SF-2000 Family SSD Processors
## New Enterprise and Industrial Products

October 2010

Michael Raam, CEO
Thad Omura, VP Marketing
Kent Smith, Sr. Dir, Product Marketing

Public Disclosure Embargo until October 7, 2010 – 06:30 (AM) PDT

Game-Changing SSD Silicon Technology

SandForce transforms data storage by pioneering the use of standard flash memory in enterprise, client & industrial computing applications with its innovative SSD Processors
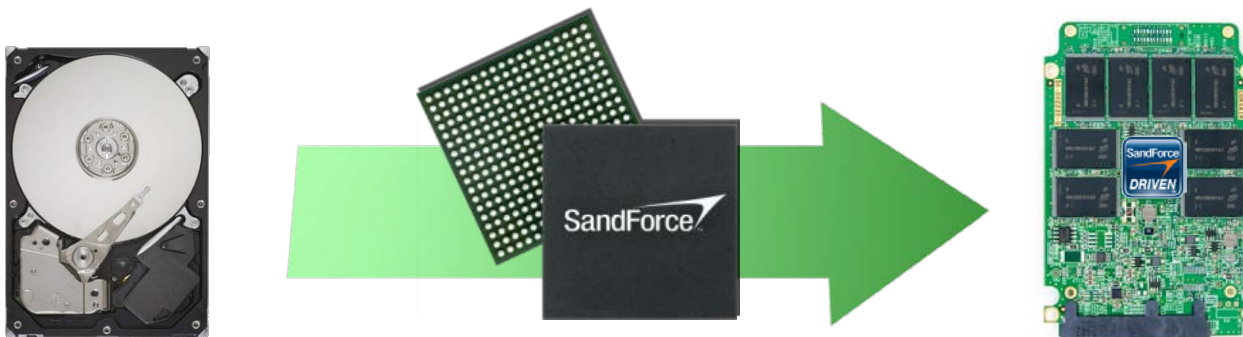
RunCore Pro V
"…easily outperforms Indilinx-based SSDs.."

OCZ Vertex 2
"…it has proven to be one of the fastest SSDs that we have ever seen here…"

OCZ Vertex LE
"….quite literally the fastest SSD we've tested on a 3Gbps SATA…"
"…One word, 'impressive.'"

Corsair Force F100
"As it sits right now, the SF-1200 is one of the fastest drives we have ever tested…."

www.greentechmedia.com
Green IT Category
Only silicon company recognized
March 2010

"These innovations can be truly disruptive and will accelerate the adoption of solid state technologies across the data center." *Mike Desens, VP System Design*   THE WALL STREET JOURNAL.   WSJ.com   May 2, 2010

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SandForce

Company Profile

- Fabless silicon supplier for SSD OEMs
  - Founded December 2006, First Revenue Q1 2010
  - Business Model: SSD processor design & sales

- Enterprise-class NAND flash SSD Processors
  - Patented DuraClass™ Technology
  - Unprecedented reliability, performance, power efficiency
  - Enables most advanced NAND in SSD

- Solid financial position with leading investors
  - DCM, Storm, Translink, Canaan, LSI & leading storage companies
  - $25M Series D in September 2010
  - Total funding of $67M

- HQ in Saratoga, CA with 88 employees

Management Team

Exec Management

| Title	Name	Background
President & CEO	Michael Raam	GM/VP AMCC, VP Mobilygen, VP Procket Networks
Chief Architect	Earl Cohen	CISCO, AuroraNetics, Amdahl, Key Computers
VP Business Dev	Steffen Hellmold	VP Mkt & BD Seagate, GM/VP Lexar, Dir. Samsung, Fujitsu
VP Operations	Ray Holzworth	VP Ops Magnum Semi, Transmeta, Triscend, AMD
VP H/W	Kamran Malik	VP Processor AMCC, VP Eng. HiFn, VP Eng. Nishan
VP Marketing	Thad Omura	VP Prod Mkt Mellanox, Motorola, Marvell, Galileo
VP Sales	Matt Ready	VP Sales eASIC, PLX, Opti, Genesis Micro
Corp Admin/HR	Steve Rowe	VP HR PDF Solutions, Trident Microsystems, OPTi, Olivetti
VP SW/FW	Andy Tomlin	Sr. FW Dir. SanDisk, Dir. F/W Quantum/Maxtor, IBM

Board of Dir

Name	Affiliation
Michael Raam	President & CEO
Carl Amdahl	DCM
Ryan Floyd	Storm Ventures
C.S. Park	Former CEO and Chairman of Maxtor & Hynix
S. 'Sundi' Sundaresh	Former President and CEO of Adaptec
Jackie Yang	Translink Capital
Eric Young	Canaan Partners

