

Lab Validation Report

EMC Unified Storage

Simplicity & Efficiency, Looking Beyond the 20% Guarantee

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ESG Lab Reports

The goal of ESG Lab reports is to educate IT professionals about emerging technologies and products in the storage, data management and information security industries. ESG Lab reports are not meant to replace the evaluation process that should be conducted before making purchasing decisions, but rather to provide insight into these emerging technologies. Our objective is to go over some of the more valuable feature/functions of products, show how they can be used to solve real customer problems and identify any areas needing improvement. ESG Lab's expert third-party perspective is based on our own hands-on testing as well as on interviews with customers who use these products in production environments. This ESG Lab report was sponsored by EMC.

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Introduction

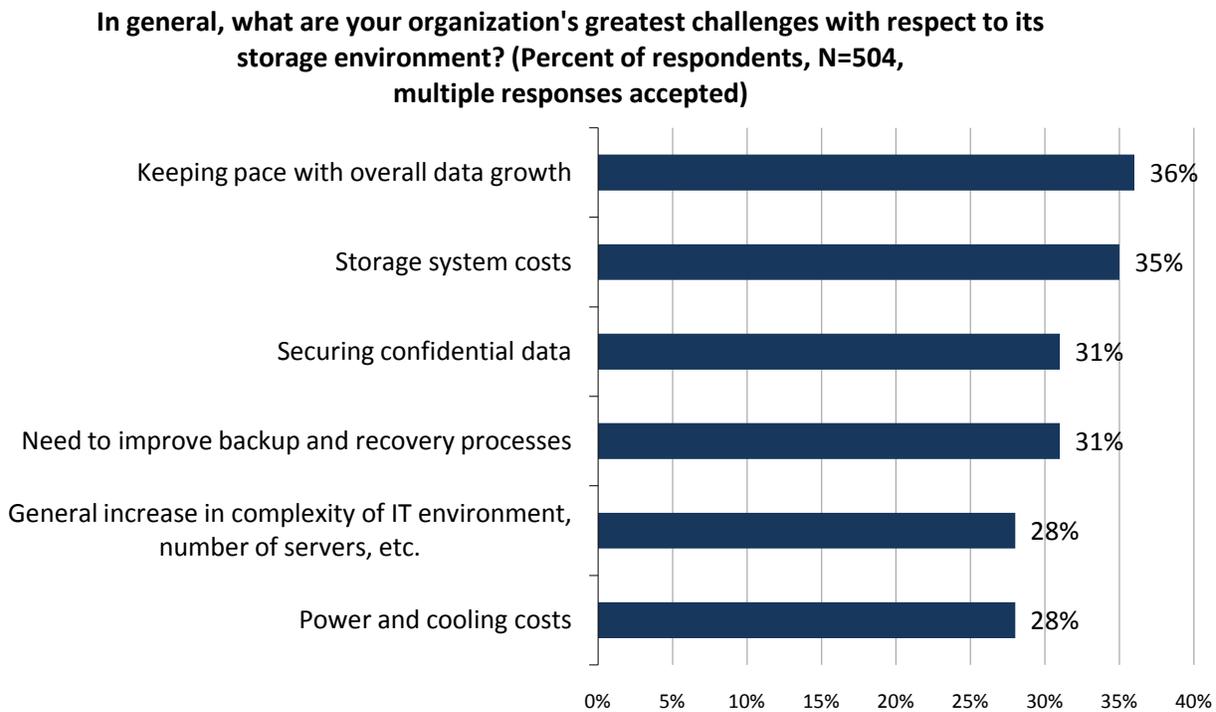
This ESG Lab report documents hands-on testing of [EMC Unified Storage](#) with a focus on major usability and efficiency upgrades, Unisphere integrated management, Enhanced [VMware](#) integration, FAST Cache, FAST Automated Storage Tiering, and Primary Data Compression.

Background

For many years, the total amount of storage users needed to support application and file environments just wasn't a prime IT concern. The amount of *raw* storage needed to generate a given amount of *usable* storage was just arithmetic; utilization was known, but it didn't really drive buying behavior. IT managers just bought more capacity when it was needed because getting the job done was all that mattered. Explosive data growth, the rapid adoption of server virtualization technology, and economic concerns have combined to change that; while getting the job done—effectiveness—is still crucial, doing it as *efficiently* as possible is now equally critical in most IT organizations. IT managers are looking for ways to be more productive and get more out of key applications with the same—or more likely less—budget.

