A DBA’s Crash Course on Flash-Based Architectures

Roye Avidor
Technical Marketing Engineer, HGST
Agenda

• About HGST
• Our “Street Cred” SSDs and Software
• Technical Details
  - Flash vs. SSD—Why DBAs should care about the difference
  - How Flash changes storage architecture designs
  - How current storage architecture designs compare
  - Two rather special Flash-based offerings from HGST
• Business Benefits
• Q&A
Company Profile

- Founded in 2003 through the combination of the hard drive businesses of IBM, the inventor of the hard drive, and Hitachi, Ltd. (“Hitachi”)
- Acquired by Western Digital in 2012
- Headquartered in San Jose, California
- Approximately 41,000 employees worldwide
- More than 4,700 active worldwide patents (YE2013)

Mission: HGST is optimizing storage efficiency and reliability for today’s data-centric economy, delivering technology innovations and enabling new ways to capture and utilize data, and reduce total cost of management.
Wikibon Server SAN Projection

Traditional Enterprise Storage, Hyperscale Server SAN & Enterprise Server SAN Revenue Projections 2013-2027

Wikibon Server SAN Projections

- Traditional Enterprise Storage
- Enterprise Server SAN
- Hyperscale Server SAN

$ - $10,000 $20,000 $30,000 $40,000 $50,000 $60,000 $70,000

$1B Invested into On-ramping “Hot” Storage

- Intel JDA
- sTec
- VeloBit
- Virident

Applications
Processing
Storage
SSD
HDD

Enhanced Controller
Advanced Caching
App-Optimized Flash Shared Server Flash Flash-Aware App API

$1B Invested into On-ramping “Hot” Storage
HGST Hardware Technologies

**PCIe SSDs**
- Big Data Analytics
- Virtualization, VDI, VSAN
- HF Trading
- Databases / OLTP
- Scale-out DBs

**SAS SSDs**
- Big Data Analytics
- VSAN
- HF Trading
- Databases / OLTP
- Indexing

**Performance**
- Databases / OLTP
- Content Serving
- Business Intelligence
- Cloud Gaming
- HPC

**Capacity**
- Cloud Storage
- Virtualized Servers
- VSAN
- Cloud Computing
- Storage Arrays
- Social Networks
- Long-Tail Content
- Big Data Storage

**Capacity Scale**
- Long-Tail Content
- Video on Demand
- Cloud Storage
- Replicas
- Mail Servers
- Surveillance

**Cold Storage**
- Archives
- Regulatory & Compliance
- Surveillance
- Medical Records

**Hot** -> **Warm** -> **Cold**
HGST Software Solutions

Device Manager
- Discover
- Monitor
- Manage
- Report
- For Standalone Windows, Linux, & Solaris

Profiler
- Capacity Planning
- Optimize Flash Usage
- Caching Analysis
- Any Application
- For Standalone Windows & Linux

ServerCache
- Application Acceleration
- Read Caching & Writeback Caching
- For Standalone Windows & Linux

HA
- Synchronous Replication
- Failover
- Low Latency
- InfiniBand

Share
- Shared Flash
- Low Latency
- High Performance
- Linux
- Oracle® RAC

ClusterCache
- Clustered Server Caching
- Endurance
- Ultimate Performance
- Linux
- Oracle® RAC

Space
- Server SAN Volume Manager
- Add Spaces
- Replicate
- Share
- Manage
- Linux

SSD
Pcie SSD

Long Live Data™
Enterprise IT Solutions

“3x server consolidation on MySQL”

“5x IOPS improvement on Oracle® RAC”

“10X Latency Reduction for Exchange”

“46X faster report generation on MS SQL”

“7X Increase in VDI Instances”

Brands: Microsoft Exchange, SharePoint, Oracle, MySQL, VMware, DataCore, Windows Server, Hadoop, GridStore, Fluidata, Vail, Ping An, LinkedIn, Imperial PFS, Yahoo, Kayak
What’s Inside of SSD/Flash

- SATA
- SAS
- PCIe

- NAND:
  - SLC
  - MLC

- Block Management
- Wear Leveling
- Error Correction

Architecture of a solid-state drive

- Host Interface Logic
- Processor
- Buffer manager
- RAM buffer
- Flash controller
- Flash memory package #0
- Flash memory package #1
- Flash memory package #2
- Flash memory package #3

