forecasted to grow at 86% cagr during the 2010-14 time frame.

# SSD Filling Price/Perf Gaps in Storage



Source: IMEX Research SSD Industry Report ©2011

## ➤ **SCM (Storage Class Memory)**

Solid State Memory filling the gap between DRAMs & HDDs  
Marketplace segmenting SCMs into SATA and PCIe based SSDs

## ➤ **Key Metrics Required of SCMs**

- **Device** - Capacity (GB), Cost (\$/GB),
- **Performance** - Latency (Random/Block RW Access-ms);
  - Bandwidth W(R/W- GB/sec)
- **Data Integrity** - BER (Better than 1 in  $10^{17}$ )
- **Reliability** - Write Endurance (No. of writes before death); Data Retention (Years); MTBF (millions of Hrs),
- **Environment** - Power Consumption (Watts); Volumetric Density (TB/cu.in.); Power On/Off Time (sec),
- **Resistance** - Shock/Vibration (g-force); Temp./Voltage Extremes 4-Corner ( $^{\circ}$ C,V); Radiation (Rad)

# Advantage: SSD vs. HDD in Enterprise Storage

Manufacturer's Required Specs				
<b>Endurance</b>	Function Failures			UBER
Enterprise	<= 3%			<=10e-16
		<b>SSD</b>	<b>HDD</b>	Diff. %
<b>MTBF</b>	Million Hr	2.1	1.0	-110%
<b>Failure Rate</b>	Per Year	<<3%	4%	-33%

## Reliability

## Environmental

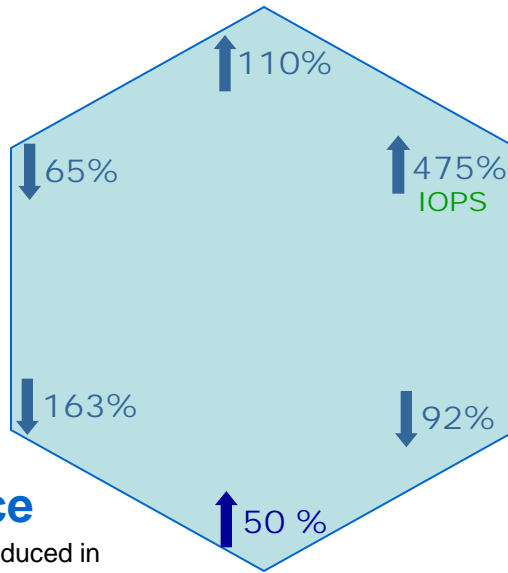
**Shock/Vibration** Higher Resistance to  
-Shock 8x Better, Anti-Vibration 16x Better  
**Operating Temp**

Spec'd at 2x Wider Operating Temp Range

**Noise** 30dB Lower

**Space** Savings in Space \$ at \$/sq.ft Office  
Space For same IOPS, Fewer Frames, Switch  
Ports, Controllers, Cables, Power Supplies etc

**Weight** 50% Less Weight



## Performance

**RW Speed** 5x Faster

**Data Access Time** <1%

**Concurrent Access** 900% Better

**IOPS** 475% Better

## Power

92% Less Power, 38% Less Temp

		<b>SSD</b>	<b>HDD</b>	Svgs %
<b>Idling</b>	<b>Power</b> Watts	0.5	6.8	<b>93%</b>
	<b>Temp</b> Surf C	85	136	38%
<b>Load</b>	<b>Power</b> Watts	0.9	10.1	<b>91%</b>
	<b>Temp</b> Surf C	94	154	39%

## TCO

50% of HDD

## Operating Maintenance

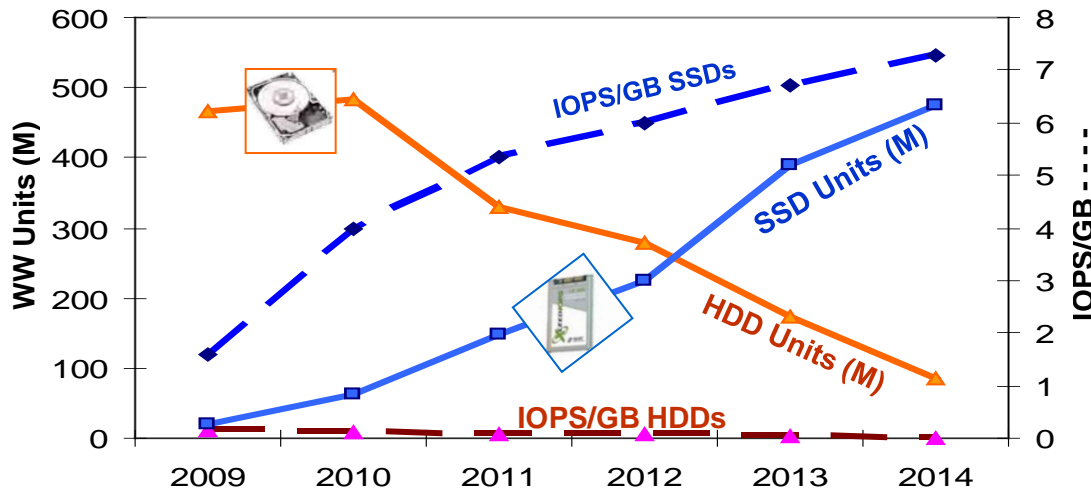
**Maintenance & Operating Time** Reduced in

- Booting Up, - Virus Scan, - Defrag, - RAID Build, -  
Patching, - Data Restoration

# Advantage: Enterprise SSDs vs. HDDs

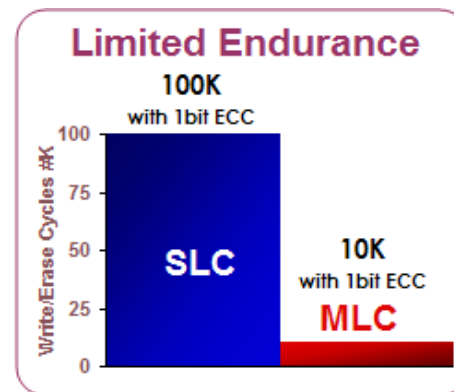
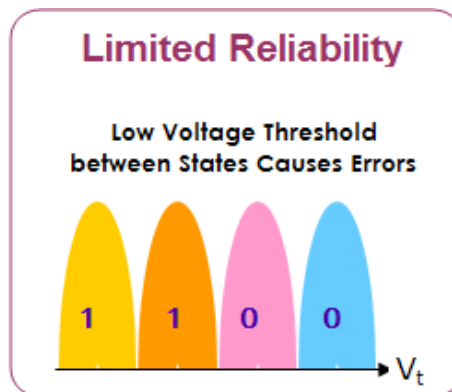
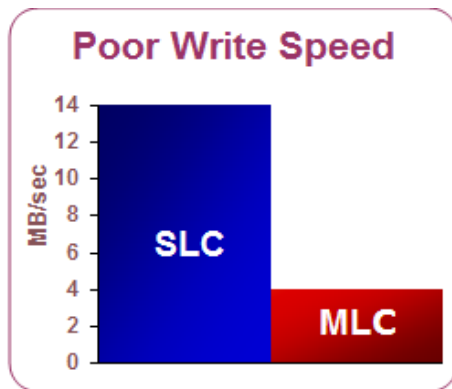


	Parameter		Improvement SSD vs. HDD
1.0 GB/in <sup>3</sup>	Storage Density	16 GB/in <sup>3</sup>	1600 %
4.2 IOPS/in <sup>3</sup>	Performance Density	1,250 IOPS/in <sup>3</sup>	30,000 %
11.4 GB/W	Power Efficiency	570 GB/W	5,000 %
43.1 IOPS/W	Performance/Power	42,850 IOPS/W	100,000 %



