Abstract

This white paper outlines key business problems facing customer IT environments and how the new Enterprise Flash Drive (EFD) technology can be used to address these challenges. This paper provides an overview of the EFD technology and its effect on specific business applications.
# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Executive summary</td>
<td>4</td>
</tr>
<tr>
<td>Introduction</td>
<td>4</td>
</tr>
<tr>
<td>Audience</td>
<td>4</td>
</tr>
<tr>
<td>Enterprise Flash Drives</td>
<td>4</td>
</tr>
<tr>
<td>What problems do Enterprise Flash Drives solve?</td>
<td>6</td>
</tr>
<tr>
<td>EMC unified platforms: Disk device options and usage</td>
<td>7</td>
</tr>
<tr>
<td>IP storage and Flash drives</td>
<td>8</td>
</tr>
<tr>
<td>Application-specific considerations for EFD</td>
<td>8</td>
</tr>
<tr>
<td>Oracle and SQL Server database use cases</td>
<td>8</td>
</tr>
<tr>
<td>Microsoft Exchange over iSCSI use case</td>
<td>9</td>
</tr>
<tr>
<td>VMware over NFS generic use case and VMware View (VDI) use cases</td>
<td>9</td>
</tr>
<tr>
<td>Tiering storage on EMC unified platforms with FAST</td>
<td>11</td>
</tr>
<tr>
<td>Will EFD add value to my environment?</td>
<td>11</td>
</tr>
<tr>
<td>Conclusion</td>
<td>13</td>
</tr>
<tr>
<td>References</td>
<td>13</td>
</tr>
</tbody>
</table>
Executive summary

With corporate data growth rates at 50 to 60 percent per year and IT budgets declining, businesses are forced to look at new approaches when deploying storage assets. At the same time, these companies are looking to innovate and build competitive advantage while maintaining control of their legacy environments. Data storage is a key enabler in the modern data center, although while capacities offered by storage systems have grown exponentially over the years, disk performance has not grown at anywhere near the same speed. In order to unleash the power of the IT infrastructure as a whole, a paradigm shift in storage offerings is required that removes the traditional storage bottleneck. That shift is upon us, with the advent of the Enterprise Flash Drive. Compared to existing (Fibre Channel) technology, Flash delivers up to 30 times the throughput at one-tenth of the response time.

The primary benefit of Flash drives is to reduce the time taken to execute a business transaction or process by improving the efficiency of the underlying storage infrastructure; for example, the time taken to concurrently process many thousands of banking transactions or build and test software applications, or the time taken to perform compute and storage intensive manufacturing processes such as CAD/CAM. Reducing the time to execute business processes allows customers to shorten product design cycles, reduce the risk of fraud in financial transactions, and show real, measurable monetary value to the business. In addition, Flash can improve the overall efficiency of the IT infrastructure by ensuring the right storage option is used for the most relevant application, especially when integrated with storage platforms that support an automated storage tiering solution. EFDs represent a truly exciting opportunity for all sizes of IT environments to accelerate the delivery and operations of new products, applications, and services while optimizing the total cost of the solution.

Introduction

This white paper considers the validity of leveraging Enterprise Flash Drives in a specific IT environment. It provides an introduction to EFD technology and its relevance to enterprise applications in the data center today, as well as in the future, as economies of scale allow for a greater breadth of applications. We will review some specific application types that have been tested and show significant benefit when implemented with Flash. We also look to future trends in the storage space that are taking place to better leverage EFD.

Audience

This white paper is aimed at business and technical decision makers, architecture consultants, procurement specialists, and application owners, or anyone interested in improving the efficiency and performance of their business applications, while potentially reducing the total cost of ownership of their IT solutions.

Enterprise Flash Drives

Enterprise Flash Drives introduce a new performance level of storage to enterprise and commercial storage users. Flash drives use solid state memory as the media for data storage in place of the rotating hard disk drive (HDD) used in storage systems for the last 40 years. Figure 1 shows the components of the HDD.
While HDD technology developments have provided impressive capacity/cost scaling over the years, the performance characteristics (input/output operations per second) have been constrained by mechanical components and have never achieved the same exponential improvements relative to both the disk capacity and CPU performance improvements over the same period. Disk performance improvements have involved reducing the dimensions of the physical drive, increasing the speed of rotation, and introducing techniques such as RAID to spread I/O loads over multiple spindles; performance improvements have achieved a mere 5 percent improvement per year, compared with the 50 percent improvement in $ cost per GB. In addition, due to the nature of the seek time when disk read/write heads are mechanically moved over the required track, response times will vary, which causes fluctuations in I/O response times. Flash addresses these issues and promises to improve the overall efficiencies that have been lacking, as evidenced in Figure 2.

