Flash economics are driving rapid adoption
Pent-up demand for improving application performance

- Multi-core processors drive up processor utilization and demand for more I/O per server, while HDD throughput remains flat.
- Flash prices falling faster than HDDs but still considerably higher than 15K HDDs.
- New form factors: PCIe cards, appliances, shared storage.
- Virtualization is increasing the demand for random I/O with the “mixer effect.”
Reliance on I/O-intensive solutions for critical applications is growing

IT Managers are looking for storage solutions that can span both, hot and cold data, optimizing for performance and value

(Note: CAGRs calculated for 2011-2016)
Flash storage can be deployed at various layers to accelerate transactional application performance.

**Indexing**
- Maintains indexes to allow quicker access to data
- Runs on databases to accelerate locating a block of data in queries

**Data Warehousing**
- Stored data used to create reports or derive Business Intelligence
- Used for data mining, analysis, hypothesis testing, modeling

**OLTP**
- Manage transaction-oriented applications, i.e., retail, banking
- Business can be hurt if data not accessible, slow
- During peak usage, customer experience can be effected

**VDI**
- Hosting desktop OS within a VM on a centralized server
- Facilitate a quick retrieval of gold images
- Boot storms, write allocations and latency are issues
“We’re successfully mitigating boot storms as well as load storms when a lot of people are logging into their virtual desktops at once. You’d be surprised how many IOPS it takes to log in—it’s one of the major challenges with large-scale VDI.”

Luther Bowens, Systems and Operations Manager
Indianapolis Public Schools

Indianapolis Public Schools deployed Compellent with SSDs to optimize **storage performance for VDI**
What characterizes your workloads?

Traditional “one size fits all” data storage strategy is unrealistic.

Performance expectations
- Application performance semantics: Concurrent users, TPS
- Storage performance semantics: throughput, IOPS, performance per GB, File performance

Access patterns and frequency
- Hot vs. cold data
- Read intensive vs write intensive
- Data optimized for tiering vs caching
- Random vs sequential

Business value
- Data that is highly valuable to the business and can be used for deriving business intelligence, financial analysis, etc.

Each type of data needs to be treated differently to align the application performance with capacity and cost requirements.
## Tiering Across Flash Types is Necessary to Accelerate Flash Economics

Dell is the first storage solution to tier sub-LUN data across SSDs.

### Workload Comparison

<table>
<thead>
<tr>
<th></th>
<th>Write-Intensive SLC SSDs</th>
<th>Read-Intensive MLC SSDs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Workload</strong></td>
<td>Mainstream Apps, Any usage</td>
<td>Mostly Read 90/10 R/W Mix</td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
<td>400 GB</td>
<td>1.6 TB</td>
</tr>
<tr>
<td><strong>Write endurance</strong></td>
<td>Great</td>
<td>Not as great</td>
</tr>
<tr>
<td><strong>Full-drive writes/day</strong></td>
<td>30</td>
<td>3</td>
</tr>
<tr>
<td><strong>Random read perf.</strong></td>
<td>Great</td>
<td>Great</td>
</tr>
<tr>
<td><strong>Write performance</strong></td>
<td>Great</td>
<td>Moderate</td>
</tr>
<tr>
<td><strong>Relative costs</strong></td>
<td>4x</td>
<td>1x</td>
</tr>
</tbody>
</table>

**Compellent Hybrid-Flash Array**
Secret sauce behind the flash optimized Compellent: **tiering with Data progression**

Flash-optimized Data Progression leverages the endurance of write-intensive SSDs and the value of read-intensive SSDs.

**Advanced software tiering seamlessly manages data**

- Incoming writes are written to write intensive SSDs for fast access
- Read intensive data is automatically moved to read optimized MLC keeping Tier 1 free for new incoming writes
- Cold data is migrated to tier-3 rotating disk
Compellent introduces **flash innovations** that change the economics of flash storage

**Storage Center 6.4**
- Extends tiering to multiple flash types
- Data progression enhancements
- Best performance at the lowest possible cost

**Flash enclosure**
- Up to 59% lower cost than most all-flash solutions
- Industry’s first MLC & SLC SSD intelligent flash tiering
- Introduces 1.6TB MLC SSDs

**Dense enclosure**
- 336TB in 5U
- Designed for cost/capacity optimized data growth
- Ideal as Tier 3 in hybrid configuration
- Ideal for large-scale file archival
New economies of flash: tiering innovations allow Compellent to offer flash at the price of disk

**Workload requirement:**
- 40,000 IOPS
- 30TB Raw Storage

**Benefits of Tiered Flash**
- 84% RU reduction
- 50% more IOPS
- 90% latency reduction
- 56% lower price

Space Savings
**Designed to address multiple performance levels**
Compellent helps align storage performance with workload requirements