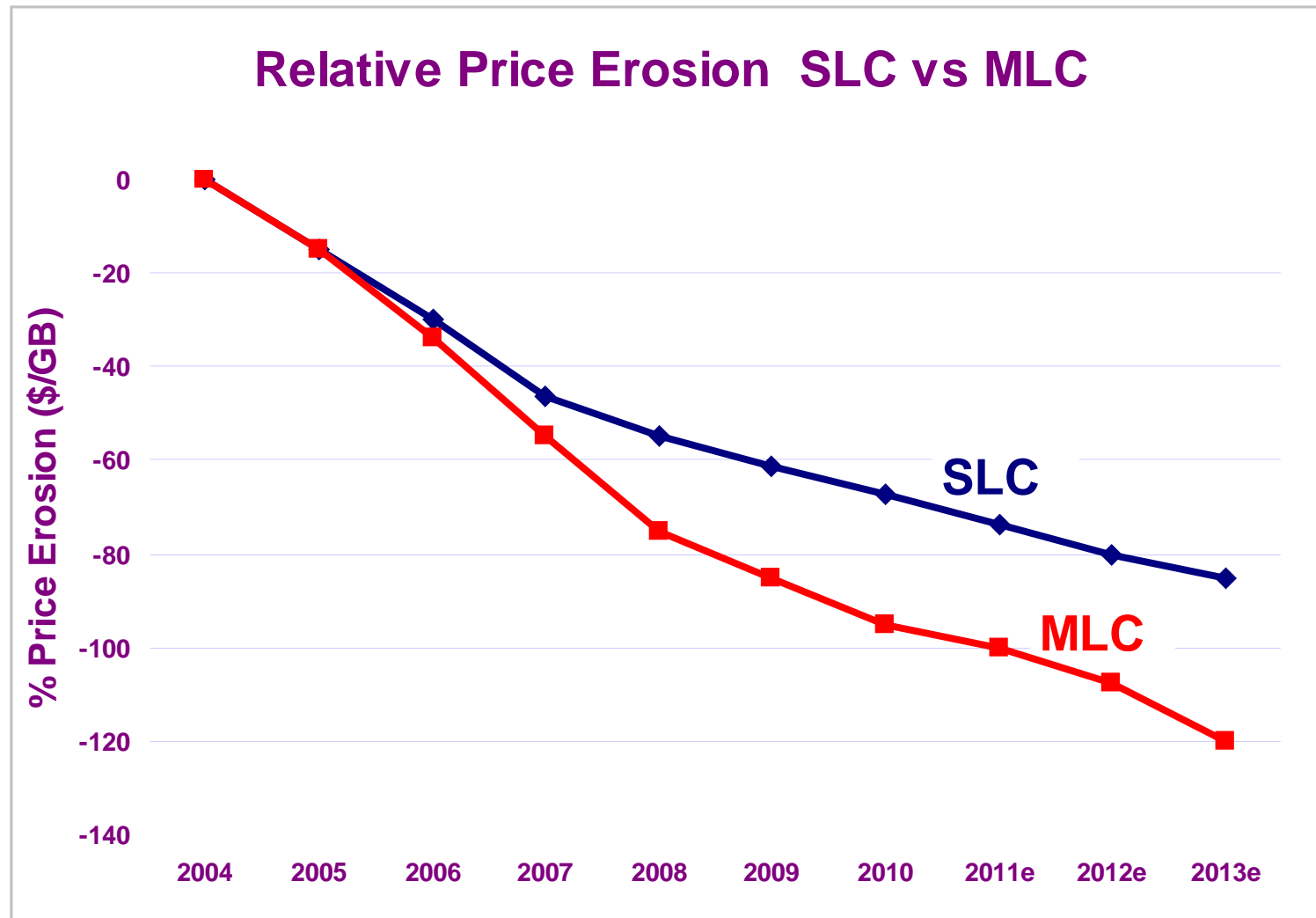
Note: 2U storage rack, • 2.5" HDD max cap = 400GB / 24 HDDs, de-stroked to 20%, • 2.5" SSD max cap = 800GB / 36 SSDs  
Source: IMEX Research SSD Industry Report ©2011

# Drivers & Challenges – MLC vs. SLC SSDs



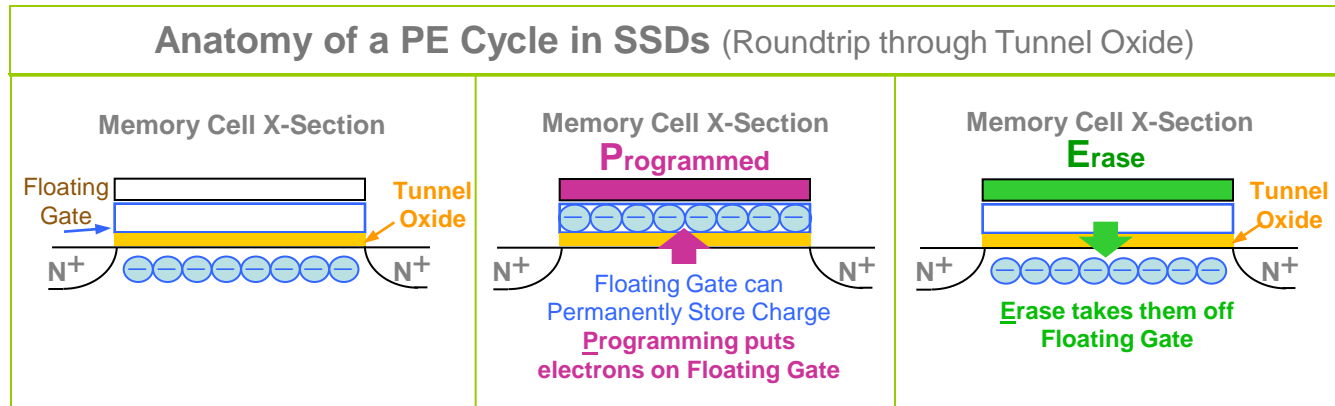
	Drivers	Challenges
<b>Raw Media Reliability</b>	<ul style="list-style-type: none"> <li>•No moving parts</li> <li>•Predictable wear out</li> <li>•Post infant mortality catastrophic device failures rare</li> </ul>	<ul style="list-style-type: none"> <li>•Higher density of MLC increases bit error rate</li> <li>•High bit error rate increases with wear</li> <li>•Program and Read Disturb Prevention, Partial Page Programming</li> <li>•Data retention is poor at high temperature and wear</li> </ul>
<b>Media Performance</b>	<ul style="list-style-type: none"> <li>•Performance is excellent (vs.HDDs)</li> <li>•High performance/Watt (IOPS/Watt)</li> <li>•Low pin count: shared command / data bus, good balance</li> </ul>	<ul style="list-style-type: none"> <li>•NAND not really a random access device</li> <li>•Block oriented; Slow effective write, erase/transfer/program) latency, Imbalanced R/W access speed</li> <li>•NAND Performance changes with wear, Some controllers do read/erase/modify/write, Others use inefficient garbage collection</li> </ul>
<b>Controller</b>	<ul style="list-style-type: none"> <li>•Transparently converts NAND Flash memory into storage device</li> <li>•Manages high bit error rate</li> <li>•Improves endurance to sustain a 5-year life cycle</li> </ul>	<ul style="list-style-type: none"> <li>•Interconnect</li> <li>•Number of NAND Flash Chips (Die); # of Buses (Real / Pipelined)</li> <li>•Data Protection (Int./Ext.RAID; DIF; ECC);Write Mitigation techniques</li> <li>•Effective Block (LBA; Sector) Size: Write Amplification</li> <li>•Garbage Collection (GC) Efficiency</li> <li>•Buffer Capacity &amp; Management: Meta-data processing</li> </ul>

# MLC vs. SLC SSDs - Price Erosion



# SSD Challenges & Solutions: Endurance/Wear-out

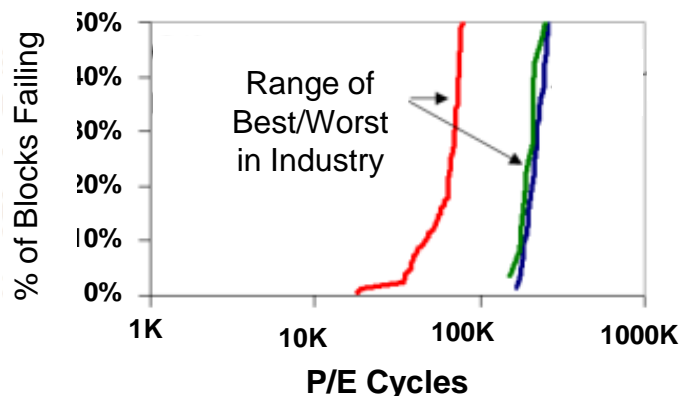
## Reason for Endurance Limitation in SSDs



- ◆ Fundamentally – NAND Flash Memory Cell is a MOS Transistor with a Floating Gate that can permanently store charge
- ◆ Programming puts electrons in Floating Gate, Erase takes them off
- ◆ 1 Program/Erase (P/E) Cycle is a round trip by the electrons
- ◆ Electrons pass through Cell's Tunnel Oxide. Back & Forth round trips gradually damage the Tunnel Oxide over hundred thousands of trips (Program/Erase or PE cycles) resulting in Limited Endurance (or Wear-Out by PE cycles) in SSDs

# SSD Challenges & Solutions: Endurance (Wear-Out)

## Challenge: Bad Block Mgmt



- ◆ The ability to erase slows down after a number of P/E Cycles.
- ◆ If NAND Memory block fails to erase, Controller is notified and another block from spares is used instead
- ◆ But there's no loss of data, so a failed NAND block does not pose a problem.
- ◆ Eventually devices will run out of spares
- ◆ The point where the % failing exceed number of spares is the most

## Basic Endurance Limit

## Solution: Over Provisioning

- ◆ Over Provisioning by Increasing Spare blocks
  - ◆ Decreases user capacity but
  - ◆ Allows SSD to more efficiently complete random Writes
  - ◆ Improves Random Write Endurance and Performance
- ◆ Methods to Implement include:
  - ◆ Setting max LBA to limit visible drive capacity or
  - ◆ Create Smaller RAID Logical Drives or
  - ◆ Create Smaller Partitions

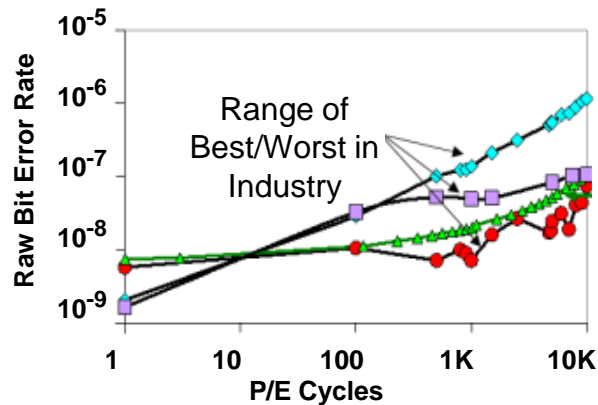
## Promise:

- ◆ Depending on workload, endurance can vary
- ◆ Endurance should match usage needs of the system to minimize costs.
  - ◆ SSD used as cache for 10 HDDs. 2 PB writes of useful life will support this.(1.1 TB writes/day for 5 years.)