ESG research indicates that a number of factors are driving IT decision makers towards more efficient storage solutions. As shown in Figure 1, accelerating data growth, storage system costs, and increasing complexity are cited as significant challenges by IT managers.¹

Figure 1. Top Storage Challenges



Source: Enterprise Strategy Group, 2009.

In addition to the storage challenges listed in Figure 1, ESG research indicates that reduced operational costs, business process improvement, and reductions in capital expenditures are also top priorities when making purchasing decisions.² As a matter of fact, compared to three years ago, 68% of respondents are significantly more aware of energy consumption and cooling requirements than in the past. Put it all together and it's clear that IT managers are looking for modular, cost effective storage solutions that are energy efficient and scalable.

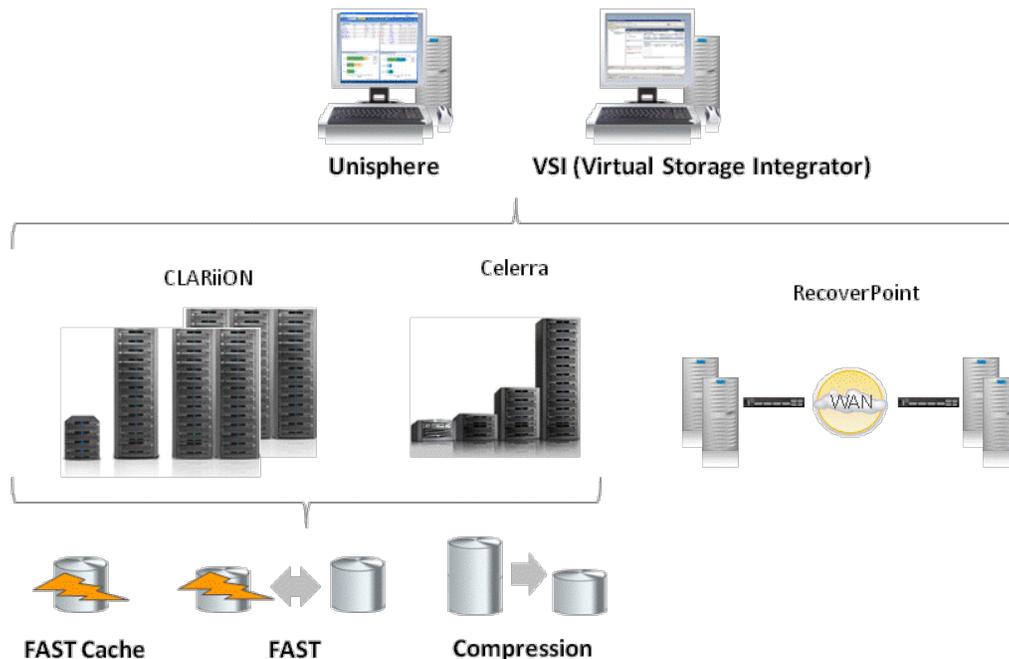
¹ Source: ESG Research Brief, [Enterprise Storage Priorities Emphasize Information and Infrastructure Efficiency](#), January 2009.

² Source: ESG Research Report, [2010 IT Spending Intentions Survey](#), January 2010.

EMC Unified Storage

EMC Unified Storage is built upon EMC's CLARiiON and Celerra storage platforms, designed to address the most crucial cost and management challenges faced by storage and IT managers. Both the Celerra and the CX4 offer storage efficiency technologies and comprehensive VMware integration. All of these platforms and technologies are managed from the EMC Unisphere management interface.

Figure 2. EMC Unified Storage Solution Set



EMC has recently announced a program guaranteeing that customers will require 20% less raw unified storage capacity (NAS and/or SAN) with EMC compared to other storage vendors.³ This is based on “out of the box” best practices for configuration provided by the vendors. This promise of savings does not take into account the compounded effect of the additional EMC storage efficiency technologies covered in this report.