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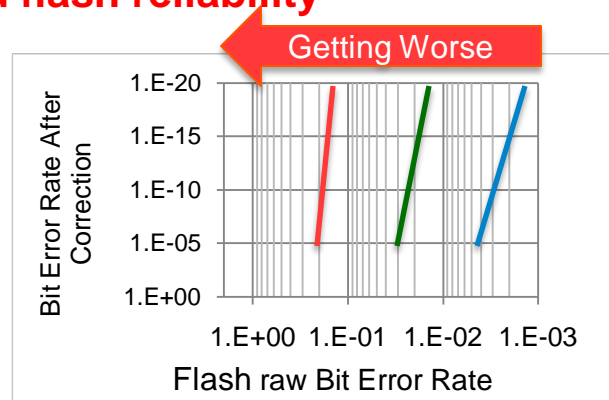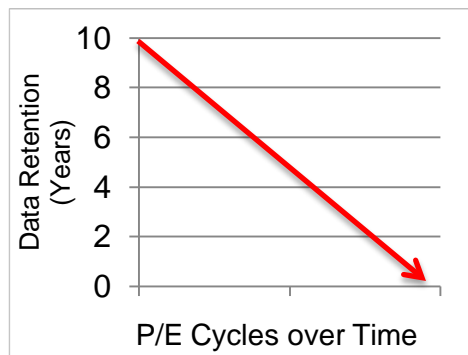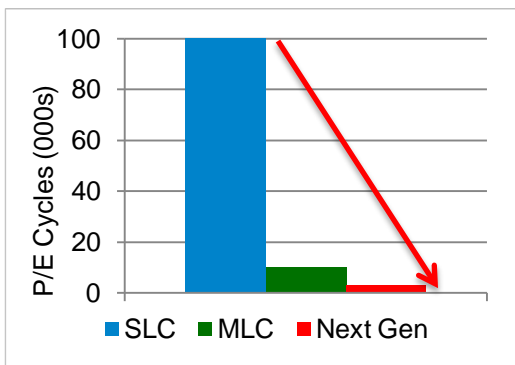SandForce

Commodity NAND Flash Conundrum for SSDs

GOOD: Rapidly declining $/Gb with orders-of-magnitude increases in performance

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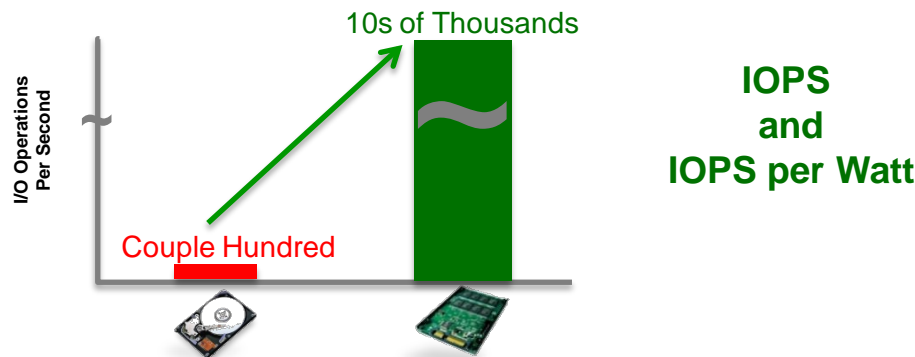
BAD: Even faster decline of endurance, data retention and flash reliability

Billion Dollar Question: How can commodity flash be used reliably in the enterprise?

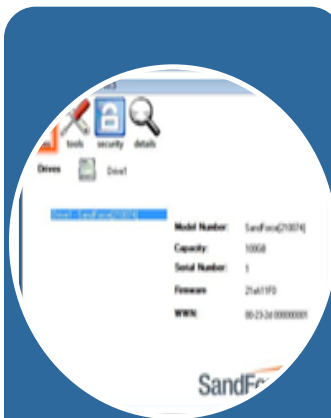SandForce®

Solution Provider

SSD Processors
- Enterprise
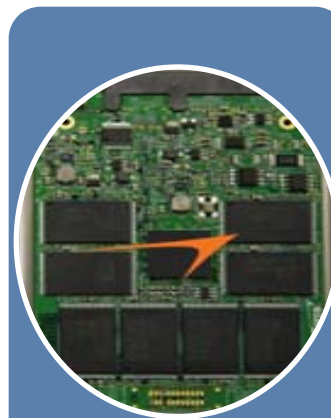- Industrial
- Client

Firmware
- Manufacturing
- Diagnostics

Tools
- Toolbox
- Mass Production
  - BIST
- FW Update

Turnkey Reference Designs
- 2.5" Enterprise SATA
- 2.5" Enterprise SAS
- 2.5" Client SATA
- MO297 SATA

- Schematics
- BOM
- Layout

Documentation and Support
- Software Reference Manual
- Hardware Reference Manual
- Whitepapers
- Application notes
- Diagnostic Manufacturing
- Jira issue tracking
- Automated document distribution system

Fast time to market, enabling broad adoption

SandForce

Solution: DuraClass™ Technology

- World Class SSD Technology
  - ► Reliability - RAISE™
    - RAID-like protection on a single SSD
    - Reduced Field Failures and Returns
  - ► Endurance - DuraWrite™
    - Optimize MLC endurance in I/O Intensive Applications with Data Intelligence
  - ► Performance
    - Sustained Balanced High R/W Performance
    - Superior Application Performance & User Experience
    - In-line AES Encryption with TCG Enterprise support
  - ► Power Consumption
    - Revolutionary IOPS/Watt for mixed workloads