# SSD Challenges & Solutions: Endurance (UBER)

## Challenge: Uncorrectable BER Mgmt

## Solution: ECC



Flash Media Starts with - 1 in 10<sup>8</sup> (1 error/100 million bits) Read  
Flash Media's Raw Bit Errors (RBER)

Corrected by ECC

UBER

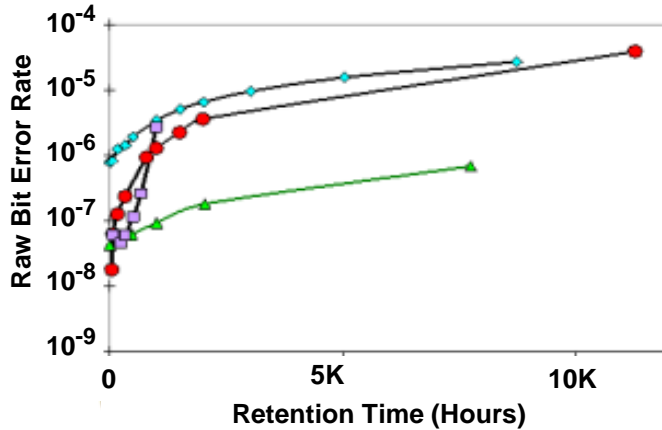
Left Uncorrected - 1 in 10<sup>16</sup> (1 error/10,000 Trillion bits Read)

- Using modern ECC techniques based controllers, vendors are providing spec at 1 in 10<sup>-17</sup> UBER

- ▶ A small of written bits gets flipped (similar to HDDs)
- ▶ This is Flash Media's **Raw Bit Error Rate (RBER)**
- ▶ ECC is used to correct/reduce this RBER
- ▶ RBER gradually increases with P/E cycles. Any bit error rate over ECC Correction capability is the **Uncorrected Bit Error Rate (UBER)**. Reaching a UBER domain user data can become corrupted.
- ▶ UBER is kept low. JEDEC Spec is 1 in 10<sup>16</sup> errors
- ▶ The point where UBER reaches this spec, is **Another Endurance Limit**

# SSD Challenges & Solutions: Data Retention

## Challenge: Data Retention



## Solution: Data Retention Firmware

- ▶ Powered-On Firmware
  - ♦ To allow Higher Retention
- ▶ Balance out SSD Data Retention vs. Endurance
  - ♦ Lower Data Retention allows for higher endurance

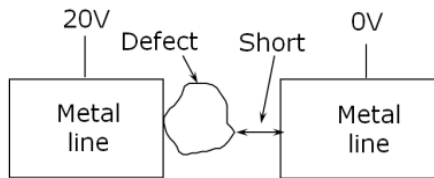
- ▶ After PE cycles, RBER increases with time. ECC corrects bit flips but only to a certain extent.
- ▶ So the industry lives with a required UBER and required Retention Time. This, in turn, determines the **Safe PE cycles that device should be exercised to**, prior to reaching the UBER and Retention time. This is also another endurance limit set by retention.

# SSD Challenges & Solutions: Functional Failure Defects

## Challenge: Electronic Component - Defects

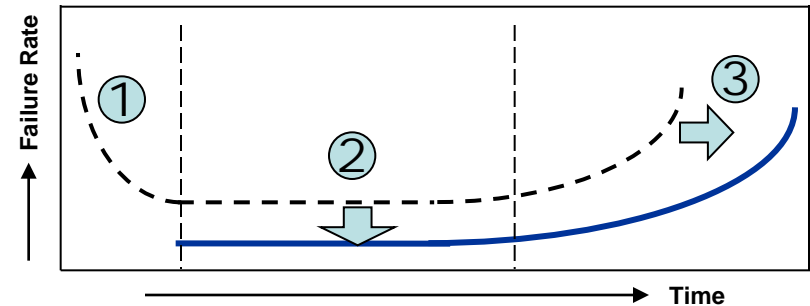
### Role of Defects in SSD Reliability


Wafer Process Defects		61%
Design Related & Test	10%	
EOS/ESD	10%	
Handling	9%	
Process Errors	5%	
Assembly & Test	5%	



- All ICs have defects that cause failures. In Flash early life failures are caused by such defects.
- Defects can cause functional failures not just data loss. Most of NAND defect failures are caused by PE cycles, coming in from high PE voltages causing defects to short.
- The point where % failing from defects would reach unacceptable limits is another boundary for endurance.

## Solution: Burn-Ins, Error Avoidance Algorithm



- **Vigorous SSD Burn-In & Testing** (1) 
  - Remove Infant Mortality
- **Compute NAND** (2)
  - $T_{read}$  to improve Read Disturbs
  - $T_{prog}$  to reduce Program Disturbs
- **SSD Error Avoidance algorithms**
  - ECC ASICS
- **Wear Leveling to avoid Hot Spots**
- **Efficient Write Amplification Factor (WAF)** (3)
  - $WAF = \text{Data written to NAND} / \text{Data Written by Host to SSD}$
  - WAF dependent on (a) SSD FW algorithm built into SSD (b) Over Provisioning Amount (c) App Workload

# SSD Challenges & Solutions: Industry Standard Testing

## JEDEC Solution: Manufacturer Requirements

Class	Active Usage	Retention	Failures	UBER
	Power On	Power Off	FFR	
Client	8 Hrs/day (40°C)	1 yr. (40°C)	$\leq 3\%$	$< 10^{-15}$
Enterprise	24 Hrs/day (40°C)	3 mo. (40°C)	$\leq 3\%$	$< 10^{-16}$

## JEDEC Solution: Specify Endurance, Verify Spec via EVT

Endurance spec is max TB written to SSD over which device meets spec

Rigorous verification of Spec using EVT (Endurance Verification Test)

JEDEC supplies the workload. Data continuously read and verified.

SSD must meet  $\leq 3\%$  fail, UBER  $< 1$  in  $10^{-16}$

EVT requires high/low temp stressing

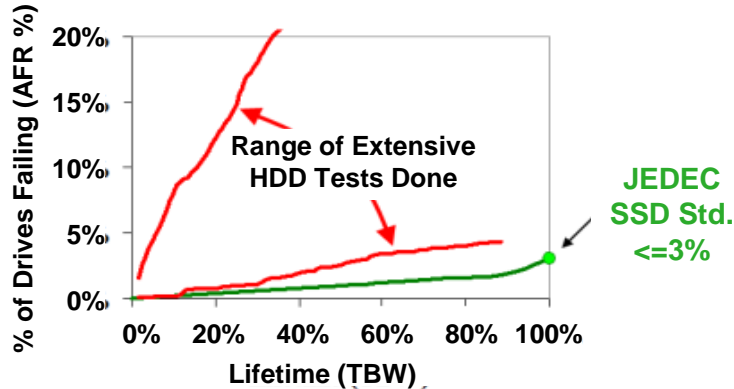
EVT represents lifetime worth of Stress Test, so can be trusted

Accelerated Test (High Temp bake) and Unaccelerated Room Temp Retention Test required

Manufacturer provides 'gauge' informing user of % of endurance life used up

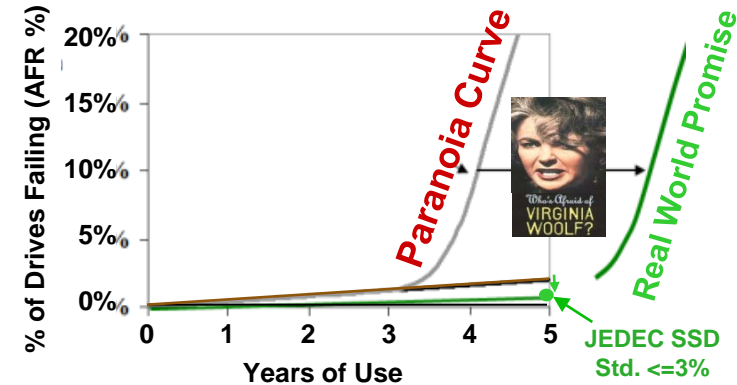
# SSD Challenges & Solutions: Goals & Best Practices

## Goals & Best Practices



- ◆ All NAND will have finite Endurance Limits due to limitations imposed by:
  - Uncorrectable Bit Error Rates
  - Functional Failures
  - Data Retention Time
- ◆ Goal is to embody technologies to Improve Life (Years of Use)
  - Push Endurance Limit to the right beyond product life as required by SSD products
  - Push the defect rate down through Burn-Ins, Error Avoidance Algorithms and Practices. so the total <=3% defects and wear-outs issues combined
  - Target data errors to be < 1 in  $10^{16}$  for Enterprise SSDs for both TBW and Retentions specs.