Channel #0
Channel #1
Flash Example

SSD Controller

SATA and Power

Config and General I/O

More FLASH on back
NAND: SLC vs. MLC

<table>
<thead>
<tr>
<th>Item</th>
<th>SLC</th>
<th>MLC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>3.3V / 1.8V</td>
<td>3.3V</td>
</tr>
<tr>
<td>Technology / Chip Size</td>
<td>0.12um</td>
<td>0.16um</td>
</tr>
<tr>
<td>Page Size / Block Size</td>
<td>2KB / 128KB</td>
<td>512B / 32KB or 2KB / 256KB</td>
</tr>
<tr>
<td>Access Time (Max.)</td>
<td>25us</td>
<td>70us</td>
</tr>
<tr>
<td>Page Program Time (Typ.)</td>
<td>250us</td>
<td>1.2ms</td>
</tr>
<tr>
<td>Partial Program</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Endurance</td>
<td>100K</td>
<td>10K</td>
</tr>
<tr>
<td>Write Data Rate</td>
<td>8MB/s+</td>
<td>1.5MB/s</td>
</tr>
</tbody>
</table>

Single-level cell (SLC) SSD drives are faster and more reliable.

Multi-level cell (MLC) SSD drives are slower, cheaper, but less reliable.
Common Technology

- Consumer
- Enterprise

PCIe Flash

SAS SSDs
SATA SSDs
Storage Base Characteristics

- Basic Storage Architecture
- Special Purpose Options
- Disk/Flash Type
Basic Storage Architecture

- Direct Access Storage (DAS)
- Flash on Server (FOS)
- Networked Storage (SAN/NAS)
- Flash on Storage Controller (FOSC)

http://wikibon.org — The Impact of Flash on Future System and Storage Architectures
Options in the “Good Old Days” (<2004)

- Direct Access Storage (DAS)
- Flash on Server (FOS)
- Networked Storage (SAN/NAS)
- Flash on Storage Controller (FOSC)

Disk/Fabric Type

Basic Storage Architecture

Special Purpose Options

RAID and/or Caching

Hybrid
Options in the “Good Old Days” (<2004)

HBA

Transfer Speeds

<table>
<thead>
<tr>
<th>Technology</th>
<th>Rate (byte/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCSI (Narrow SCSI) (5 MHz)</td>
<td>5 MB/s</td>
</tr>
<tr>
<td>Fast SCSI (8 bits/10 MHz)</td>
<td>10 MB/s</td>
</tr>
<tr>
<td>Fast Wide SCSI (16 bits/10 MHz)</td>
<td>20 MB/s</td>
</tr>
<tr>
<td>Ultra SCSI (Fast-20 SCSI) (8 bits/20 MHz)</td>
<td>20 MB/s</td>
</tr>
<tr>
<td>Ultra Wide SCSI (16 bits/20 MHz)</td>
<td>40 MB/s</td>
</tr>
<tr>
<td>Ultra-2 SCSI 40 (Fast-40 SCSI) (8 bits/40 MHz)</td>
<td>40 MB/s</td>
</tr>
<tr>
<td>Ultra-2 wide SCSI (16 bits/40 MHz)</td>
<td>80 MB/s</td>
</tr>
<tr>
<td>Ultra-3 SCSI (Ultra 160 SCSI; Fast-80 Wide SCSI)</td>
<td>160 MB/s</td>
</tr>
<tr>
<td>Ultra-320 SCSI (Ultra4 SCSI)</td>
<td>320 MB/s</td>
</tr>
<tr>
<td>Ultra-640 SCSI</td>
<td>640 MB/s</td>
</tr>
</tbody>
</table>

Fibre Channel

Technology

<table>
<thead>
<tr>
<th>Technology</th>
<th>Rate (byte/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibre Channel 1GFC (1.0625 GHz)</td>
<td>106.25 MB/s</td>
</tr>
<tr>
<td>Fibre Channel 2GFC (2.125 GHz)</td>
<td>212.5 MB/s</td>
</tr>
</tbody>
</table>

Disk

Cache Size

Spinning Magnetic Media

RAID and/or Caching

RPM’s
Plethora of Options Today

- Direct Access Storage (DAS)
- Flash on Server (FOS)
- Networked Storage (SAN/NAS)
- Flash on Storage Controller (FOSC)