Highly Differentiated SSD Processors For Volume SSD Deployment

SandForce

Key Changes in SF-2000 Family

New Enterprise and Industrial Product Lines

- Performance
  - ▸ 6Gb/s SATA III
  - ▸ 60K IOPS Random Read and Write (4K transfers)
  - ▸ 500 MB/s Sequential Read and Write
- Security
  - ▸ TCG Enterprise with AES-256/128 and double encryption
- SAS-bridge support for non-512 byte sectors
  - ▸ 520, 524, 528, 4K+DIF
- Continued multi-vendor Flash memory support
  - ▸ 3xnm & 2xnm SLC, MLC, eMLC
  - ▸ Asych/Toggle/ONFi2 interfaces
  - ▸ Up to 166MT
- Reliability
  - ▸ Enhanced ECC with BCH and 55 bits/512 byte sector
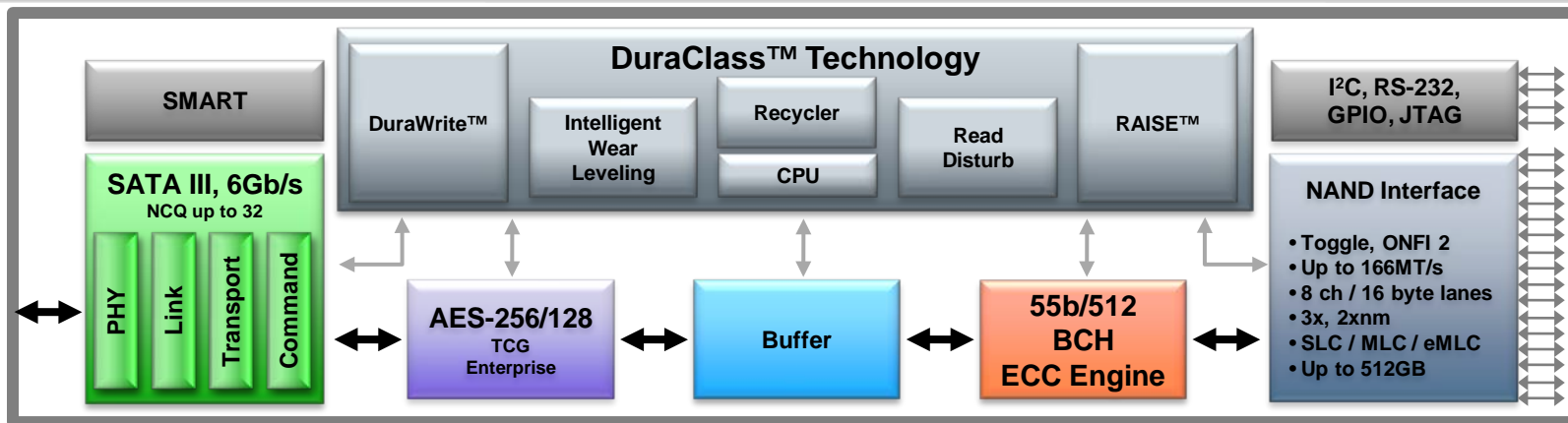- Power Management
  - ▸ Power/Performance Throttling

hynix   intel

Micron   SAMSUNG

TOSHIBA

SandForce

SF-2000 Family of SSD Processors

- No External DRAM
- ATA **& TCG Enterprise Security**
- Trim Command Support
- Flash Life Performance Throttling
- **Power Performance Throttling**
- Temperature Management
- **Non-512B sector support**
  - ▸ **Ideal for SAS deployment**
  - ▸ **520, 524, 528…, 4K+DIF**
- **14x14mm 400-TFBGA (16 byte lanes)**
  - • **0.65mm ball pitch**

SF-2600
Enterprise SAS
6Gb SATA
Non-512Byte

SF-2500
Enterprise
6Gb SATA

SF-2300
Industrial
6Gb SATA
Industrial Temp

SERVERS   **STORAGE SYSTEMS**

BLADES

EMBEDDED SYSTEMS   **MILITARY**

BOLD = New for SF-2000 vs SF-1000

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Performance
SF-1565 Actual vs. SF-2000 Estimates

Micron 34 – cMLC – Sustained Performance (up to)	SF-1565	SF-2xxx Projected	
	Actual	Estimated	% Inc.
Seq Read MB/s (seq pre)	272	500	84%
Seq Write MB/s (seq pre)	264	500	89%
Ran Read IOPS (ran pre)	29,587	60,000	103%
Ran 70/30 IOPS	29,823	60,000	101%
Ran 50/50 IOPS	28,267	60,000	112%
Ran Write IOPS (ran pre)	27,301	60,000	120%

SF-1565: 200GB (256GB physical) capacity, 28% OP, 3.0.5 (MP1) Firmware
SF-2xxx: 200GB (256GB physical) capacity, 28% OP, ONFI 2 (166MT/s)

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SF-2000 Security Enhancements
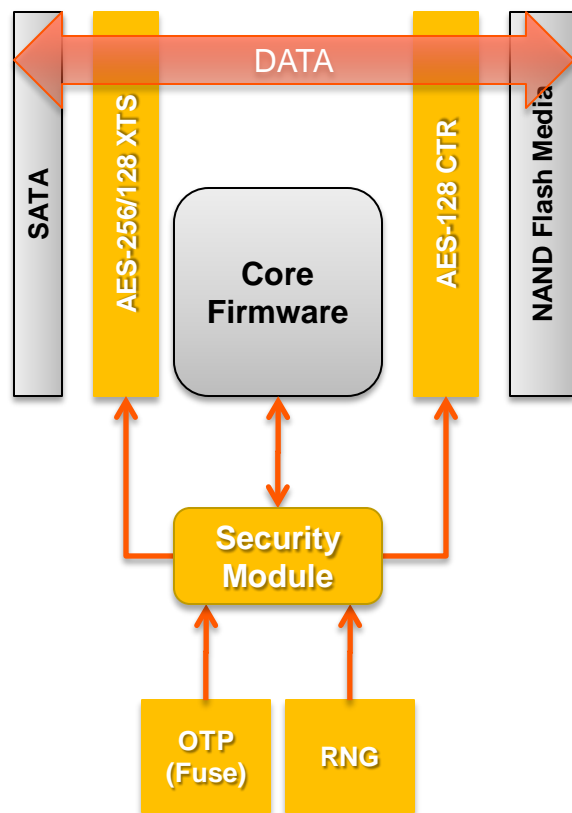
- AES-128 engine in CTR mode
  - ▸ Back-end security, IP protection
  - ▸ Always on with unique key
- AES-256 engine in XTS mode
  - ▸ NIST approved XTS Jan 2010
  - ▸ 4+1 ranges with associated different keys
  - ▸ Simultaneous access to multiple bands w/o key reloading
  - ▸ Hardware-assisted shadow MBR (master boot record)
- Fuse-based OTP (one time programming memory) for unique master key
- Hardware non-deterministic random number generator
- Firmware modules
  - ▸ FW X9.31 deterministic random number generator
  - ▸ FW SHA-256 for signature verification
  - ▸ FW PKCS#1 digital signature verification of the download image
- FIPS-197 certification of AES engines