EMC Unified Storage is designed to drive down consolidation costs and increase efficiency using features and attributes including:

- Fully Automated Storage Tiering (FAST), which enables sub-LUN/sub-volume automated, real-time data migration and placement on the appropriate tier with no intervention by administrators and no interruption to applications.
- FAST Cache technology, which utilizes EFD (enterprise flash drives) capacity as an extended cache pool to provide a performance boost across an entire storage system.
- Block data compression, which allows customers to compress inactive data and reclaim valuable storage capacity. Celerra has offered file level compression for some time with Celerra Data Deduplication.
- Virtual provisioning, which uses just in time capacity allocation and simplified volume management capabilities to reduce the total cost of ownership.
- High-speed, energy-efficient enterprise flash drive technology for applications with demanding performance requirements.
- Low power SATA drive technology, drive spin-down capability, and adaptive cooling to dynamically reduce energy use and improve efficiency.

³ See EMC 20% guarantee and efficiency calculator, http://www.emc.com/products/unified-storage-guarantee/index.htm?Pid=prod_tech_unified-unifiedguarantee-070610.

- For file systems, Celerra also has the ability to tier to secondary archive devices such as Centera, Atmos and Data Domain
- Integration with VMware vCenter for high availability, data protection, and ease of use, including VM-aware storage management, vCenter plugins, Site Recovery manager (SRM) failover and failback, and VAAI (vStorage API for Array Integration). Many of these capabilities are being consolidated into a single universal vCenter plug-in known as EMC VSI (Virtual Storage Integrator).

This report documents ESG Lab hands-on testing of the EMC Unified Storage product portfolio with a focus on its ability to increase performance, availability, and investment protection as it reduces cost, complexity, and management requirements.

ESG Lab Validation

ESG Lab performed hands-on evaluation and testing of EMC’s Unified Storage solution at multiple EMC facilities. Testing was designed to demonstrate the simplicity and efficiency of managing and maintaining a mid-tier storage environment.