**Enterprise Flash Technologies**
- Efficient use of server CPU
- TCO can be less than commercial RAID / caching Solution
- Reduced tuning / consulting costs
- Simple strategies to improve application performance

**Figure 1. Hard disk components**

**Figure 2. Historical speed improvements of CPU and storage**
Because a single higher-performing Flash drive can replace 30 or more hard disk drives in I/O-intensive environments, this technology has the potential to significantly alter system design and configuration criteria by right-sizing the configuration to better address the capacity/performance tradeoff. Flash drives also have a secondary impact of providing substantial reductions in both power consumption and physical floor space requirements.

The Flash technology used in consumer Flash products (thumb drives and the like) is simply not acceptable to operate in an enterprise storage environment. Enterprise Flash Drives (EFDs) are designed with component types, architectural features, and interfaces that make them compatible with high-performance systems and mission-critical applications. Commodity Flash drive models seek to optimize capacity rather than performance and/or durability, to target cost points closer to the individual hard disk drive they replace. In addition, server or storage system integration will affect elements related to ease of application integration, performance, and availability.

Key challenges addressed by EFDs include the following technology integration:

- **NAND Flash memory technology** — NAND is similar to a hard disk drive in that operations are sector-based (page-based) and is well suited for accessing random data. NAND devices also have bad block tracking and use error-correcting code (ECC) to maintain data integrity and provide the fastest sustained write speeds.

- **SLC based Flash** — NAND technology is available in two different cell designs. A Multi-level cell (MLC) stores more than one bit per cell by virtue of its ability to register multiple states, versus Single-level cell (SLC) that can store only one bit. SLC is the preferred technology for enterprise data applications, due to its performance and endurance. SLC read speeds are typically rated at twice those of MLC devices, and write speeds are up to four times higher. SLC devices are conservatively rated at 100,000 write erase cycles, a factor of 10 higher than that of MLC designs.

- **Write leveling and overprovisioning** — An important element of maximizing Flash drive useful life is ensuring that the individual memory cells experience uniform use. It is important to ensure that data that is frequently updated is written to different locations to avoid repeatedly rewriting the same cells. In EFDs, the device is designed to ensure that with any new write operation, the youngest block is used. In addition to the write leveling aspects of controller design, overprovisioning is another design feature used to improve device durability. Designing the drive with additional Flash memory above its rated capacity enables the controller to rotate the writes over additional cells in a manner known as write leveling. The extra capacity also provides a buffer to facilitate write management as the drive fills up.

- **Full data path protection** — In hard disk drives, one of the design elements that differentiate enterprise drives from commodity products is the provision for full data path protection. EFDs share this characteristic, using error detection and correction from interface to media and back to guard against data corruption and loss.

- **Dual-ported high-performance interfaces** — High-performance storage device interfaces such as Fibre Channel (FC) and SAS are engineered for high bandwidth combined with a high level of signal integrity, and provide additional features such as a larger queue depth than SATA for improved random I/O performance. In addition, they support a native dual ported interface, enabling two channels to the device for implementing high-availability storage architectures.