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Market-Wide Adoption of SandForce Driven SSDs

ENTERPRISE

CLOUD COMPUTING

SERVERS

STORAGE SYSTEMS

CLIENT

LAPTOPS

PCs

INDUSTRIAL

EMBEDDED SYSTEMS

MILITARY

amp inc
Apacer — Access the best
CORSAIR
DigiCube
extrememory
G.SKILL

Global Wireless Medium
mushkin
STORM
OCZ Technology
OWC
PATRIOT MEMORY

PRETEC — Small size, Big impact.
SMART Modular Technologies
SOLIGEN CORP.
Unigen
Team
VIKING MODULAR SOLUTIONS — SANMINA-SCI CORPORATION

Other OEMs & Manufacturers

A-DATA
IBM
LSI
R — RunCore SSD
Seagate
SUPER★TALENT

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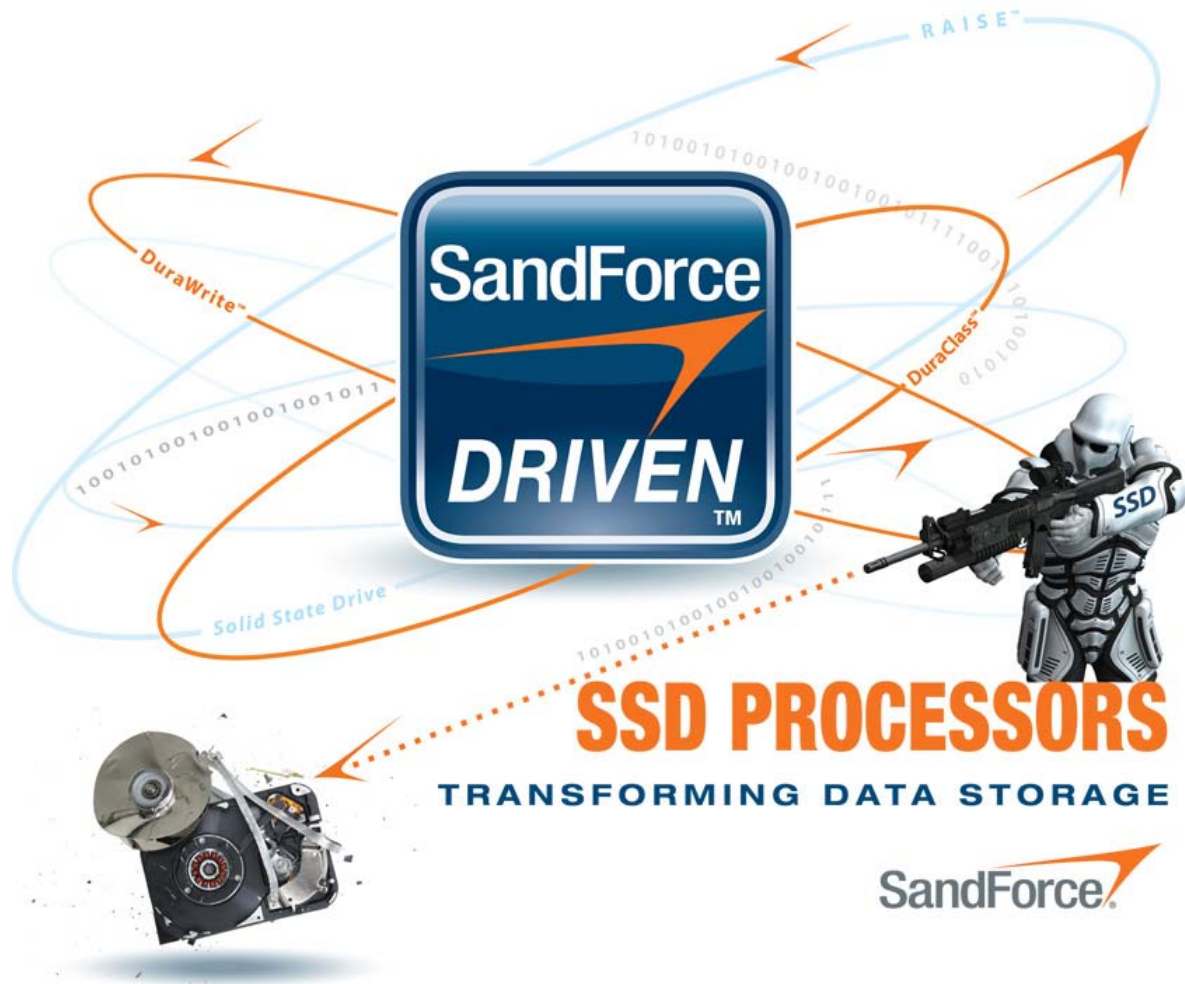
SSD Technology & Market Leadership
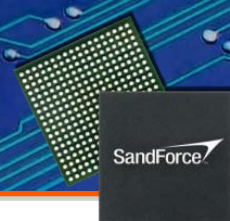
- Accelerating SSD adoption in Enterprise, Client & Industrial Markets
  - ▸ Leverage multi-vendor, commodity flash economies of scale
  - ▸ **Best Enterprise performance, price/performance & efficiency**
  - ▸ **Award-winning Client SSD Processors shipping in high volume**