## Afraid of SSD Adoption in your Enterprise? Be aware of Tools & Best Practices... And you'll be OK !!

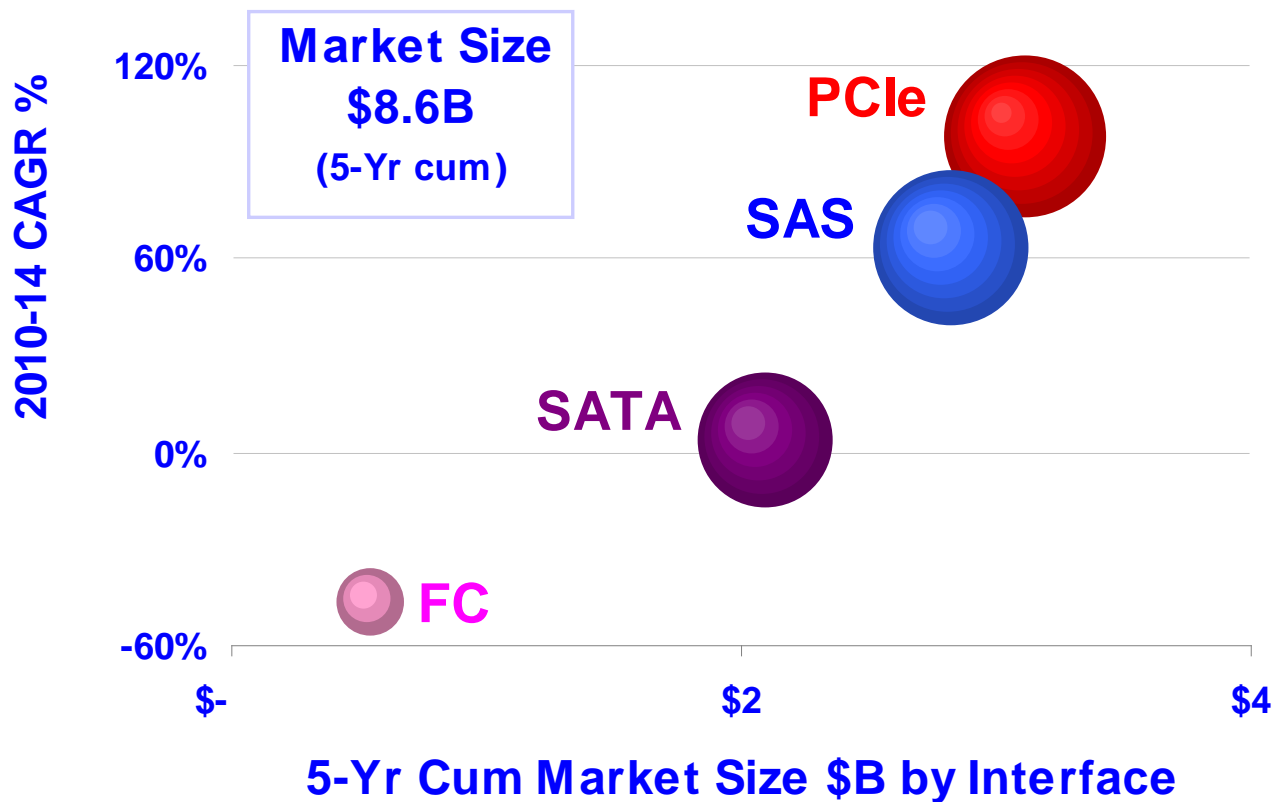


### Best Practices

- By leveraging Error Avoidance Algorithms, Verification Testing and Best Practices, so that total functional failure rate <=3% with defects and wear-outs issues combined
- In practice, endurance ratings are likely to be significantly higher than typical use, so data errors and failures will be even less.
- Capacity reduction can provide large increases in random performance and endurance.
- Select SSD based on confirmed EVT Ratings
- Use MLC within requirements of Endurance Limits

# WW Enterprise SSD Market Opportunity

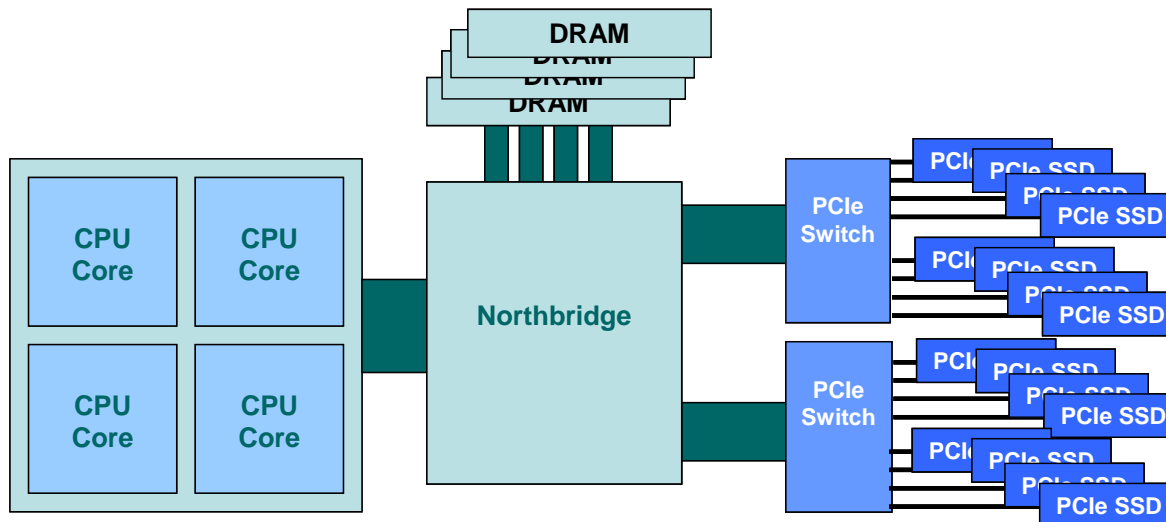
## WW Enterprise SSD 5-Yr Mkt Opportunity Cum \$B (2010-14)






Source: IMEX Research SSD Industry Report ©2011

## ► PCIe based SSD Storage

- ◆ Target Market – Servers Storage
- ◆ SSD as backend storage to DRAM as the front end
- ◆ 36 PCIe Lanes Availability,
- ◆ 3/6 GB/s Performance (PCIe Gen2/3 x8),
- ◆ Low Latency in micro sec,
- ◆ Low Cost (via eliminating HBA cost)



# PCIe based SSD Storage

Usage for	Device	Storage Metric Target	Central Storage	Server Based
Caching		\$/IOP, Latency *1	LBA Cache	LBA Cache
Performance		\$/IOP/GB *2	Hot App Data	Hot App Data
Capacity		\$/GB, Watts/GB *3	Cold/Lukewarm App Data	Lukewarm App Data