### What problems do Enterprise Flash Drives solve?

At the technical level, storage users continue to demand ever-increasing performance capabilities to meet the insatiable growth of business applications and the data that serves them. In the past, very high I/O requirements were met by simply throwing more disks at a specific workload. Flash drives change that and provide up to 30 times the throughput (EMC conservatively estimates 2,500 input/output operations per second (IOPS) per Flash drive for a suitable I/O profile, compared with 180 IOPS for conventional drives) and consistently up to one-tenth the response time of hard disk drive technology (<1 ms compared with 6-10 ms). This is why Flash is such an innovative technology, particularly as the price of Flash continues to drop.
Flash drives provide two key benefits to business applications. The primary benefit of Flash drives is to reduce the time taken to execute work. Some examples include the time taken to process a financial database transaction, compile a software application, or execute a CAD/CAM build process. Reducing the time to execute business processes allows customers to shorten business cycles, reduce risk, and show real, measurable monetary value to the business. Where a performance gain can be easily quantified in financial terms, then this is the easiest way to justify Flash and the return on investment can be most effectively proved. For example, being able to process a risk analysis on a credit card purchase in real time allows credit card companies to offer new value-added services. If a software house can perform software builds in 3 hours compared to 15 hours, they can produce new software titles, beating competitors to market. If an Oracle database can perform five times the number of transactions per second without the need to build out expensive new server hardware and software infrastructure, the value of Flash can be justified in a matter of months.

A second benefit is that Flash drives can significantly improve total cost of ownership. While this may sound contradictory for a storage technology that is expensive on a $/GB basis, to understand this benefit it is necessary to consider how capacity planning works for storage when planning for new applications. Traditionally, customers will first plan for performance and then for capacity. By way of illustration, Customer A is planning to implement a database application that is required to support 10,000 users and must process 2,000 transactions per second, which, for example, translates to 20,000 disk level IOPS. If using FC hard disk drives (which can sustain around 180 IOPS) to meet the performance requirement, we would need to implement 111 FC disks. The customer then looks at capacity requirements. In the case we are considering, this application requires 2 TB of capacity. If they configure 111 x 146 GB 15k rpm FC drives, this provides 16 TB of raw capacity, more than the application requires, but necessary to meet the performance expectations. In this case, by implementing Flash drives, we can easily meet the performance requirement with far fewer drives (a single Flash drive can provide up to 2,500 IOPS). Even though the per-drive price of Flash drives is higher than FC drives, the fact that fewer drives are required, along with reductions in power and space consumption, makes the TCO for this application with Flash superior to that of FC drives.

**EMC unified platforms: Disk device options and usage**

One of the primary value propositions for customers considering Flash technology with EMC is that the technology is available across the whole product portfolio. The existing investment in an enterprise storage infrastructure can be leveraged to support EFD. This provides tremendous flexibility where a single platform is required to support all application types from the highest-performance mission-critical applications via EFDs, to archival and very low activity applications on Serial-ATA drives. What is more, all the existing functionality available in each of the platforms can be applied to Flash-based storage devices in exactly the same fashion as for the existing storage technologies – deduplication, virtual provisioning, local and remote replication, file tiering/archiving, and so on.

There are four types of storage device technologies available for use on EMC® unified platforms: Enterprise Flash Drive (EFD), Fibre Channel (FC), Serial Attach SCSI (SAS), and Serial-ATA (SATA). While all of these drives store data, they have different operating characteristics, interfaces, and price points that make them more suitable to different operating environments. For example FC, SAS, and SATA drives have spinning media whereas EFDs have solid state media – this characteristic makes them suitable for different kind of environments.

There are two main types of operating environments: performance-intensive environments and capacity-intensive environments. Performance environments need high throughput, high bandwidth, and high reliability. Typical performance environments are transaction-based systems with workloads characterized by random reads and writes.

Capacity-intensive environments need large amounts of low-cost storage, high reliability, and modest throughput and bandwidth performance. Typical capacity-intensive environments are archival systems with a workload characterized by sequential reads.
EMC unified platforms support FC and iSCSI block-based protocols and also support NAS (NFS and CIFS). This allows the highest levels of flexibility as all the protocols can share the different device technologies from a pool. IP-based protocols tend to support a broad range of applications, so there is more of a requirement to provide storage-level performance tiering in a single system.

EFDs are recommended for performance-intensive applications or parts of applications with low-response-time and high-throughput requirements. FC hard drives should continue to be the choice for environments with large-capacity high-performance requirements. SAS hard drives provide performance and reliability that are equivalent to FC drives. SATA hard drives are the choice in modest-performance and high-capacity environments. In addition, SATA drives can provide energy-efficient bulk storage capacity at low cost.