- DuraClass Technology is proven to address key flash issues
  - ▸ Unprecedented reliability with MLC-based enterprise SSDs
  - ▸ Superior performance over the life of the drive
  - ▸ Unmatched power efficiency

- Extensive roadmap for next generation flash & interfaces
  - ▸ Newest 2nd generation product will further market leadership in 2H 2010
  - ▸ Shrinking geometries, 3 & 4-bit per cell technologies
  - ▸ 6Gb/s SATA, SAS, PCI Express, USB 3.0 and others

Thank You!

Other Background Information
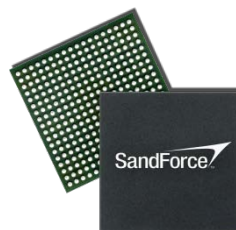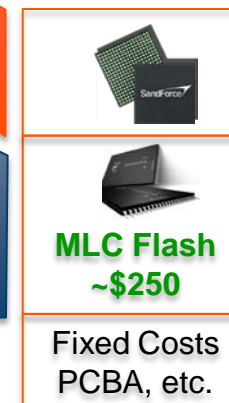
MLC Required for Volume Enterprise Adoption

- Standard controller solutions
  - Expensive SLC Flash
  - Greater levels of over-provisioning to enable Enterprise duty cycles
  - Requires production firmware development
  - DRAM (up to $10 and increasing!)

- **SandForce SSD Processors**
  - Dramatic cost savings with MLC
  - Enterprise reliability & duty cycles
  - Includes production firmware
  - No DRAM
    - Simplified power fail circuitry
    - Small form factor designs
    - Lower power consumption
    - Lower BOM cost

SLC Drive Cost

Firmware

DRAM

SLC Flash
~$800

Fixed Costs PCBA, etc.
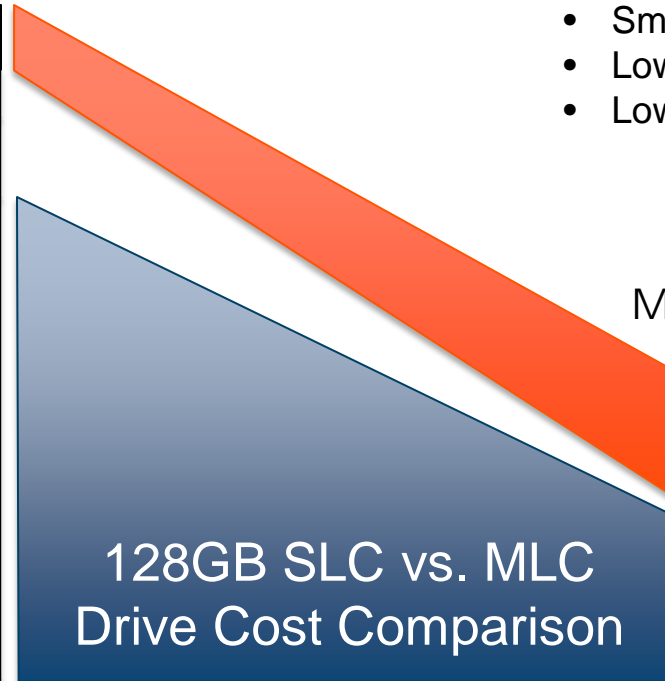
SandForce MLC Drive Cost

MLC Flash ~$250

Fixed Costs PCBA, etc.

