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# Revolutionizing Enterprise Storage Infrastructure with Enterprise Flash Technology

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## Executive Overview

Businesses increasingly rely on datacenters to provide access to services, applications, and data. As demand rises and applications grow in complexity, datacenter infrastructure must provide tremendous capacity and rapid access to information in order to keep pace with business priorities. Today companies can add storage capacity easily by augmenting infrastructure with additional hard disk drives and arrays. Unfortunately, the devices that provide the highest capacity fail to provide the I/O performance needed to keep systems supplied with the data for processing—and inflate storage infrastructure costs.

By contrast, enterprise flash technology has the potential to provide dramatic improvement in storage infrastructure economics and performance. Originally developed in the 1980s, flash technology is low-cost, nonvolatile computer memory that can be electrically erased and reprogrammed. Recent technological advancements are moving flash technology rapidly past simple commodity use and making it a strong storage alternative for the enterprise that can help rebalance system and storage I/O performance.

## Overcoming the CPU-to-Storage Bottleneck with Flash Technology

The CPU-to-storage bottleneck is hindering application and service performance—a trend that continues unabated as system performance outpaces disk throughput year over year. Indeed, many enterprise servers in use today can generate hundreds of thousands of I/O operations per second (IOPS)—yet the entire collection of hard disk drives available to systems can often only perform at a rate of thousands of IOPS combined. The disparity in IOPS between systems and disks, and the I/O bottleneck introduced by storage adapters, forces CPU cycles to be lost waiting for I/O to complete, which impacts system throughput and application performance.

To compensate, IT managers typically add more external devices and DRAM to help speed throughput—extra DRAM lets systems store working sets in memory to avoid disk latency, while adding more disk spindles can help increase throughput by letting I/O operations be performed in parallel. However, the result is an expensive infrastructure that is difficult to manage and cannot reliably keep pace with throughput demands. Fortunately, flash technology provides a compelling alternative.

Nearly everyone is familiar with some sort of commercially available flash device, from memory cards used in MP3 players, cell phones, and digital cameras to store music, photographs, and other digital information, to removable USB drives used to backup and transport data from one computer to another. Flash solutions provide robust data integrity, reliability, and availability combined with breakthrough performance and power characteristics to create a whole new class of storage device.

## Enterprise Solid State Devices

Solid state devices (SSDs) based on flash technology are emerging as a new enterprise class storage option. With fast read and write performance, a compelling price point, and incredibly low power requirements, devices based on flash memory are poised to disrupt the industry.

### High Performance

Keeping systems supplied with data is critical to overall datacenter performance. Flash technology completes operations in microseconds, placing it between hard disk drives (milliseconds) and random access memory (nanoseconds) for access time. Because flash technology contains no moving parts, it avoids the seek times and rotational latencies associated with traditional hard disk drives. As a result, data transfer throughput to and from solid state storage media is faster than electromechanical disk drives can provide—enterprise SSDs provide tens of thousands of IOPS compared to hundreds of IOPS for hard disk drives (see Figure 1). Unlike DRAM, enterprise SSDs do not need to reload cached data, helping services to resume faster.

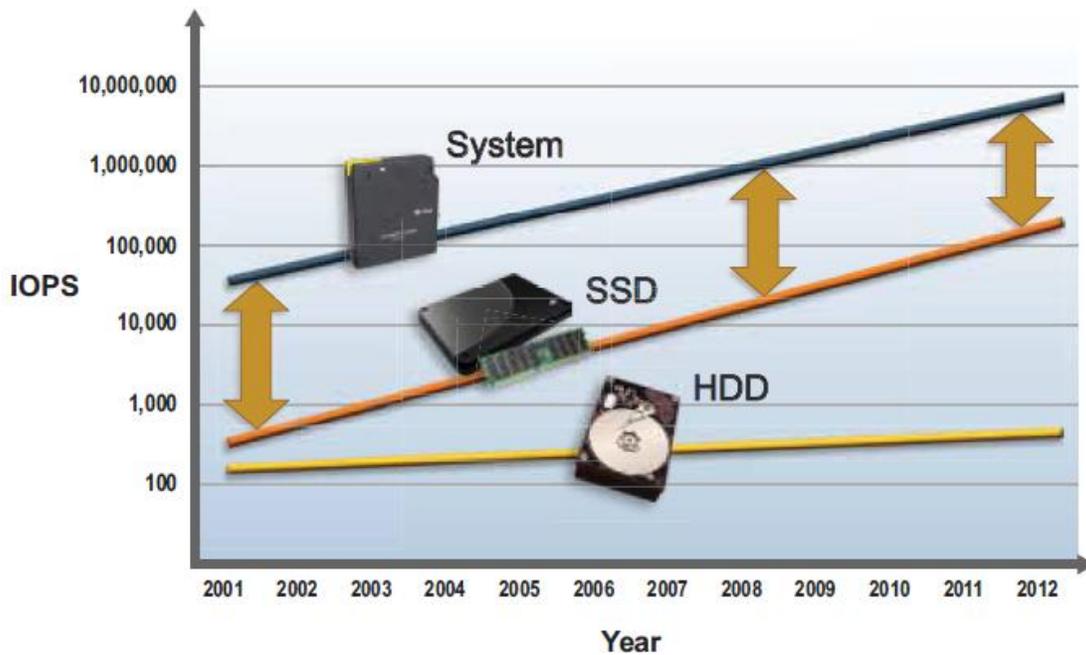


Figure 1. Enterprise SSDs provide higher performance to help handle system demand.