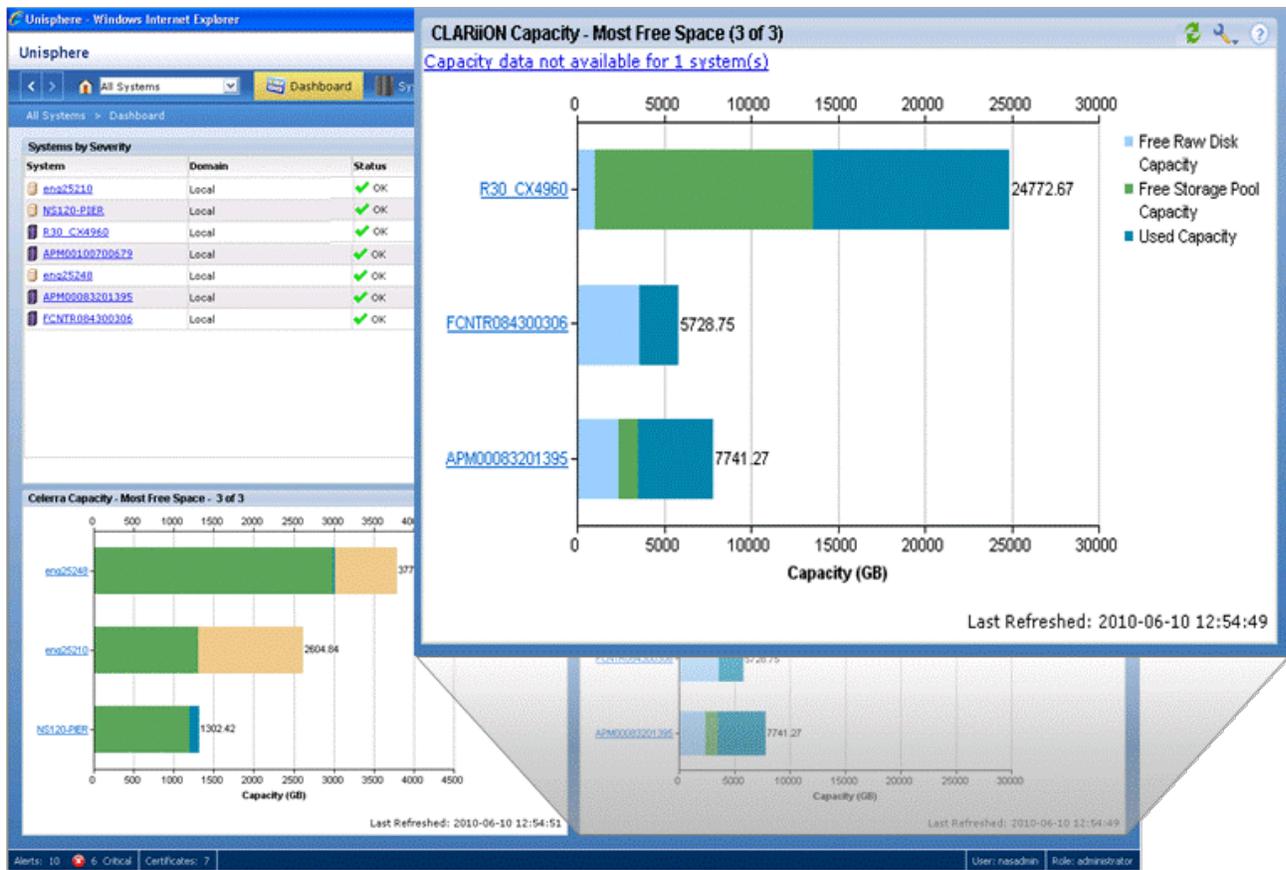
Simply Unified Storage Management

EMC Unisphere gives storage administrators the ability to manage the complete storage ecosystem with one simple web-based management tool. Unisphere is a unified management interface for three EMC products: CLARiiON, Celerra and RecoverPoint. It has evolved from the CLARiiON Navisphere administrative interface and is compatible with previous releases of CLARiiON FLARE and with the current release of Celerra DART. It also still supports existing customers’ CLI scripts. EMC’s stated direction with Unisphere is to continue to integrate more device and information management capability into the product. Over time, Unisphere will also provide a common communication point for broader IT infrastructure management tools like VMware vCenter.