128GB SLC vs. MLC Drive Cost Comparison

SandForce

The Power of RAISE™ – Improved Reliability

- ## Correctable Errors
  - ▶ SSD can fix flash errors and return valid data

  Solution: Error Correction Engine w/55 bits per 512 Bytes

- ## Uncorrectable Errors
  - ▶ SSD detects an error, can't return valid data

  Solution: RAISE™ Protection

- ## Silent Errors
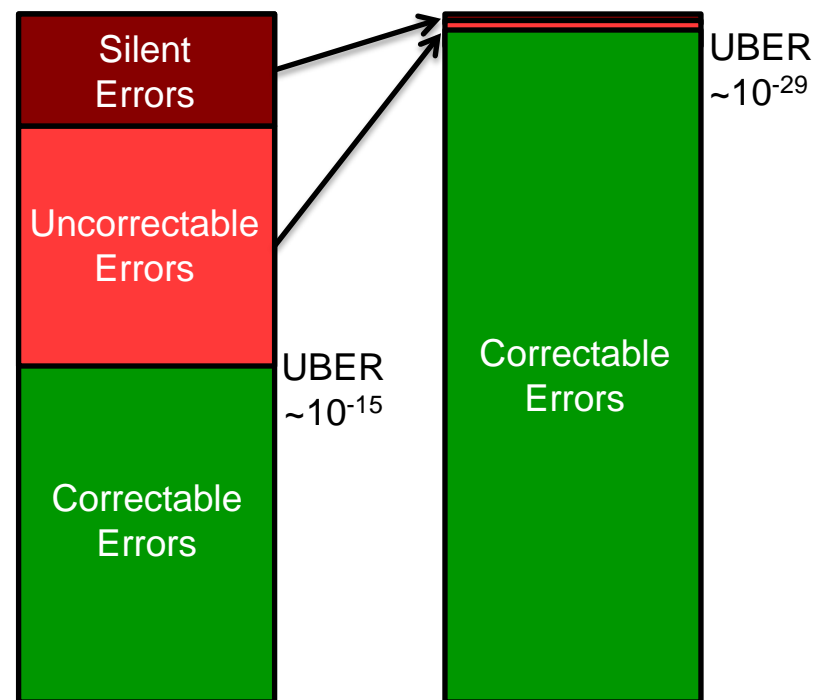 - ▶ SSD doesn't detect an error, returns invalid data

  Solution: End-to-End CRC Protection

**Nearly One Quadrillion times fewer uncorrectable errors**

Standard SSD Controller

SANDFORCE SSD PROCESSOR

Silent Errors

Uncorrectable Errors

Correctable Errors

UBER $\sim 10^{-15}$

UBER $\sim 10^{-29}$

Correctable Errors

SandForce®

RAISE™ Improves Total SSD Reliability

- RAISE™: Redundant Array of Independent Silicon Elements
  - ▸ Data protection beyond ECC
  - ▸ Benefit of RAID without additional write overhead

Up to 16 parts/SSD

Up to 8 die/part

> 1000 PPM failure rate per die
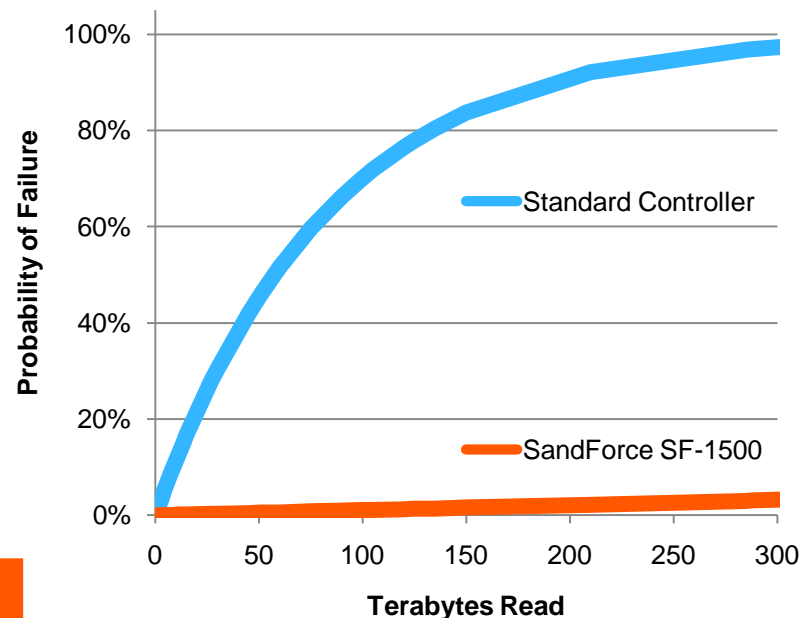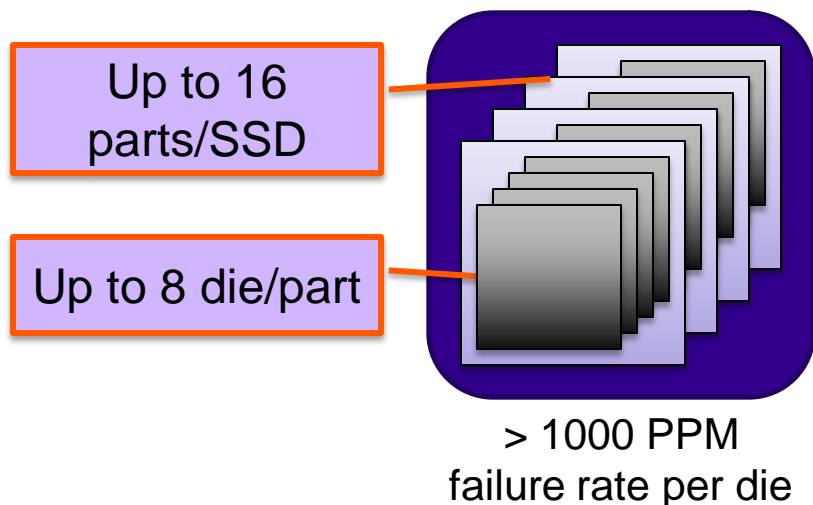
	Standard UBER=1×10^{-15}	Advanced UBER=1×10^{-16}	SandForce UBER=1×10^{-17}
5 year Cumulative Failure Rate	99.60%	45.82%	0.00%