- Disk/Flash Type
- Basic Storage Architecture
- Special Purpose Options
- RAID and/or Caching
Plethora of Options Today

- SATA SSDs
- SAS & SATA Magnetic Disks
- SAS SSDs
- PCIe Flash
Plethora of Options Today

- **10GbE**
- **InfiniBand**
- **Fibre Channel**
- **RAID and/or Caching**

<table>
<thead>
<tr>
<th>Technology</th>
<th>Rate (byte/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SATA revision 1.0</td>
<td>150 MB/s</td>
</tr>
<tr>
<td>Serial Attached SCSI (SAS)</td>
<td>300 MB/s</td>
</tr>
<tr>
<td>SATA Revision 2.0</td>
<td>300 MB/s</td>
</tr>
<tr>
<td>SATA Revision 3.0</td>
<td>600 MB/s</td>
</tr>
<tr>
<td>Serial Attached SCSI (SAS) 2</td>
<td>600 MB/s</td>
</tr>
<tr>
<td>Serial Attached SCSI (SAS) 3</td>
<td>1,200 MB/s</td>
</tr>
<tr>
<td>SATA revision 3.2 - SATA Express</td>
<td>2,000 MB/s</td>
</tr>
<tr>
<td>Serial Attached SCSI (SAS) 4 (prelim spec)</td>
<td>2,400 MB/s</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technology</th>
<th>Rate (byte/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibre Channel 4GFC (4.25 GHz)</td>
<td>425 MB/s</td>
</tr>
<tr>
<td>Fibre Channel 8GFC (8.50 GHz)</td>
<td>850 MB/s</td>
</tr>
<tr>
<td>Fibre Channel 16GFC (17.0 GHz)</td>
<td>1,500 MB/s</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technology</th>
<th>Rate (byte/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>iSCSI over Fast Ethernet</td>
<td>12.5 MB/s</td>
</tr>
<tr>
<td>iSCSI over gigabit Ethernet</td>
<td>125 MB/s</td>
</tr>
<tr>
<td>iSCSI over 10GbE</td>
<td>1,250 MB/s</td>
</tr>
<tr>
<td>FCoE over 10GbE</td>
<td>1,250 MB/s</td>
</tr>
<tr>
<td>iSCSI over InfiniBand 4x</td>
<td>4,000 MB/s</td>
</tr>
<tr>
<td>iSCSI over 100G Ethernet (hypothetical)</td>
<td>12,500 MB/s</td>
</tr>
<tr>
<td>FCoE over 100G Ethernet (hypothetical)</td>
<td>12,500 MB/s</td>
</tr>
</tbody>
</table>
Advantages of PCIe Flash

• **Performance:** The biggest benefit is increased performance. Not only does the PCIe interface have low latency for data transfer, it also bypasses any storage area networking to store or retrieve data. It is, therefore, the fastest way to access data. It delivers microsecond latencies versus millisecond latencies for traditional SAN-based storage.

• **Energy Savings:** Server-attached PCIe SSDs eliminate the need for additional storage servers, thus saving power on cooling. Traditional storage solutions for high throughput, low latency, and high IOPS need hundreds of hard disk drives, Fibre Channel controllers, and significant amounts of power and cooling.