ESG Lab Testing

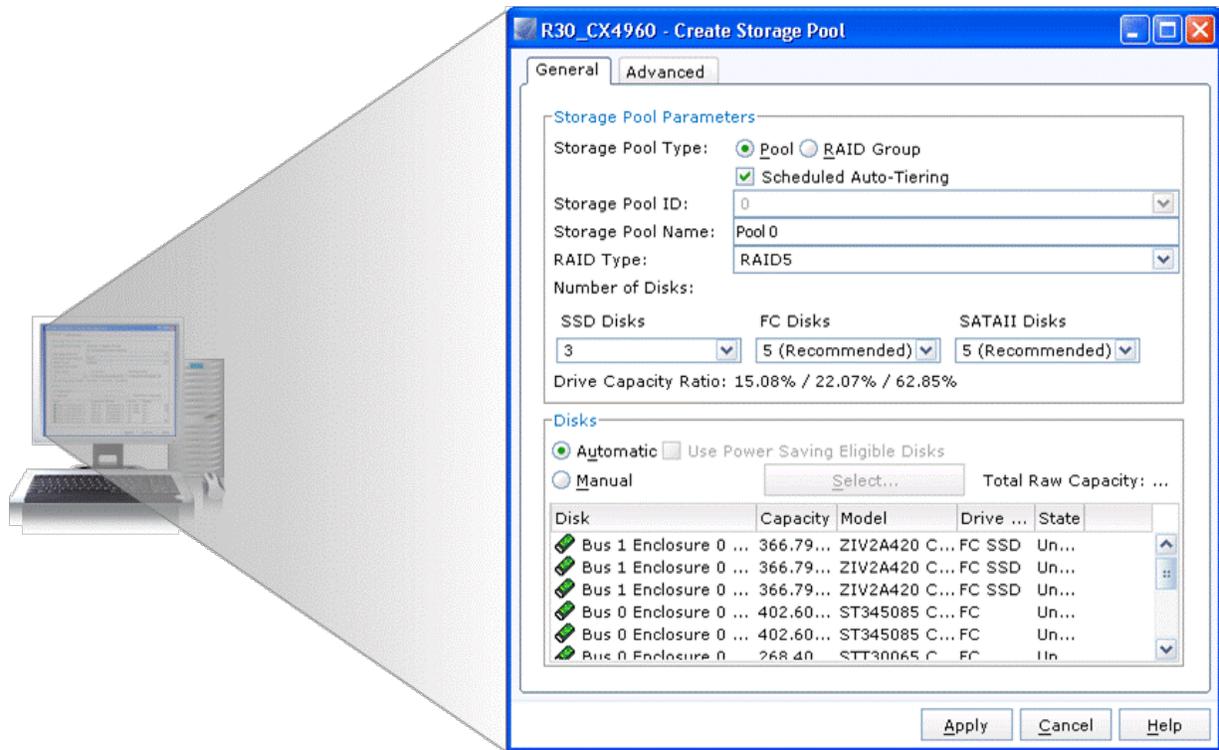
ESG Lab tested Unisphere by examining the components contained in the management tool. Unisphere can be accessed locally or through an array controller. By setting up a domain containing Celerra and CLARiiON environments, ESG Lab was able to log in with one account and aggregate those multiple environments into a customizable dashboard. From the dashboard view, ESG lab was able to drill down to any function using the tabs located at the top of the screen or by clicking directly on one of the links presented in the summary views. An intuitive “Most Free Space” view is highlighted in Figure 3.