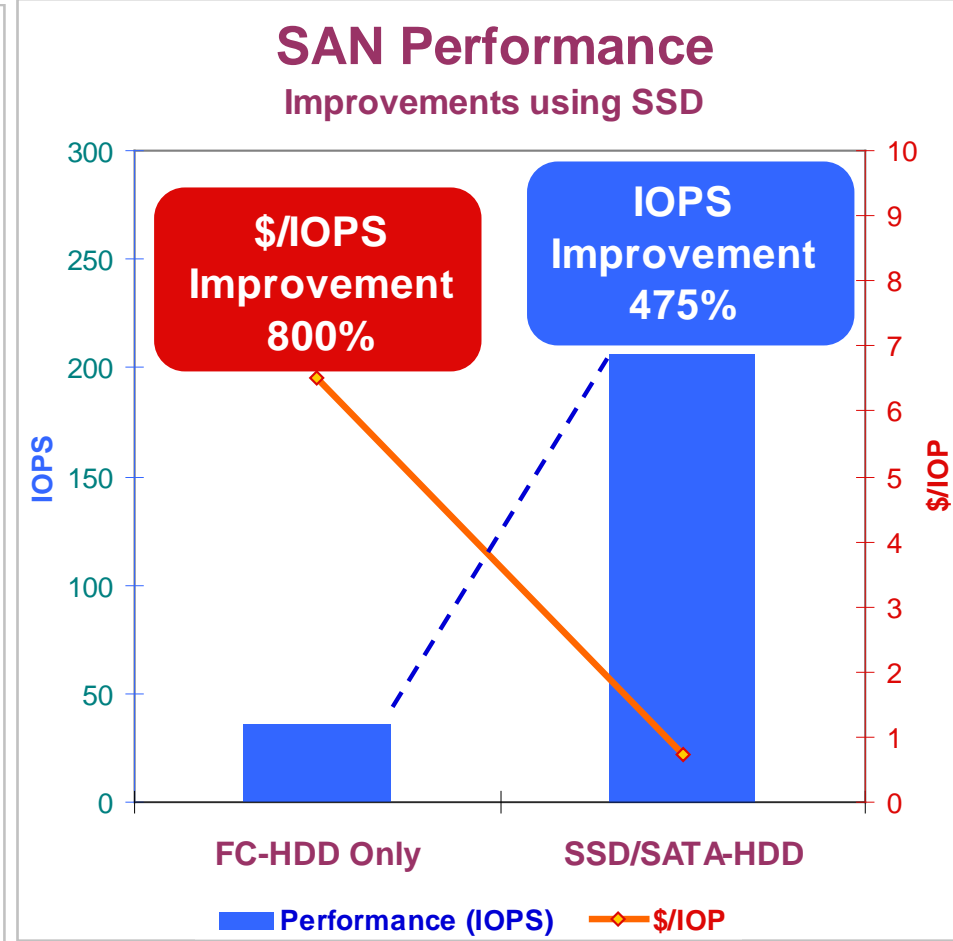
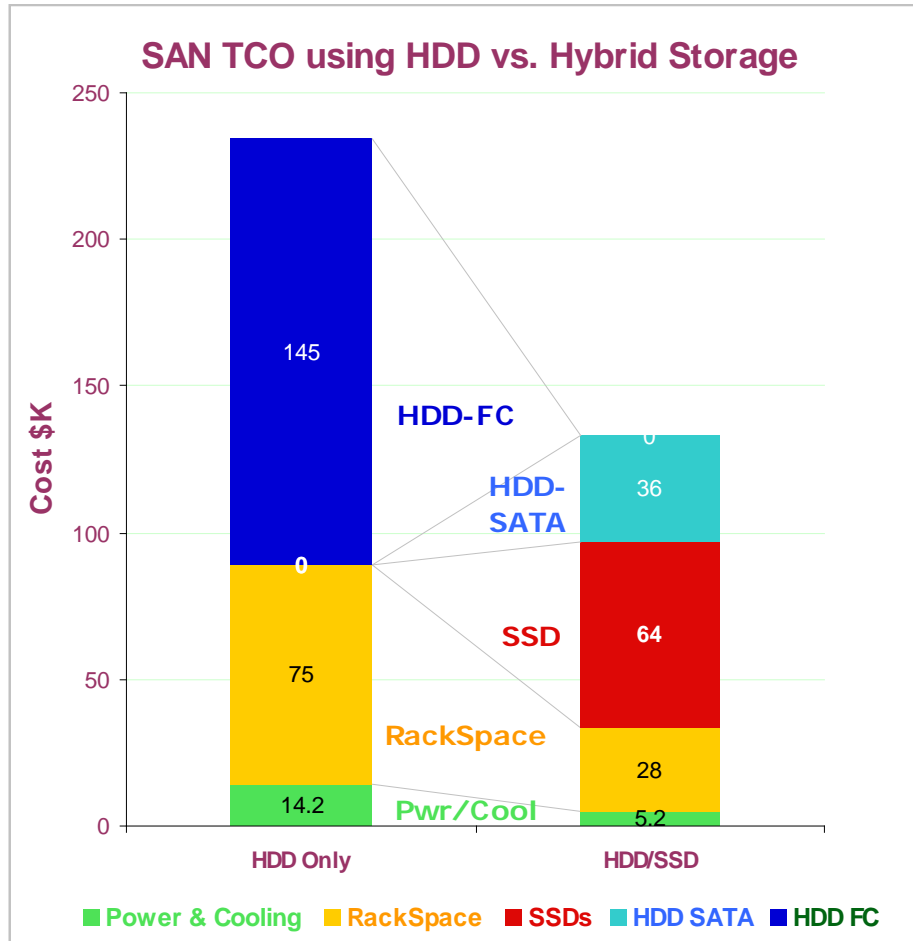
- \*1 – PCIe SSD performance enables new storage caching “IOPS Tier” as Application Managed Caching
- \*2 - PCIe SSDs of many flavors replace HDDs for High Performance Storage in some apps (e.g. Financial, DB etc)
- \*3 – HDDs best for Data at Rest as \$/GB storage leader

**PCIe SSD attributes of high IOPS, high Bandwidth, Low Latency and lower cost are a good match for Caching**

## ➤ Hybrid Storage – SAS or SATA SSD+HDD

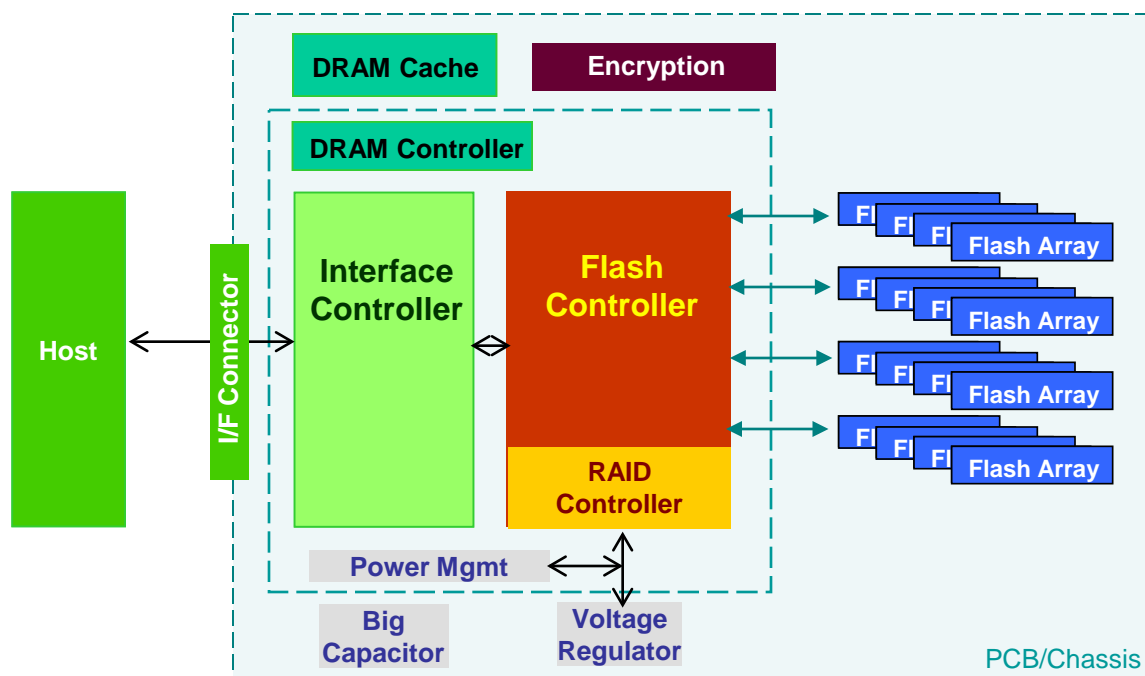
- ◆ Target market – External Storage Systems
- ◆ Combines best features of SSDs - outstanding Read Performance (Latency, IOPs) and Throughput (MB/s) with extremely low cost of HDDs giving rise to a new class of storage - Hybrid Storage Devices
- ◆ SSD as Front End to HDD
- ◆ Controller emulates SSD as HDD
- ◆ Use of Adaptive Memory sends High IOPS requirements to SSD while capacity requiring Apps sent to HDD
- ◆ Simple Add on to SATA HDD Storage
- ◆ SAS 6Gb/sec announced by multi-vendors

# Hybrid SSD Storage - Perf & TCO



Source: IMEX Research SSD Industry Report ©2011

# New Intelligent Controllers: SSD Storage Architecture



1	Interface Controller	Signaling Mgmt, Interpret WR/RD/Status Commands, Native Command Queuing, Move Data <-> Host
2	Flash Controller	Signaling Mgmt, Format, Interpret WR/RD/Status Commands for Flash Arrays, Move Data. Defect Mapping/Bad Block Mgmt, Wear Leveling, Physical<>Logical Translations, ECC...
3	RAID Controller	RAID Type & RD/WR/Parity Manipulation
4	Channels	Multiple Channel to Increase Speed between NAND Flash Arrays & Flash Controller
5	DRAM	Increase Performance using fast DRAM Cache Buffer
6	Power Failure	Power Failure Protection using Big Capacitor
7	Power Mgmt	Power/Performance Balancing, Sleep Mode Mgmt
8	Encryption	Security Schemes Implementation & Manipulation

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# New Intelligent Controllers: Managing NAND Media in NextGen SSDs

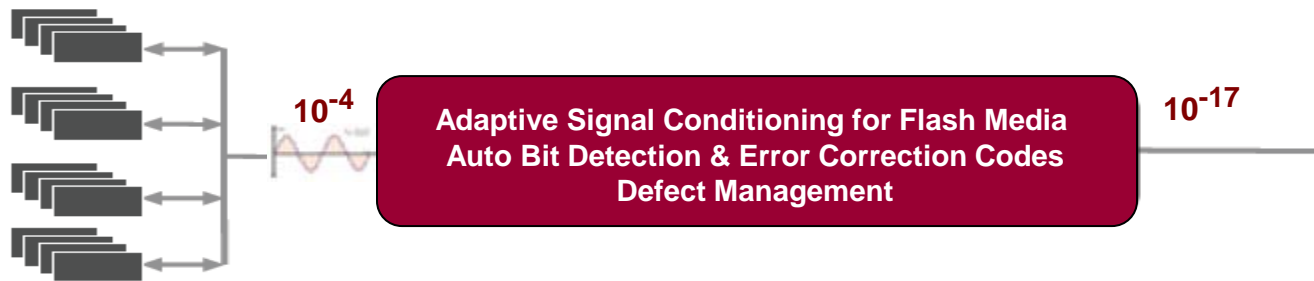
## Leveraging Long History of managing HDD's imperfect media & high error rates

- Characterizing the quality & capabilities of media
- Allocating data based on quality of media