• **Space Savings:** PCIe SSDs are compact and fit into the PCIe slot of a server. They eliminate the need for rack space, cooling, and power for storage servers.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Rate (byte/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCI Express 1.0 (×1 link)</td>
<td>250 MB/s</td>
</tr>
<tr>
<td>PCI Express 1.0 (×2 link)</td>
<td>500 MB/s</td>
</tr>
<tr>
<td>PCI Express 2.0 (×1 link)</td>
<td>500 MB/s</td>
</tr>
<tr>
<td>PCI Express 3.0 (×1 link)</td>
<td>984.6 MB/s</td>
</tr>
<tr>
<td>PCI Express 1.0 (×4 link)</td>
<td>1,000 MB/s</td>
</tr>
<tr>
<td>PCI Express 1.0 (×8 link)</td>
<td>2,000 MB/s</td>
</tr>
<tr>
<td>PCI Express 2.0 (×4 link)</td>
<td>2,000 MB/s</td>
</tr>
<tr>
<td>PCI Express 3.0 (×4 link)</td>
<td>3,934 MB/s</td>
</tr>
<tr>
<td>PCI Express 1.0 (×16 link)</td>
<td>4,000 MB/s</td>
</tr>
<tr>
<td>PCI Express 2.0 (×8 link)</td>
<td>4,000 MB/s</td>
</tr>
<tr>
<td>PCI Express 3.0 (×8 link)</td>
<td>7,880 MB/s</td>
</tr>
<tr>
<td>PCI Express 1.0 (×32 link)</td>
<td>8,000 MB/s</td>
</tr>
<tr>
<td>PCI Express 2.0 (×16 link)</td>
<td>8,000 MB/s</td>
</tr>
<tr>
<td>PCI Express 3.0 (×16 link)</td>
<td>15,750 MB/s</td>
</tr>
<tr>
<td>PCI Express 2.0 (×32 link)</td>
<td>16,000 MB/s</td>
</tr>
<tr>
<td>PCI Express 3.0 (×32 link)</td>
<td>31,500 MB/s</td>
</tr>
</tbody>
</table>
## PCIe Flash Speed (IOPS)

<table>
<thead>
<tr>
<th>Performance</th>
<th>Standard Models</th>
<th>Performance Models</th>
<th>Capacity Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacities (GB²)</td>
<td>550, 1100</td>
<td>1100, 2200</td>
<td>4800</td>
</tr>
<tr>
<td>Read throughput (max MB/s, sequential 64k)</td>
<td>1,600</td>
<td>2,700</td>
<td>2,600</td>
</tr>
<tr>
<td>Write throughput (max MB/s, sequential 64k)</td>
<td>550</td>
<td>1,000</td>
<td>900</td>
</tr>
<tr>
<td>Read IOPS (max IOPS, random 4k)</td>
<td>174,000</td>
<td>345,000</td>
<td>269,000</td>
</tr>
<tr>
<td>Write IOPS (max IOPS, random 4k)</td>
<td>27,000</td>
<td>57,000</td>
<td>51,000</td>
</tr>
<tr>
<td>Peak write IOPS (max IOPS, random 4k)</td>
<td>109,000</td>
<td>245,000</td>
<td>213,000</td>
</tr>
<tr>
<td>Mixed IOPS (70/30 R/W, random 4k)</td>
<td>72,000</td>
<td>138,000</td>
<td>128,000</td>
</tr>
<tr>
<td>Peak mixed IOPS (70/30 R/W, random 4k)</td>
<td>161,000</td>
<td>315,000</td>
<td>264,000</td>
</tr>
<tr>
<td>Read IOPS (max IOPS, random 8k)</td>
<td>125,000</td>
<td>250,000</td>
<td>214,000</td>
</tr>
<tr>
<td>Write IOPS (max IOPS, random 8k)</td>
<td>13,000</td>
<td>28,000</td>
<td>27,000</td>
</tr>
<tr>
<td>Latency 512B (µs)</td>
<td>21</td>
<td>22</td>
<td>19</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Performance¹</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacities (GB²)</td>
<td>1100</td>
<td>2200</td>
</tr>
<tr>
<td>Read throughput (max MB/s, sequential 128k)</td>
<td>2,700</td>
<td>2,700</td>
</tr>
<tr>
<td>Write throughput (max MB/s, sequential 128k)</td>
<td>1,400</td>
<td>1,400</td>
</tr>
<tr>
<td>Read IOPS (max IOPS, random 4k)</td>
<td>531,000</td>
<td>531,000</td>
</tr>
<tr>
<td>Write IOPS (max IOPS, random 4k)</td>
<td>59,000</td>
<td>59,000</td>
</tr>
<tr>
<td>Peak write IOPS (max IOPS, random 4k)</td>
<td>308,000</td>
<td>308,000</td>
</tr>
<tr>
<td>Mixed IOPS (70/30 R/W, random 4k)</td>
<td>150,000</td>
<td>150,000</td>
</tr>
<tr>
<td>Peak mixed IOPS (70/30 R/W, random 4k)</td>
<td>335,000</td>
<td>335,000</td>
</tr>
<tr>
<td>Read IOPS (max IOPS, random 8k)</td>
<td>281,000</td>
<td>281,000</td>
</tr>
<tr>
<td>Write IOPS (max IOPS, random 8k)</td>
<td>30,000</td>
<td>30,000</td>
</tr>
<tr>
<td>Latency 512B (µs)</td>
<td>22</td>
<td>22</td>
</tr>
</tbody>
</table>