Figure 3. Unisphere Customizable Home Page



ESG Lab examined the storage pool feature that has been updated in the latest release of Unisphere. In earlier releases, pools were used for thin provisioning of LUNs. Release 30 introduces Thick LUNs to the pool, which can be contained in the same pool as thin LUNs. ESG Lab observed that many of the new data services, such as FAST tiering (shown in Figure 4), are available only in pool LUNs. ESG Lab was able to configure a pool that contained a combination of different disks including flash, Fibre Channel, and SATA, since pools contain no restrictions in terms of the types or location of drives.

Figure 4. Create Storage Pool



Why This Matters

Managing a modular storage environment can be a costly and time consuming endeavor at a time when most IT departments are asked to do more with less. EMC has worked to deliver a next generation management tool that consolidates multiple environments into a single management interface. Similar functions are shared across those environments and the interface is simple and intuitive to use. Building simplicity into managing these complex environments helps to significantly reduce time to deployment and decrease management costs.

ESG Lab was able to create a multi-tiered storage pool containing Flash, Fibre Channel, and SATA drives and provision LUNs to servers in just a few clicks. The intuitive design and improved ease of use of the newest release of Unisphere made storage tasks easy to find and quick to complete.

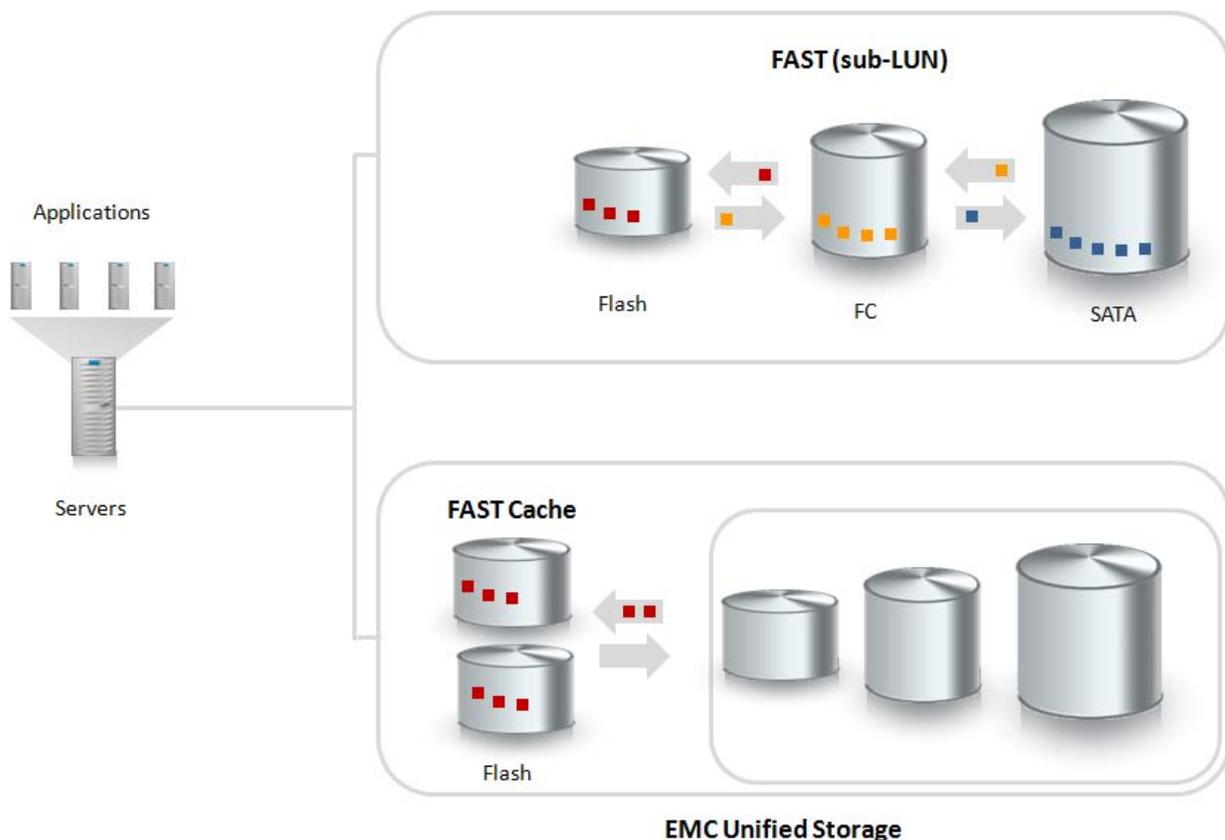
Fully Automated Storage Tiering

As information continues to grow exponentially, storage systems need to be intelligent enough to automatically optimize for both performance and cost savings. EMC FAST (Fully Automated Storage Tiering) and FAST Cache capabilities were designed with these goals in mind. As shown in Figure 5, applications can have access to a mix of FAST and FAST Cache storage configurations in a networked environment. FAST operates within a pool LUN, moving sub-LUN slices of data between storage drives according to activity level. FAST Cache utilizes standard Enterprise Flash Drives (EFD) that can be dynamically added to the storage hardware, and there are no requirements for pool based LUNs. Applications can automatically take advantage of the performance improvements as data is moved to the cache as needed.

EMC's approach, using standard Enterprise Flash Drives (EFD), provides a flexible and scalable solution for cache. Adding EFD's to an array requires no scheduled outage and can scale to 2 TB mirrored R/W dynamically in a FAST Cache configuration. Both FAST and FAST Cache utilize the same flash drive technology allowing EFD's to be easily reconfigured for use with either solution.

Both solutions provide highly complementary performance improvements and are optimized to work together. FAST Sub-LUN tiering optimizes capacity and lowers costs as colder data can be moved to slower and less expensive drives. FAST Cache accelerates performance to address unexpected spikes in workloads. FAST Cache provides greater performance returns since it examines data at a higher granularity (64k chunks) than FAST (1 GB chunks). Since both FAST and FAST Cache utilize the same flash drive technology, EFD's can be easily reconfigured for use as either cache, or as Tier 0 storage. EMC's unified storage systems can support up to 64TB of FLASH drive technology.