**IP storage and Flash drives**

The EMC unified storage platform is changing the way the industry buys storage. From the entry-level NS-120 to the massively scalable NS-960, Celerra unified platforms natively support NAS (CIFS and NFS) and iSCSI as well as CLARiiON®’s proven FC connectivity technologies. The Celerra unified storage platform is available natively with Flash drives, extending Celerra’s unique value proposition into the ultra-high-performance space and allowing Flash technology to be leveraged and shared with FC connected hosts.

Traditionally the highest-performing applications are built out on top of the highest-performing storage connectivity technology, namely Fibre Channel. As such the early focus of the application of Flash has been in this segment of the market. There is evidence to support the assertion that there is also a significant value proposition for Flash usage in the IP storage space. IP storage currently can support higher bandwidth connections than FC or SAS (10 Gb vs. 8 Gb vs. 6 Gb), although this is not the only aspect of storage performance. The skepticism around IP storage and EFD typically involves the perceived overhead of the TCP, IP, and NAS protocols when compared to the FC overhead. In actuality, this overhead is relatively insignificant in most cases as long as the network design ensures plenty of headroom for the specific workload. For applications that require the NAS protocol for reasons of data sharing, such as CAD/CAM, software design, web serving, and so on, they may need to scale in a similar fashion to large FC-based storage applications, and in that case, EFD is a definite fit. In addition, many customers look to NAS to support non-traditional applications such as Oracle databases and VMware infrastructures, where a simplistic management model drives the decision criteria and high performance is a major requirement. The next section provides more detail on specific application performance expectations over IP storage.

**Application-specific considerations for EFD**

Based on our application experience and real-world testing performed in the EMC labs, we have identified the following applications as good candidates for Flash usage over IP:

- Very active Oracle table spaces over NFS
- High-performance block applications over iSCSI, for example, SQL Server, Exchange
- VMware View (VDI) with aggressive use of linked clones (View Composer) and traditional, high-load Citrix solutions, particularly for boot storms or AV scan storms
- Software engineering, for example, for reducing ClearCase compilation times
- Large CAD/CAM build processes
- High-load web search engines

We will look at a number of these that were tested in EMC labs in more detail next.

**Oracle and SQL Server database use cases**

Oracle is probably the premier high-end database deployed in the world today, controlling most of the world’s companies mission-critical structured application data. In addition, many customers have looked to implement Oracle over the NFS protocol for simplicity of storage and data management. Now, with Oracle
11g, Oracle has strongly validated this implementation methodology by including an Oracle optimized NFS stack (Direct NFS, or dNFS) within the Oracle application itself.

One of the key challenges for improving performance in Oracle architectures is alleviating the storage I/O bottleneck. Traditional approaches involve increasing the number of FC spindles (short-stroking) to ensure high-load application I/O requirements are met. But this does not guarantee improved performance, comes with increased complexity, and does not make efficient use of resources, leading to larger footprints and much more electrical power requirements than a performance optimized solution. EFDs are a simple and reliable way to increase performance by moving 5 to 10 percent of the frequently accessed data to EFD, thereby allowing costly Oracle applications and infrastructure to process many more transactions per second with the same application infrastructure investment.

EMC has done much investigation and produced guidance in the form of white papers that actually look at the applied usage of EFD from the Oracle end-user perspective, how to use Oracle tools such as Automated Workload Repository (AWR) to find the top 5 wait events, and prioritize where EFDs may be most appropriate. We also document the results of testing based on real-world simulated environments for OLTP and DSS workloads and provide specific examples of efficiency savings we can hope to provide customers. Some examples of findings include 30 to 1 improvement in transaction response time, 10x increase in transactions per second executed, and 10 to 1 consolidation of FC drives compared to EFD. Mileage will, of course, vary for each individual customer, but the numbers demonstrate our belief in the value of this technology to simply and easily improve the efficiency of customer IT infrastructure investments.

The Microsoft SQL Server database has seen tremendous growth in recent years and is considered a critical application in many IT organizations. We are seeing larger-scale implementations of SQL-based database applications as customers look to a more cost-effective deployment model for their critical applications. Being able to scale up the supporting storage infrastructure in SQL environments becomes a key requirement, as it is for traditional “enterprise” class databases such as Oracle. Many of the same considerations for Oracle apply to SQL also, with similar improvements seen in our internal testing. SQL implementation documentation is available from EMC.