Probability of Failure vs **Terabytes Read**

Standard Controller

SandForce SF-1500
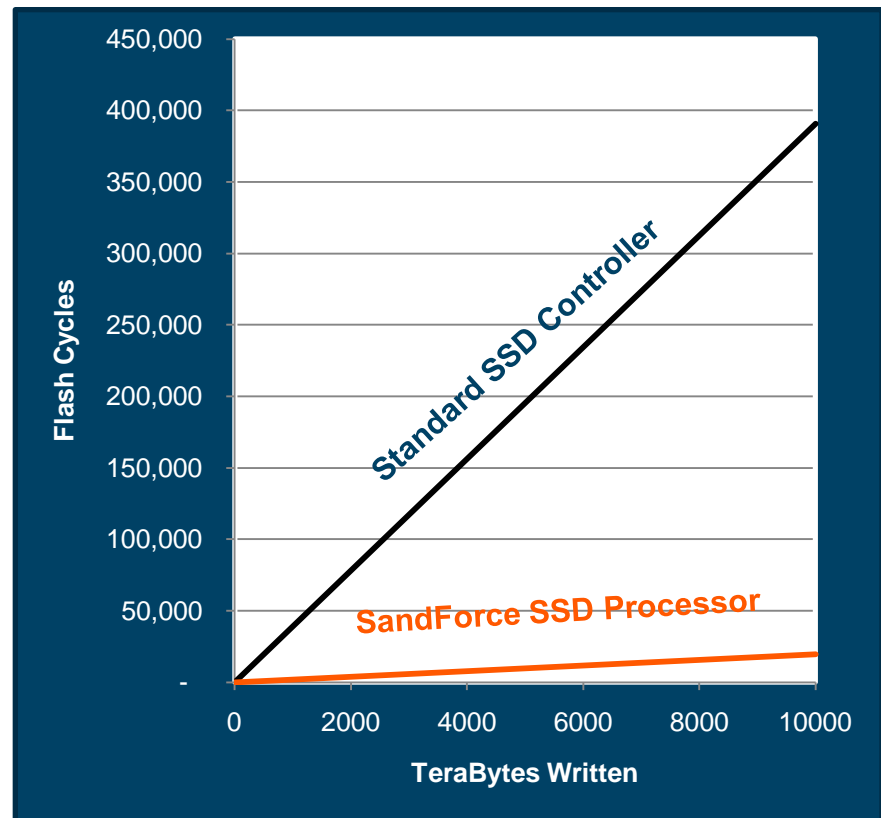
Assumptions
- **JEDEC Enterprise App Class 1 (proposed)**
- **200GB capacity, 4GB MLC die**

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The Power of DuraWrite™

Optimize Endurance, Performance, Data Retention & Power Consumption

- Write Amplification
  - Key Indicator to Predict Lifetime
  - Industry Typical ≈ 10
    - Block based, random + seq I/O
  - SandForce Typical ≈ 0.5

- What helps Write Amplification
  - Page Based Volume Manager
  - Data Intelligence
  - Trim (e.g. Win7)

- What hurts Write Amplification
  - Block Based Volume Manager
  - Background Garbage Collection
  - OS Misalignment

Chart: Flash Cycles (y-axis, 0 to 450,000) vs TeraBytes Written (x-axis, 0 to 10000). "Standard SSD Controller" (steep black line), "SandForce SSD Processor" (low orange line).

SSDs follow this simple life equation:

$$\frac{\text{Flash Endurance} * \text{Capacity}}{\text{Write Speed} * \text{D/C} * \text{Write \%} * \text{Write Amp}} = \text{SSD Total Life}$$
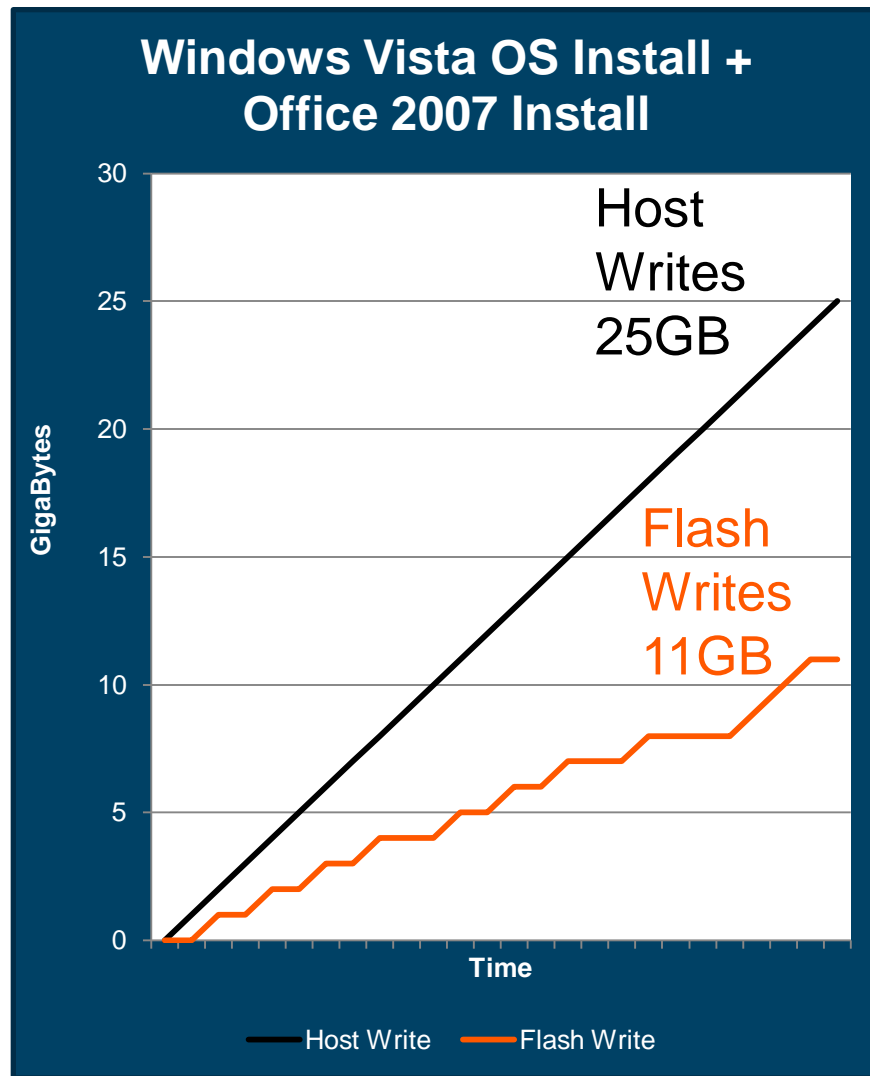
SandForce®