<table>
<thead>
<tr>
<th>All-flash for business critical workloads</th>
<th>Hybrid for general workloads</th>
<th>Cost optimized HDD-based for lowest $/GB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large capacity flash with low latency and scalability</td>
<td>Capacity with mainstream application performance</td>
<td>Large capacity, lowest $/GB</td>
</tr>
<tr>
<td>• Tier 1 applications</td>
<td>• Better performance with limited flash capacity</td>
<td>• When large datasets are required</td>
</tr>
<tr>
<td>• OLTP Oracle database</td>
<td>• General workloads</td>
<td>• Data that is not performance sensitive</td>
</tr>
<tr>
<td>• VDI gold images and logs</td>
<td></td>
<td>• Backup and archive</td>
</tr>
<tr>
<td>• Big data analytics</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **15K RPM HDDs**
- **7K RPM HDDs**

- **7K RPM SSDs**
- **WI & RI SSDs**

- **WI & RI SSDs**
How do you scale your business when budgets are fixed?
Even with Flash-Optimized Storage, Latency can be an Application Performance Killer

Application IOPS = $\text{Fn}(\text{rpm}, \text{lrot}, \text{lseek}, \text{lvl}_{\text{RAID}}, \text{sze}_{\text{RAID}}, \text{n}_{\text{drives}}, \ldots) + \text{Fn}(\text{lsan}, \text{bsan}) + \text{Fn}(\text{Ctrl}_{\text{san}})$
Introducing Dell Fluid Cache for SAN
Advanced Integrated Host-based Caching Solution

1. Install Fluid Cache software
2. Add PCIe SSD
3. Configure a cache network
4. Integrate administrative services

**Cache Client Servers**

*Cache Contributor Servers*

Private cache network (10/40 GbE)

Storage network (FC or iSCSI)

Dell Compellent SAN
Extraordinarily Low Latency Maximizes Transactional Workload Performance

**Federation**
- All hosts see all cache capacity
- RDMA-over-Ethernet (RoCE)
- Host failure results in no data loss

**Asymmetry**
- Cache capacity can be distributed unevenly across the cluster
- Hosts with no PCIE cache can leverage the benefits
- Non-Dell servers supported

**Write-Back**
- Accelerates read and write performance
- Maximizes true IO performance
- Fast mirroring over RDMA to protect data

**Fully Integrated**
- Snapshots are consistent
- Replication is consistent
- Fully managed through Compellent Enterprise manager
OLTP Workload: SQL on VMware
3 node architecture Dell lab test

Dell R720  Dell R720  Dell R720

PCIe SSDs*  PCIe SSDs*

Shared PCIe SSD cache

Dell Networking
Low latency 10GBe switch

Private cache network

Storage network (Fibre Channel or iSCSI)

Dell Compellent SC8000 and storage array

Storage Area Network (SAN)
Dell Storage Center SC6.5
3-Node Host Cache Delivers Excellent SQL Performance Gains

Average Response Time (ms)

- **86% reduction**

Cost per concurrent user

- **56% reduction**

Transactions per second

- **2.5x improvement**
OLTP Workload: Oracle on Bare Metal
8 Node Architecture Dell Lab test

Private cache network (10/40 GbE)
Dell Compellent SC 8000 and storage array
Storage network (FC or iSCSI)
8-Node Host Cache Delivers Amazing Oracle Improvements

Average Response Time (ms)
- **99.3% reduction**

Concurrent Users
- **6x more users**

Transactions per Second
- **4x more TPS**
3 Node Architecture

- No. of concurrent users: 1900
- Transactions/Second: 1979
- Average Response Time: 46ms.

8 Node Architecture

- No. of concurrent users: 14000
- Transactions/Second: 12609
- Average Response Time: 6ms.

Comparative Data:
- 7.4x increase in No. of concurrent users
- 6.4x increase in Transactions/Second
- 87% decrease in Average Response Time
Compellent extends the **economic value** with a **feature-rich** storage platform

**Optimal $/GB & $/IO**
Lower TCO by balancing performance and capacity needs in a single platform, extending from the cold HDD tier all the way to the host.

**Automated Tiering**
Automatically move data between Flash tiers and HDD tiers based on IO demand. Includes compression as a tier.

**Scalability**
Scale to meet storage requirements with either SSD or HDD. Full thin provisioning of block and file simplify administration.

**Investment Protection**
Perpetual licensing eliminates forced refreshes. Software life > hardware life.

**Scale-out File**
Clustered multi-PB NAS solution fully integrated. All inclusive license.

**Co-Pilot Support**
Leverage best of breed enterprise class proactive support.
Dell Storage

Workload-optimized solutions for any size enterprise

- **Compellent**
  - High-performance scalable storage

- **EqualLogic**
  - Easy-to-use virtualized storage

- **PowerVault**
  - Affordable, entry level storage

- **DR Solutions**
  - Data management and protection

- **Converged infrastructures**
- **Cloud deployments**
- **I/O intensive applications**
- **Vertical file-intensive apps**

Maximize efficiency, drive results faster and boost resiliency