### Low Power Consumption

With energy costs rising, power has become the dominant factor in high-scale hardware decisions. Hard disk drives draw significant amounts of power to operate the motor and spin media. By contrast, the use of efficient flash memory and a lack of motors and other mechanical parts result in enterprise SSDs consuming a fraction of the power of conventional hard disk drives. In fact, enterprise SSDs use only 5 percent of the power used by hard disk drives when idle, and a little as 15 percent when performing operations.

### Very Low Cost Per Gigabyte and I/O Operations Per Second

In today’s challenged economy, creating cost effective storage infrastructure is paramount. While flash devices are more expensive per gigabyte than a comparable disk drive, flash memory costs are dropping significantly year over year. In addition, as electricity costs rise and flash memory costs decrease in price, the relative cost per available gigabyte and cost per IOPS of flash memory improves.

For example, hard disk drives cost approximately \$1.25/IOPS, compared to only \$0.02/IOPS for enterprise SSDs.

Since hard disk drives must be powered on to be available, the low power consumption of enterprise SSDs makes them a smart choice for datacenters looking to reduce operating costs. While a gigabyte of mechanical disk costs less than a gigabyte of flash memory, the fact that flash memory outperforms hard disk storage by at least an order of magnitude in reading and writing data makes the cost per gigabyte of flash devices exceptionally low.

### Higher Reliability Than Hard Disk Drives

While enterprise SSDs provide similar functionality to traditional hard drives, they offer improved reliability features. Both hard disk drives and enterprise SSDs support bad block management, wear leveling, and error correction codes (ECC) to foster data integrity.

However, unlike hard drives that use a motor to spin magnetic media and a read/write head that must move to perform operations, enterprise SSDs contain no moving parts—data is stored on integrated circuits that can withstand significant shock and vibration. In addition, enterprise SSDs operate in a wider thermal operating range and wider operational vibration range than hard disk drives to deliver significantly higher Mean Time Between Failure (MTBF), approximately 2.0 million hours versus 1.2 million hours.

### Creating a New Storage Tier

Applications running on current multicore, multsocket servers are increasingly held back by slow storage systems. Technological advancements are changing the way storage devices can be used to rebalance systems and storage and create optimized solutions. While hard disk drives provide the capacity needed to handle large amounts of I/O, they are slow to perform. On the other hand, enterprise SSDs provide required I/O throughput, yet cannot provide the capacity needed at competitive price points.

The right approach combines the strengths of both technologies. Flash devices can be placed in a new storage hierarchy to assist disk drives by holding frequently accessed data to minimize the impact of disk latencies and improve application performance. With the addition of flash storage, applications access data stored on a combination of enterprise SSDs and hard disk drives, resulting in more balanced I/O throughput (see Figure 2).

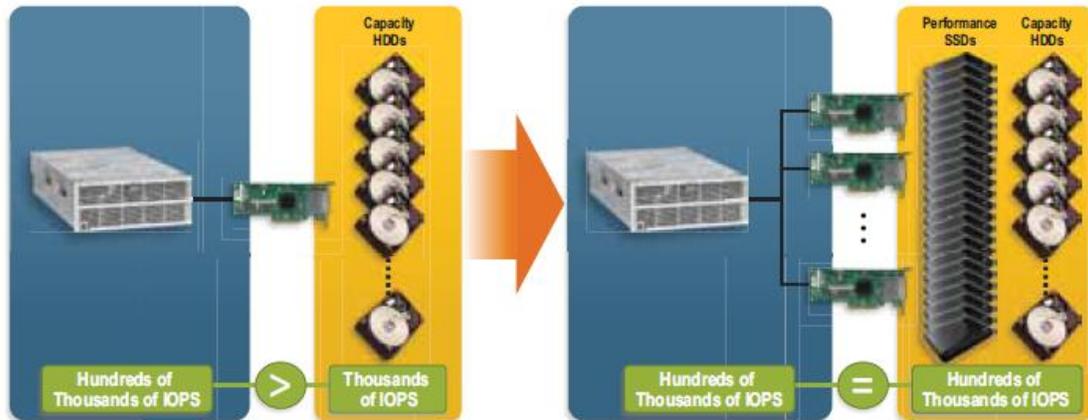


Figure 2. Flash technology complements existing storage infrastructure to help meet system demand.

### Caching and the Hybrid Storage Pool

Integrating flash devices into the storage hierarchy as a disk cache can result in significant performance gains for I/O intensive workloads, without the need to modify applications. In such an environment, flash devices are used to store actively used data, making the entire storage infrastructure appear as fast as flash storage to applications.