**Microsoft Exchange over iSCSI use case**

Microsoft Exchange is the foremost e-mail application deployed today. In many industries, particularly financial and legal markets, e-mail has become a mission-critical application. As businesses place more emphasis on a virtual workplace model, more business is being done via e-mail than ever before as face-to-face meetings become less practical. There is also a move to a mobile personnel model, as employees productivity relies more on technologies such as smart phones (iPhone and BlackBerry primarily) than on traditional desktops and laptops, and this changes the way IT organizations deploy e-mail. Traditional e-mail implementations class users as light, medium, heavy, or very heavy, with I/O profiles of 0.1-0.5 IOPS per user. These usage models do not typically benefit from Flash as the capacity to performance requirements (based on typical mailbox sizes of around 500 GB to 1 TB) are more suited to FC implementations. With a BlackBerry or iPhone server for e-mail, I/O profiles can be as high as 2 IOPS per user. The typical use cases for which EFD should be considered for Exchange are:

- Users with very high I/O requirements and/or exceptional response time requirements
- User mailboxes that are relatively small or that can be augmented by e-mail archiving
- Environments where power, cooling, and floor space are particularly important factors

Internal EMC testing with EFD and Exchange has shown improvements of 10 times the IOPS of an equivalent number of FC drives with improved response times. For more information, please see EMC solutions documents on EMC.com.

**VMware over NFS generic use case and VMware View (VDI) use cases**

VMware virtualization is revolutionizing the way IT organizations deploy IT infrastructure. The virtualized model allows businesses to pool resources and deploy applications as portable units of work that can be
moved for purposes of recovery as well as for workload balancing. The nature of VMware virtualization ensures that hardware resources (clusters of servers) are consolidated, in that they run multiple logical servers and applications, on each cluster node. This means that the I/O loads are much more concentrated than on physical server deployments.

In the generic VMware use case, as VMware is more extensively deployed, users find many application tiers implemented across the VMware infrastructure, from Tier 1 mission-critical applications, to lower-tier, performance-insensitive business support type applications. The ability to tier both the connectivity model (NAS, iSCSI, and FC) as well as the disk types (SATA, FC, and EFD) available within a single storage platform provides a storage solution that is ideal for the varied requirements imposed by a virtualized infrastructure.

With VMware View (VDI), each virtual machine is used as a virtual desktop for a client running thin client hardware outside the data center. One of the key challenges in a virtual desktop environment is to meet desktop performance SLAs while optimizing the use of disk storage. Snap technologies such as VMware linked clones and array-based snaps can reduce the storage required for desktop boot images by up to 90 percent. But the optimization benefits of snap technologies are mitigated by the combined I/O requirements of the desktops, particularly during high activity periods such as system wide anti-virus scans and boot storms. EFDs are a simple and reliable way to meet the high I/O rates required for performance while taking advantage of the reduced storage requirements enabled by the use of snaps.

As an example, consider the case of 4,000 virtual desktops, each with a 10 GB boot image and generating 5 IOPS of storage I/O. We can reduce the required storage for all users by 90 percent to between 2 to 4 TB using linked clone technology. However, what is the impact on performance? A 15k FC drive can deliver about 180 IOPS of sustained performance meaning that 112 drives would be required to service the I/O requirements of all 4,000 users. The space optimization benefits of linked clones are mitigated by the combined I/O requirements of the desktops. We are forced to purchase hundreds of disks to service just a few TB of storage. By replacing the FC drives with EFDs (at ~2500 IOPS/drive), the number of required drives is very significantly reduced. This solution not only reduces the number of drives purchased, but also eliminates the power and cooling costs of maintaining hundreds of spinning disks.
Tiering storage on EMC unified platforms with FAST

One of the primary value propositions for customers considering EMC unified storage platforms is the ability to deliver flexible performance service levels within a single storage frame.

Celerra Fully Automated Storage Tiering (FAST) provides the ability to move data between tiers of storage to meet business, performance, or other requirements with minimal or no negative impact to application operations. With EFDs, this proposition is even more powerful when we consider the current price target of the Flash tier.