### HDD Media



### Flash Media



## Leveraging Long History of managing HDD's imperfect media & high error rates

- Endurance for Long Life Cycle
- Reliability through RAID of Flash Elements
- Adaptive Digital Signal Processing Technology
- Dynamically adjust Read/Write characteristics of each chip
- Tune adjustments over life of media
- ECCs - PRML Deploying Enhanced Error Correction Codes

Source: IMEX Research SSD Industry Report ©2011

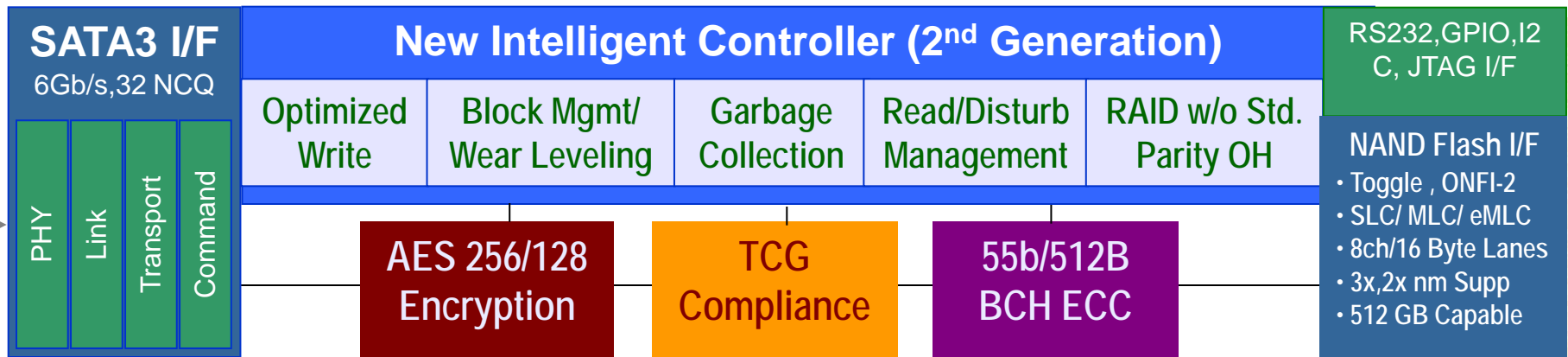
Are SSDs Ready for Enterprise Storage Systems?

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# New Intelligent Controllers: Managing Enterprise Requirements

## ➤ Meet Enterprise Requirements

- ◆ **Always-On 24x7 Reliability** and performance supersede cost
- ◆ **Fast I/O Performance** required by business-critical applications and
- ◆ **5-Yr. Life Cycle Endurance** required by mission-critical applications in the enterprise.
- ◆ **Use State-of-the-Art** new sophisticated controllers and firmware technologies to run mission critical applications in the enterprise, using
  - Robust ECC, Internal RAID, Wear Leveling (To reduce hot spots), Spare Capacity, Write Amplification, Avoidance, Garbage Collection Efficiency, Wear Out Prediction Management etc.



Are SSDs Ready for Enterprise Storage Systems?

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# New Intelligent Controllers : Managing Endurance in NextGen SSDs

## ➤ Managing Endurance

To overcome NAND's earlier endurance shortfalls due to limitation in write/erase cycles/block, intelligent controllers manage NAND SSDs using

- ◆ **ECC Techniques** – Correct and guard against bit failures, same as in HDDs
- ◆ **Wear Leveling Algorithms** – Writing data to evenly distributes it over all available cells to avoids a block of cells being overused and cause failures.
- ◆ **Over-provisioning Capacity** – Extra spare raw blocks are designed-in as headroom and included to replace those blocks that get overused or go bad. Additionally provide enough room for wear-leveling algorithms to enhance reliability of the device over its life-cycle.
- ◆ Typical SSD device's specified GB device will actually contain 20-25% extra raw capacity to meet these criterions.

# New Intelligent Controllers

## Managing Reliability in NextGen SSDs

### ➤ **Managing Reliability**

Multiple techniques are being used to improve the reliability, such as:

#### **In-Flight**

Corruption upstream disk controllers, Corruption in SSD controller itself

Flush at power loss using large cap elements

#### **At-Rest**

ECC

Scanning & scrubbing

Redundancy

#### **Meta-data**

Error correcting memory

Data integrity field

### ➤ **Managing Performance / Key Metrics Impact**

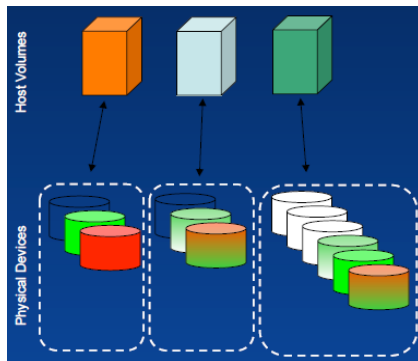
- ◆ Factors Impact Performance
- ◆ **Hardware** - CPU, Interface, Chipset ...
- ◆ **System SW** - OS, App, Drivers, Caches, SSD specific TRIM, Purge, ...
- ◆ **Device** - Flash Generation, Parallelism, Caching Strategy, Wear-Leveling, Garbage Collection, Warranty Strategy...
- ◆ **Write History** - (TBW, spares...)
- ◆ **Workload** - Random, Sequential, R/W Mix, Queues, Threads...
- ◆ **Pre-Conditioning** - Random, Sequential, Amount ...
- ◆ **Performance** - Short “Burst” First On Board (FOB)
  - Steady State post xPE Cycles

Using interleaved memory banks, caching and other techniques being designed in modern controllers, the performance of MLC SSDs today started to match and even outshines performance offered by some SLC SSDs

# AutoSmart Storage-Tiering SW: Storage Mapping

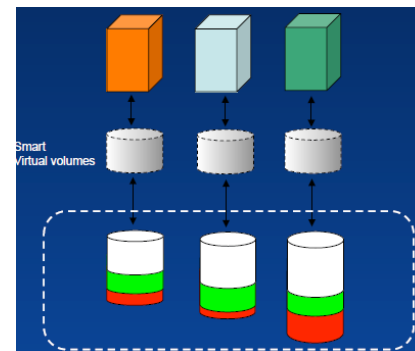
## ➤ Automated Storage Tiering Principles

- ◆ Continuously monitor and analyze data access on the tiers
- ◆ Automatically elevate hot data to “Hot Tiers” and demote cool data/volumes to “Lower Tiers. Allocate and relocate volumes on each tier based on use
- ◆ Reduces OPEX vs. managing SANs manually. All major Computer System manufacturers adopted it such as FAST, Easy Tier, Data Progression, Adaptive Optimization, Dynamic Tiering, Smart Pools...



## ➤ Traditional Disk Mapping

- ◆ Volumes have different characteristics. Applications need to place them on correct tiers of storage based on usage



## ➤ Smart Storage Mapping

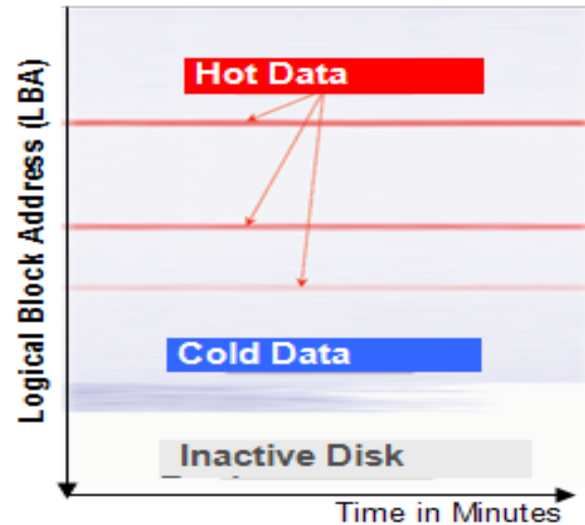
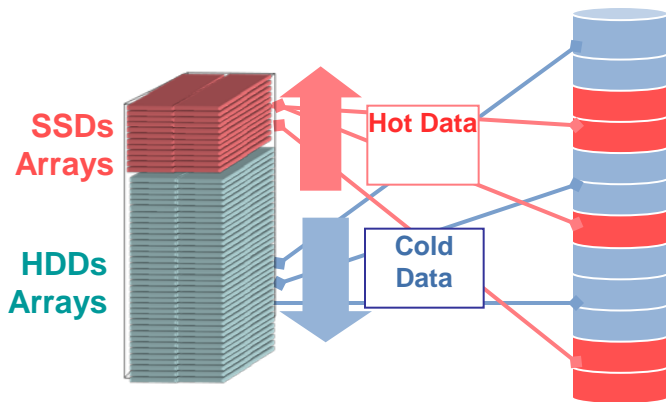
- ◆ All volumes appear to be “logically” homogenous to apps. But data is placed at the right tier of storage based on its usage through smart data placement and migration