With the right hardware and software technology, disk caches can be extended beyond the physical limitations of a single device. Such an approach groups flash devices to create a single large disk cache that can hold frequently accessed data and free hard disk drives from performing small updates.

Indeed, by utilizing enterprise SSDs to handle CPU I/O, and hard disk drives to store large data sets, a hybrid storage pool gives organizations significant performance gains without sacrificing capacity.

### Other Uses for Flash Devices

- Flash devices can be used in other ways to help datacenters improve performance and reduce operational expenses. Flash devices can be used as a boot disk replacement to save on space and power consumption
- Used to replace time-consuming disk access protocols with more efficient memory-to-memory transfers and help scale to many millions of IOPS

### Integration Based on Open Standards

As enterprises struggle to cope with the phenomenal rise in digital data volumes and budget pressures, they are looking for storage architectures that provide greater flexibility and better economics. For years, enterprises utilized servers and storage systems that were closed, proprietary, and expensive.

Just as open systems changed high-scale computing with affordable architectures, open standards are revolutionizing data management with innovation and choice. By delivering integrated hardware and

software platforms based on open standards, Oracle provides creative technologies for developing and deploying new storage faster.

Oracle is breaking down the barriers of deploying state-of-the-art storage systems with truly open architectures—giving companies the ability to select the right hardware and software components to meet business needs.

### Freedom to Adapt to Application Needs

Unlike traditional storage deployments, environments built using storage systems from Oracle that support open standards let enterprises freely mix, match, and maximize computing and storage components—including hard disk drives and new flash devices—within a single environment to support user and application demands and adapt as business needs change.

Such freedom holds promise for companies in any industry. Financial, Web 2.0, ecoresponsible IT, high-performance computing (HPC), and virtualization environments can take advantage of systems build on open standards to handle growth, manage storage I/O bandwidth and latency needs, and consolidate systems to affect better resource utilization and reduce storage costs by up to 90 percent.

## A Bright Future for Flash Technology

Devices based on flash technology are poised to help increase application performance and response time dramatically, while utilizing less datacenter floor space and energy at a fraction of the cost of hard disk drive storage.

As flash technology continues to develop and gain in popularity, several significant trends are expected.

- Driven by economies of scale, higher capacity (2 TB+) flash devices like Oracle's Sun Storage F5100 Flash Array are moving from consumer applications into the datacenter.
- Flash technology-based enterprise solid state device reliability already exceeds that of enterprise hard disk drives by twofold and is expected to continue increasing reliability over the coming years.
- Demanding high performance workloads such as OLTP that rely on low IO latency will increasingly turn to flash technology to solve performance bottlenecks instead of hard disk drives. This is already being demonstrated with new TPC and SPC benchmarks being set with the Sun Storage F5100 Flash Array.
- As flash technology makes its way into the storage infrastructure, the use of enterprise hard disk drives is likely to shift from a performance focus to providing massive capacity.
- As flash technology takes hold in the datacenter, applications can be redesigned to take advantage of the technology directly, or utilize innovative approaches such as hybrid storage pools that result from the application of Oracle's Sun systems, the Oracle Solaris operating system, the Oracle Solaris ZFS file system, and other software advancements like the Smart Flash Cache technology in Oracle Database 11gR2.

- By incorporating SSDs, Oracle’s Sun Storage 7210 and Sun Storage 7410 systems can take advantage of the hybrid storage pool available with Oracle Solaris ZFS to unlock new levels of performance.
- With 32 GB SSD’s now shipping in the Oracle’s Sun SPARC Enterprise T5000, Sun Fire X4000, and Sun Blade 6000 server families, Oracle delivers on the promise to integrate flash memory with the least amount of disruption to deliver high-performance, low power, general-purpose storage, servers, and appliances that accelerate any software running on these platforms.

## Conclusion

Data can be a competitive weapon, but it becomes less so if it is not accessible or costs too much to store. Oracle innovation and advanced design result in solutions that save time and money for companies seeking to use technology to find opportunity.

With an unwavering commitment to technological innovation and open standards based solutions, Oracle continues to drive storage technology forward. With the introduction of flash technology and related hardware and software products, Oracle helps enterprises reduce the risk, cost, complexity, and deployment time of multitiered storage environments—all while providing the right data at the right time at the right cost.

Take advantage of innovative, fast, rugged, low cost flash technology

- Reduce the CPU-to-storage bottleneck by incorporating flash technology like the Sun Storage F5100 Flash Array in a new storage hierarchy that will turbo charge database performance. Combine disk drives and flash devices like Sun Flash Modules into an integrated hybrid storage pool with Oracle Solaris ZFS to deliver massive capacity and improve performance
- Integrate solid state devices (SSDs) in Oracle’s Sun SPARC Enterprise T5000 servers, Sun Fire X4000 servers, and Sun Blade 6000 Modular Systems for instant application acceleration
- Simplify data management and increase performance with automated data placement of Oracle Solaris ZFS and the efficiencies of the hybrid storage pool with SSDs integrated in Oracle's Sun Storage 7000 systems



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