Figure 5. FAST and FAST Cache

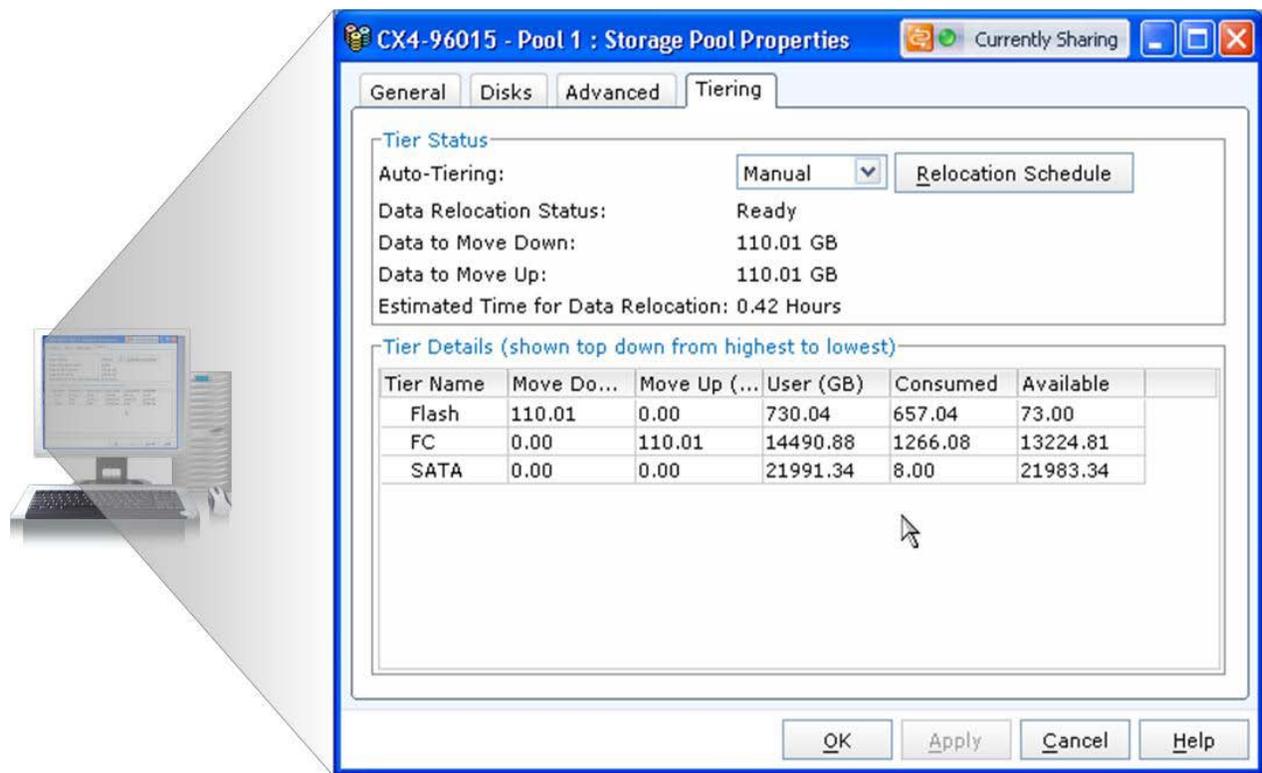


ESG Lab Testing

ESG Lab performed several performance tests for both FAST and FAST Cache. The test bed for FAST contained a CLARiiON CX4-960 with a mix of EFD, Fibre Channel and SATA II drives.⁴ Testing began on an Oracle test bed with a multi-user online transaction processing (OLTP) system that emulates a warehouse order entry application. The capacity consumed by the Oracle database was 1.2 TB.

ESG Lab examined the configuration of FAST in a CLARiiON storage pool. The properties of the tier were easy to configure and allowed ESG Lab to tier manually or according to a schedule. Data was moved automatically between tiers based on activity level. FAST moved in sub-LUN portions as a background process running within the CLARiiON. As shown in Figure 6, ESG Lab created a policy to move data within a 110 GB LUN between three tiers of storage (Flash, FC and SATA). Tiering was set to manual to allow ESG Lab to run a baseline performance test first before moving the data.

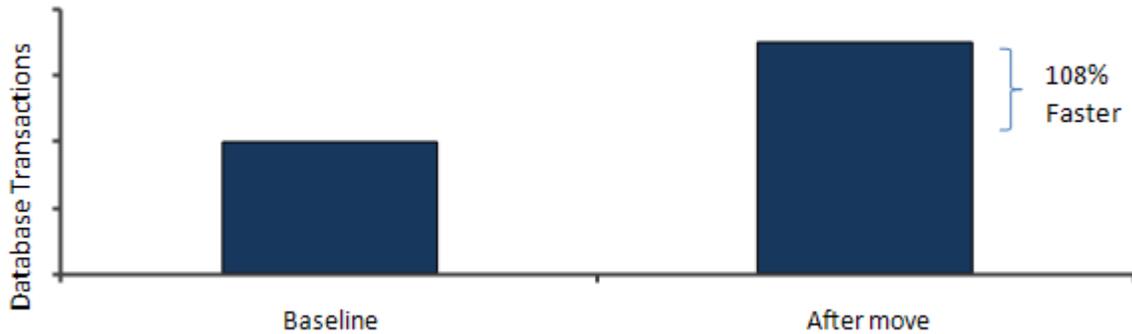
Figure 6. FAST Configuration



ESG Lab ran a baseline performance test with only the 45 Fibre Channel disks. The test was repeated after a FAST pool was created, adding the five flash drives and 15 SATA drives. Performance in the form of relative transactions per minute improved significantly after data was moved to different drives in the tier, optimizing the faster flash drives for hot data and moving less frequently accessed data to the Fibre Channel and SATA drives. Figure 7 shows transactions per minute were 108% faster after data was moved using FAST.