Use cases for FAST in conjunction with Flash drives include:
- Move stagnant data to lower-cost storage to reduce capital expenditures
- Recall data to higher-performing storage to meet temporary or permanent application requirements
- Shorten backup windows through data reduction on higher tiers
- Reduce redundant data to minimize storage requirements

Celerra FAST leverages the functionality of the Rainfinity® File Management Appliance. FMA integrates with the Celerra FileMover API to move inactive data from production file systems to lower-tier storage (archive and inactive archive). As the data ages to a point of very low access, it can be moved again to low-performing, more cost-effective disk such as SATA, where deduplication can be enabled for even greater savings in operational costs. Should the data access patterns increase over time, the data can be promoted back to the higher storage tier.

FAST technology will become a fundamental storage requirement when considering the storage platform of the future. Due to the huge performance advantage of EFD over standard HDD technology, it is likely that storage systems will ship with a mix of Flash and SATA drives and FAST technology. The FAST component allows dynamic and automated movement of data between the Flash and SATA disk types.

Will EFD add value to my environment?

Understanding the value of EFD in any environment is a three-step process. Typically, if IT is currently battling with known performance problems on specific applications, or there is a desire to shorten the cycle times for business processes, then this should be the first place to look for EFD opportunities. Second, if high-performance applications are leveraging short-stroked storage configurations, there is an opportunity to provide a “right-sized” solution with improved TCO with Flash drives. The three-step process includes these steps:

**Step 1 – Understand your environment**
For applications demanding the highest possible IOPS, EFDs may be an ideal fit, particularly if the application is deployed today across a large number of smaller high-speed FC drives.
- For your highest-performing application(s), how many IOPS do you require?
- What capacity is required?
- Is the I/O access pattern of the application(s) typically random or sequential?
- What is the read/write mix for the application(s)?
- What are your response time goals?
- What are the predominant I/O sizes required?

**Step 2 – Calculate the impact**
Use EMC-provided tools and product monitoring features (for example, the Celerra server_stats command) to help with this step.
• Work with an EMC Sales Representative who can provide details of the TCO for Enterprise Flash Drives to see if the use of EFDs makes financial sense with current pricing levels
  ▪ To be a viable solution from a cost perspective, EFDs require a much higher ratio of I/Os per GB than a traditional drive due to the cost of the EFDs.

• Validate the I/O pattern
  ▪ EFDs offer a high degree of performance acceleration when applied to random I/O. Sequential I/O is not an ideal fit for EFD (alternative, less expensive solutions can use larger, slower rotating disks that will still provide similar performance).
  ▪ EFDs are going to deliver their best performance with small I/O – 4 KB or 8 KB.

• Validate the read/write mix
  ▪ EFDs have the most positive effect when applied to applications with at least an 80 percent read ratio.
  ▪ At ratios under 80 percent reads some applications may not perform well enough with EFD to provide the expected “performance” TCO level. These ratios will require more analysis up-front.

Step 3 – Size the solution
• Ensure the storage platform can meet the aggregate I/O performance requirements
  ▪ This is important. With FC drives, systems scale to near maximum drives, but EFDs will hit array limits with a much smaller number of drives
  ▪ If the capacity requirement is over the stated number of drives, then the solution can be RPQ’d. All that needs to be acknowledged is that performance of the solution will not exceed the maximum of the array, regardless of the number of EFDs employed.
Conclusion

Enterprise Flash Drives promise to change the storage landscape. Storage performance with EFD takes a revolutionary step forward and allows this traditionally lagging technology to catch up with the exponential performance improvements seen in the server industry over prior decades. Whether your application environment is a database, e-mail, CAD/CAM, or any other that is key to your business success and that might be experiencing a constraint due to storage bottlenecks, there is a good chance that the solution to the problem is EFDs. Even if the performance is addressed in another way today, such as short-stroking, there is a solution with EFDs that could improve the TCO of the overall solution. Since EFDs are made available on a unified platform, the benefits of EFD can be implemented regardless of connectivity model, whether the application server uses FC, iSCSI, or NAS (NFS/CIFS).

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URL : Available on Powerlink®
Audience : Customer, Employees, Partners
Technical Depth : High

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Type : Technical/White Paper
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Audience : Customer, Employees, Partners
Technical Depth : High

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