**HGST FlashMAX II**

**HGST FlashMAX III**
DAS – Still a Viable Option

Single Instance

Database

HBA

All Disk

Disk + SSD

RAC Instance #1

HBA

RAC Instance #2

HBA

All SSD
Oracle® Data Appliance (ODA X3-X4)

Many Experts’ Blogs:

- First thing to go on Flash/SSD should be data
- Redo logs = many sequential writes where spinning disk good enough
Oracle® Data Appliance (ODA X5)

Many Experts’ Blogs:

- First thing to go on Flash/SSD should be data
- Redo logs = many sequential writes where spinning disk good enough

[Diagram showing RAC Instance #1 and RAC Instance #2 with HBA connections to All Disk, Disk + SSD, and All SSD. Redo Logs & ODA Flash Cache highlighted.]
DAS + FOS

Single Instance

Database

HBA

All Disk

Disk + SSD

RAC Instance

RAC Instance

- DB Smart Flash Cache (Read Only)
- Redo Logs or Temp
- Hot DB Objects
- General I/O Cache

- DB Smart Flash Cache (Read Only)
- Redo Logs
- Cluster I/O Cache

All SSD

X

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Networked Storage – Current Mainstay

- Single Instance
  - Database
  - 10GbE Switch

- Shared SAN/NAS

- RAC Instance #1
- RAC Instance #2
  - Fibre Channel Switch
  - InfiniBand Switch

- All Disk
- Disk + SSD
- All SSD
  - Could be LUN’s or I/O cache
SAN/NAS + FOS

Single Instance

Database

10GbE Switch

Shared SAN/NAS

- DB Smart Flash Cache (Read Only)
- Redo Logs or Temp
- Hot DB Objects
- General I/O Cache

RAC Instance #1

- DB Smart Flash Cache (Read Only)
- Redo Logs

RAC Instance #2

- Cluster I/O Cache
- HGST Share

Fibre Channel Switch

InfiniBand Switch

All Disk

Could be LUN’s or I/O cache

Disk + SSD

All SSD

- DB Smart Flash Cache (Read Only)
- Redo Logs
- Cluster I/O Cache
- HGST Share
HGST FlashMAX® + ClusterCache®

Single Instance
Database

Shared SAN

RAC Instance #1

RAC Instance #2

Fibre Channel Switch

InfiniBand Switch

10GbE Switch

General I/O Cache

Cluster I/O Cache

All Disk

Disk + SSD

Could be LUN’s or I/O cache

All SSD

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Long Live Data™
HGST Share software enables FOS Flash modules to be shared across all RAC nodes as if it were FOSC....
SAN/NAS + FOSC

Single Instance
- Database

Shared SAN/NAS

RAC Instance #1

RAC Instance #2

10GbE Switch

Disk + Flash:
- Could be LUN’s or I/O cache

All Flash:
- Could be LUN’s or I/O cache

Fibre Channel Switch

InfiniBand Switch
Oracle® Exadata X2-X3

Cell-Offloading / Smart-Scan
- Column Filtering
- Row Filtering
- JOIN Filtering
- Storage Indexes
- Function Offload
- Virtual Columns
- HCC Decompress
- Decryption

HC = 7,200 RPM Disk + Flash
Could be LUN’s or I/O cache

HP = 15,000 RPM Disk + Flash
Could be LUN’s or I/O cache
Oracle® Exadata X4-X5

Cell-Offloading / Smart-Scan
- Column Filtering
- Row Filtering
- JOIN Filtering
- Storage Indexes
- Function Offload
- Virtual Columns
- HCC Decompress
- Decryption

HC = 7,200 RPM Disk + Flash
HP = All Flash

Could be LUN’s or I/O cache

InfiniBand Switch

All in one rack cabinet
SAN/NAS + FOS + FOSC

Single Instance

Database

Shared SAN/NAS

RAC Instance #1

RAC Instance #2

10GbE Switch

Fibre Channel Switch

InfiniBand Switch

Disk + Flash

Could be LUN’s or I/O cache

All Flash

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# Compare Storage Options for Oracle® RAC