# AutoSmart Storage-Tiering SW: Workload I/O Monitoring/Smart Migrations

## Storage-Tiered Virtualization

Storage Tiering at LBA/Sub-LUN Level

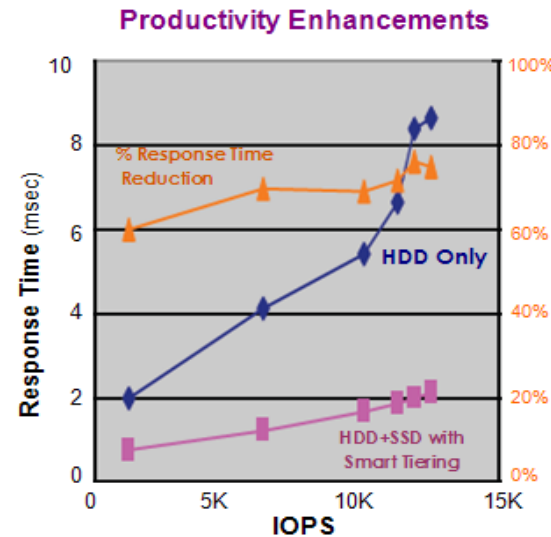
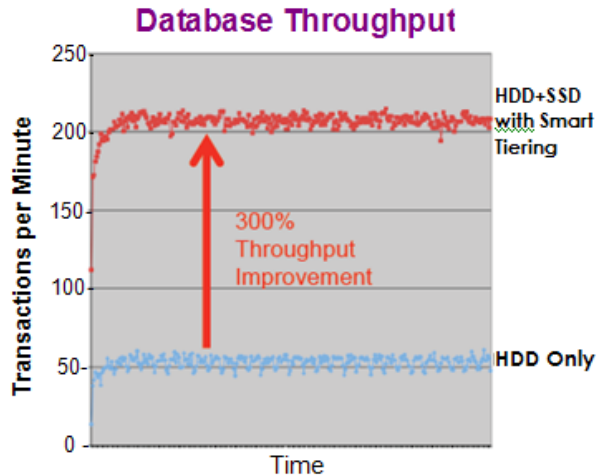
Physical Storage      Logical Volume



## LBA Monitoring and Tiered Placement

- Every workload has unique I/O access signature
- Historical performance data for a LUN can identify performance skews & hot data regions by LBAs
- Using Smart Tiering identify hot LBA regions and non-disruptively migrate hot data from HDD to SSDs.
- Typically 4-8% of data becomes a candidate and when migrated to SSDs can provide response time reduction of ~65% at peak loads.

# AutoSmart Storage-Tiering SW: Enhancing Database Throughput



## DB Throughput Optimization

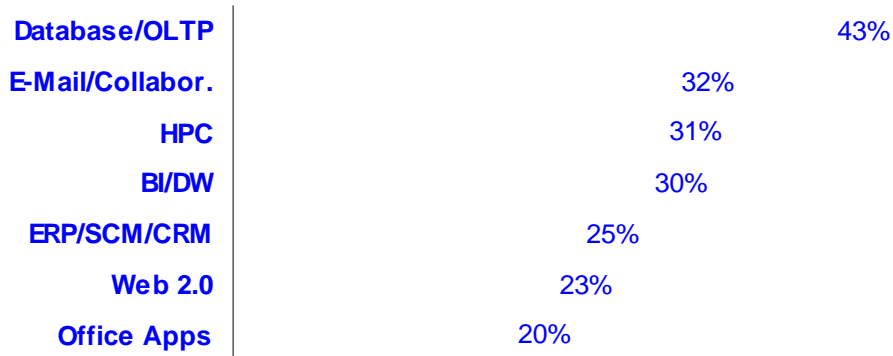
- Every workload has unique I/O access signature and historical behavior
- identify hot “database objects” and smartly placed in the right tier.
- Scalable Throughput Improvement - 300%**
- Substantial IO Bound Transaction Response time Improvement - 45%-75%**

## Productivity (Response Time) Improvement

- Using automated reallocation of hot spot data (typically 5-10% of total data) to SSDs, performance improvements is achieved
- Response time reduction of around 70%+ or
- Through put (IOPS) increase of 200% for any I/O intensive loads experienced by Time-Perishable Online Transactions like:
  - Airlines Reservations,
  - Wall Street
  - Investment Banking Stock Transactions
  - Financial Institutions Hedge Funds etc. as well as Low Latency seeking HPC Clustered Systems etc.



## Applications most benefitting from SSDs Use



## Apps and impact from SSD Usage

### ➤ Databases

- ◆ Databases have key elements of commit files – logs, redo, undo, tempDB

### ➤ Structured data

- ◆ Structured data access is an excellent fit for SSD
- ◆ Exception—large, growing table spaces

### ➤ Unstructured data

- ◆ Unstructured data access is a poor fit for SSD
- ◆ Exception – small, non-growing, tagged files

### ➤ OS images

- ◆ boot-from-flash, page-to-DRAM

## Typical Cases - Impact on Applications

### ➤ Financial Credit Card/ATM Transactions

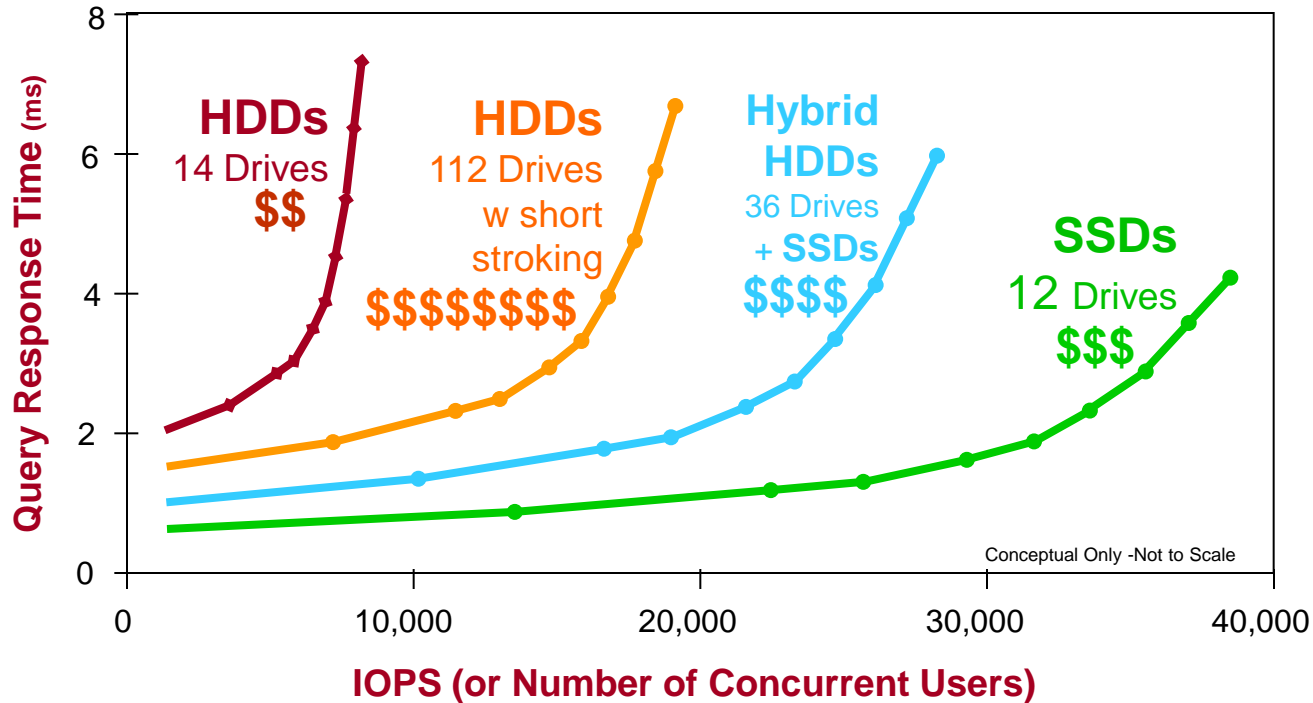
- ◆ **Improvements:** Batch Window 22%, App Response Time 50%, App I/O Rate 50%

### ➤ Messaging Applications

- ◆ **Cost Savings:** 200+ FC HDDS into only 16 SSDs

Source: IMEX Research SSD Industry Report ©2011

# Apps Best Suited for SSDs: OLTP to Improve Query Response Time

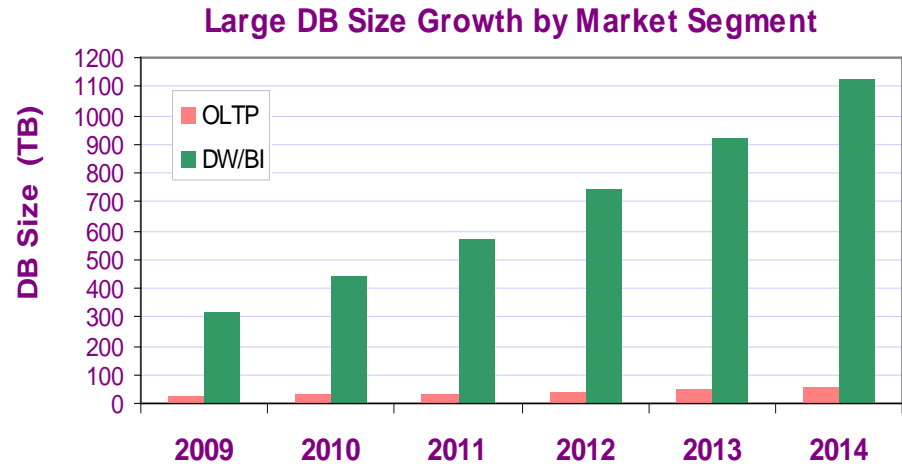
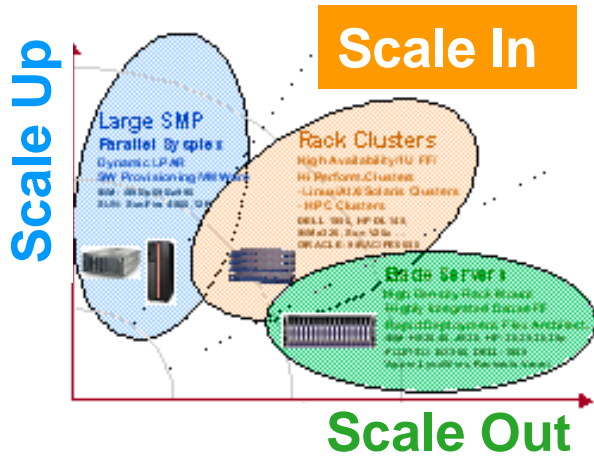