The Power of DuraWrite™
Minimize Write Amplification

- # Measured data showed WA < 0.5
  - ▸ Included executables and CAB files

Flash Write / Host Write = Write Amplification

Windows Vista OS Install + Office 2007 Install

Host Writes 25GB

Flash Writes 11GB

GigaBytes: 0, 5, 10, 15, 20, 25, 30

Time

— Host Write   — Flash Write

Measured On:
Intel® Core™ 2 Duo CPU E8500 @ 3.16GHz, G45/G43 Express Chipset (ICH10R)

SandForce®

Dramatic Enterprise System Advantages
First Large Scale System Benchmark (TPC-C) with MLC-based SSDs

- **60 SandForce eMLC-based SSDs**
  - ▶ 10.6 Terabytes of Solid State Storage
- **IBM Power® 780, 8-core, two-socket system**
- **OLTP (online transaction processing) benchmark**
  - ▶ Total system performance & cost
  - ▶ Performance in Transactions per minute (tpmC)
  - ▶ System Price/performance in $/tpmC

Benchmark	SandForce DRIVEN™	Comparison to Next Leading System	Impact
tpmC	**1,200,011**	**81% higher** (661,475)	**MEAN** <u>Highest total performance</u> of all 8-core systems
tpmC/CPU core	**150,000**	**~50% higher** (101,116)	**GREEN** <u>Highest efficiency</u> of all systems benchmarked
$/tpmC	**$0.69**	**36% better** ($1.08)	**LEAN** <u>Best price/performance</u> of all 8-core systems

IBM's #1 TPC-C Benchmark Uses SandForce!
8/17/2010: Highest Reported TPC-C Benchmark of ALL TIME

3 x IBM Power 780 Server
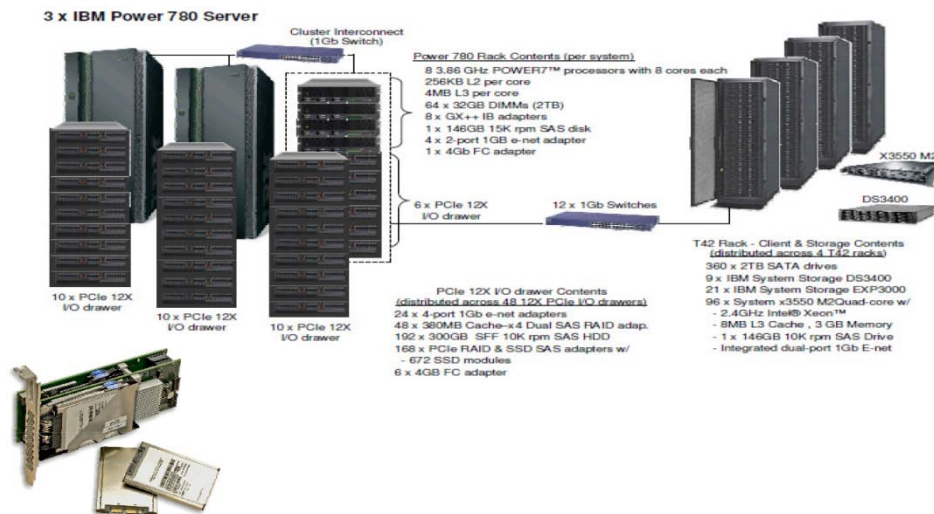
- 672 SandForce-based 1.8" SSDs
  - 177GB eMLC per SSD, ~120TB!
- System availability 10/13/2010
- $14.3M System Cost
- $18M for Sun/Oracle System Cost
  - HDD only

- Previous IBM TPC-C benchmark
  - 60 SSDs, 8 cores, $825K

Benchmark	IBM SandForce DRIVEN	Comparison to Next Leading System (Sun/Oracle)
tpmC	**10.366M** **192 cores**	**36% higher** (7.646M, 384 cores)
$/tpmC	**$1.38**	**41% lower** ($2.36)

Rank	Company	System	Performance (tpmC)	Price/tpmC	Watts/KtpmC	System Availability	Database	Operating System	TP Monitor	Date Submitted	Cluster
1	IBM	IBM Power 780 Server Model 9179-MHB	10,366,254	1.38 USD	NR	10/13/10	DB2 9.7	AIX Version 6.1	Microsoft COM+	08/17/10	Y
2	ORACLE	Sun SPARC Enterprise T5440 Server Cluster	7,646,486	2.36 USD	NR	03/19/10	Oracle Database 11g Ent. Ed. w/Real Application Clusters w/Partitionin	Sun Solaris 10 10/09	Tuxedo CFS-R	11/03/09	Y

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