## Rough “Theoretical” Comparison

<table>
<thead>
<tr>
<th></th>
<th>Best (ms)</th>
<th>Worst (ms)</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional SAN with spinning drives</td>
<td>3 disk + FC</td>
<td>10 disk + FC</td>
<td>$</td>
</tr>
<tr>
<td>Add SSDs to existing SAN</td>
<td>.06 flash + FC</td>
<td>10 disk + FC</td>
<td>$$</td>
</tr>
<tr>
<td>All-Flash Array (SAN with all flash)</td>
<td>.06 flash + FC</td>
<td>.06 flash + FC</td>
<td>$$$$</td>
</tr>
<tr>
<td>Oracle Exadata (Engineered System)</td>
<td>.06 flash + IB</td>
<td>3 disk + IB</td>
<td>$$$$$$</td>
</tr>
<tr>
<td>Oracle DB Smart Flash Cache</td>
<td>.06 flash</td>
<td>10 disk + FC</td>
<td>$</td>
</tr>
<tr>
<td>HGST FlashMAX® + HGST ClusterCache</td>
<td>.06 flash</td>
<td>10 disk + FC</td>
<td>$$</td>
</tr>
<tr>
<td>HGST FlashMAX® + HGST Share</td>
<td>.06 flash</td>
<td>.06 flash</td>
<td>$$</td>
</tr>
</tbody>
</table>

Assumption: network access + transfer time = .06 ms
Compare Storage Options for Oracle® RAC

- Traditional SAN with spinning drives
- Add SSDs to existing SAN
- All Flash Array (i.e. SAN with flash)
- Oracle Exadata (Engineered System)
- Oracle DB Smart FlashCache
- HGST FlashMAX + ServerCache
- HGST FlashMAX+ Share

Legend:
- Red: Best IO
- Blue: Worst IO
- Purple: Average IO
- Green: Cost ($)

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Oracle® RAC Solution—Major Telecom Win

HGST Share software running on HGST FlashMAX “blew away” the incumbent technology.

Reference architecture established for RAC deployments in all of the customer’s business units.

Why we won:
- **Performance**: 6x improvement over SAN
- **Cost**: 1/3rd the cost of SAN
- **Ease of Use**: We look like “any other LUN”
- **Energy Efficient**: Reduced power/cooling
- **Validation**: Solution on Oracle web site

### Three Year TCO, HGST vs. SAN

<table>
<thead>
<tr>
<th></th>
<th>HGST FlashMAX Solution</th>
<th>Alternative Storage Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost</strong></td>
<td>$200,000</td>
<td>$400,000</td>
</tr>
<tr>
<td><strong>$200,000</strong></td>
<td>$600,000</td>
<td>$800,000</td>
</tr>
<tr>
<td><strong>$400,000</strong></td>
<td>$1,000,000</td>
<td>$1,200,000</td>
</tr>
</tbody>
</table>

- Staff Personnel
- Professional Services
- Maintenance & Support
- Datacenter Costs
- Software
- Hardware
Three Year TCO, HGST vs. PMO

- HGST FlashMAX Solution
- Alternative Storage Solution

Cost Breakdown:
- Staff Personnel
- Professional Services
- Maintenance & Support
- Datacenter Costs
- Software
- Hardware

- 700K IOPs
3-Year TCO vs. Enterprise SAN—700K IOPs

Three Year TCO, HGST vs. PMO

- Staff Personnel
- Professional Services
- Maintenance & Support
- Datacenter Costs
- Software
- Hardware

HGST FlashMAX Solution vs. Alternative Storage Solution

$1,000,000
$900,000
$800,000
$700,000
$600,000
$500,000
$400,000
$300,000
$200,000
$100,000
$-

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HGST Free Performance Assessment

- Process-driven analysis tied to actual workloads
- Performed by our in-house Oracle ACE, Mr. Scalzo
- Completely secure
  - ORAchk, Diagnostics & Tuning Packs
  - Only accesses data dictionary & metadata
  - HGST reviews/parses text output
- 3 steps to actionable insights
  - Collection
  - Analysis
  - Read-out
- Recommendations on tuning and potential benefits of Flash
Thank You

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