## ➤ Improving Query Response Time

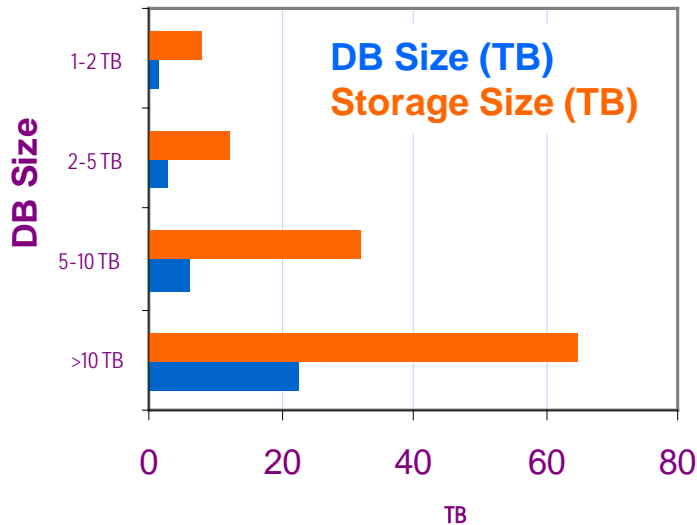
- ◆ Cost effective way to improve Query response time for a given number of users or servicing an increased number of users at a given response time is best served with use of SSDs or Hybrid (SSD + HDDs) approach, particularly for Database and Online Transaction Applications

Source: IMEX Research SSD Industry Report ©2011

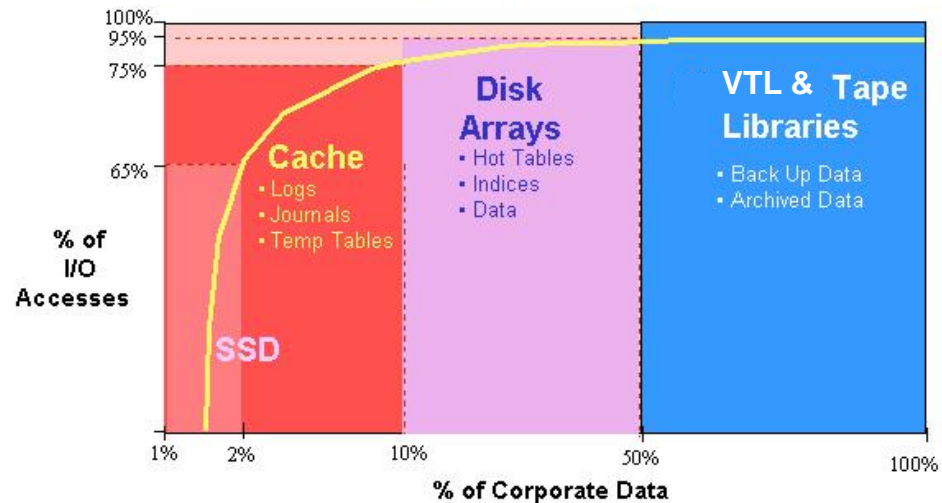
# Apps Best Suited for SSDs: DB in Memory for Data Warehouse/BI



Storage Usage vs DB Capacity



Corporate Data Usage  
I/O Access Frequency vs. Percent of Data

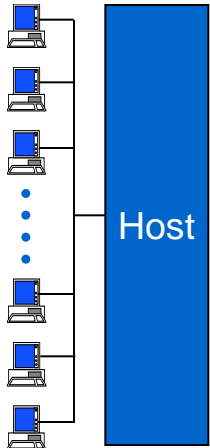


# Apps Best Suited for SSDs: Collaboration using Virtual Desktops

## ➤ Mitigating Boot Storms

- ◆ Boot Storm created by simultaneous Logins by users at start of office day
- ◆ Over provisioning SAN capacity just for short morning burst expensive, while sitting almost idle rest of the day
- ◆ Three potential solutions with pros and cons include:
- ◆ (1) DAS Storage, (2) Virtual Desktop Images on SSD (3) SS Cache to accelerate SAN,

Virtual  
Desktops



Solution	Pros	Con
New DAS Storage	<ul style="list-style-type: none"> <li>- Popular with Desktop SW Vendors</li> <li>- Lowered Cost</li> </ul>	<ul style="list-style-type: none"> <li>- Additional Cost for Dedicated Storage</li> <li>- Wasted existing SAN Storage</li> <li>- Data Protection &amp; Mgmt Challenges</li> </ul>
SSD	<ul style="list-style-type: none"> <li>- SSD Ideal for read intensive app</li> <li>- Instant-On/Immediate Boot Response –</li> <li>- Images Stored with High Efficiency</li> </ul>	<ul style="list-style-type: none"> <li>- Using most expensive storage</li> <li>- High Speed Needed just for an hour</li> <li>- Not simple shoe-in w existing storage</li> </ul>
SAN w SSD Accelerator	<ul style="list-style-type: none"> <li>- Possibly best way to solve problem</li> <li>- Small SSD optimized for image store</li> <li>- No change to existing Data Protection</li> </ul>	<ul style="list-style-type: none"> <li>- Not feasible without existing SAN</li> <li>- SSD in SAN Integration still a challenge</li> </ul>

Providing a perfect balance of access and storage is achieved through  
Integrating SATA HDDs with SSDs and using Automatic Tiering Solutions

Are SSDs Ready for Enterprise Storage Systems?

# Apps Best Suited for SSDs: HPC/Web 2.0

## Smart Mobile Devices

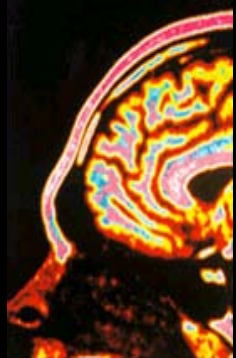
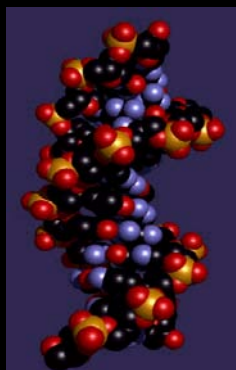
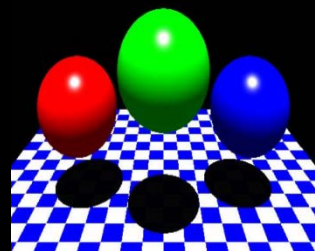
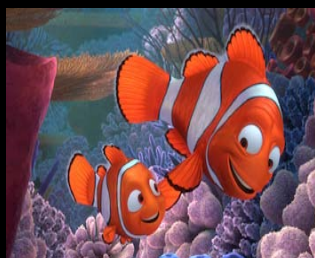
## Commercial Visualization

## Bioinformatics & Diagnostics

## Decision Support Bus. Intelligence

## Entertainment- VoD / U-Tube

Data: IMEX Research & Panasas



Instant On Boot Ups  
Rugged, Low Power

1GB/s, \_\_ms

Rendering (Texture & Polygons)  
Very Read Intensive, Small Block I/O

10 GB/s, \_\_ms

Data Warehousing  
Random IO, High OLTPM

1GB/s, \_\_ms

Most Accessed Videos  
Very Read Intensive

4 GB/s, \_\_ms

- **Optimize Infrastructure to meet needs of Applications/SLA**
- **Solid State Storage creating a paradigm shift in Storage Industry**
  - ◆ Leverage the opportunity to optimize your computing infrastructure with SSD adoption after making a due diligence in selection of vendors/products, industry testing and interoperability
- **Enterprise SSD Market Segments: PCIe vs. SAS/SATA**
  - ◆ 5-Year cum Market \$8.6B Segments by Revenues: 36% PCIe, 33% SAS, 24% SATA, 6% FC based SSDs
- **Understand Drivers and Challenges of SSDs for Enterprise Use**
- **Intelligent Controllers key to adoption & success of SSDs**
  - ◆ Mitigate Endurance, Wear-Out, Life issues
- **Optimize Transactions for Query Response Time vs. # of Users**
  - ◆ Improving Query Response time for a given number of users (IOPs) or Serving more users (IOPS) for a given query response time
- **Select Automated Storage Tiering Software**

- Please send any questions or comments on this presentation to SNIA: [tracksolidstate@snia.org](mailto:tracksolidstate@snia.org)

**Many thanks to the following individuals  
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