⁴ Configuration details can be found in the Appendix.

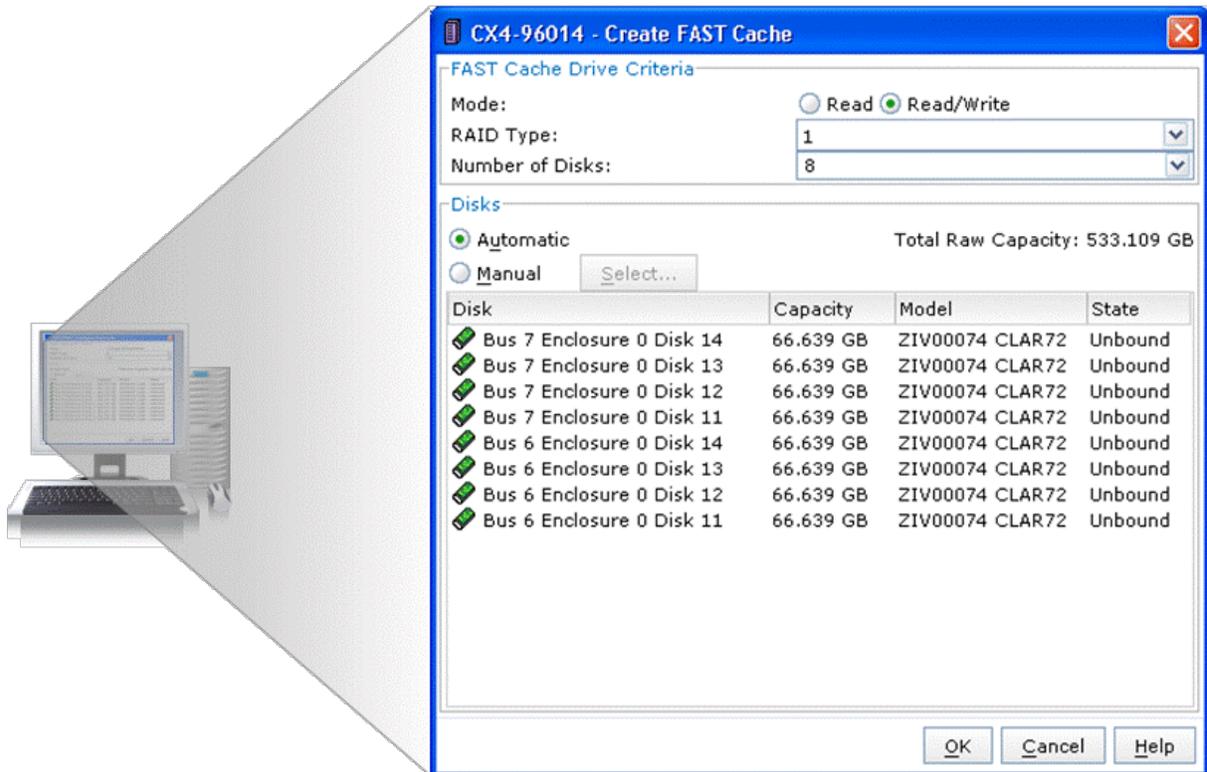
Figure 7. Oracle Performance Improvement with FAST



ESG Lab performed testing to examine the configuration and performance improvements of FAST Cache when added to Fibre Channel disk drives. The test bed for FAST cache contained a CLARiiON CX4-960 with 45 15k RPM 600 GB Fibre Channel Drives and just eight 73 GB Flash drives. The Fibre Channel drives were presented to a test server running Oracle on Windows 2003 SP2. The database and server configuration were the same as the FAST test.

ESG Lab used Unisphere to configure FAST Cache, as seen in Figure 8. In this example, eight 73 GB flash drives were configured for read/write caching. Once enabled on the drives, FAST Cache operation was completely automatic. There was no need to adjust settings or tie FAST Cache to any LUNs.

Figure 8. FAST Cache Configuration



ESG Lab ran a baseline performance test with 45 Fibre Channel disks and repeated the test after enabling FAST Cache. Performance in the form of relative transactions per minute improved significantly, 143% faster, with FAST Cache enabled, as shown in Figure 9.

Figure 9. Oracle Performance Improvement with FAST Cache

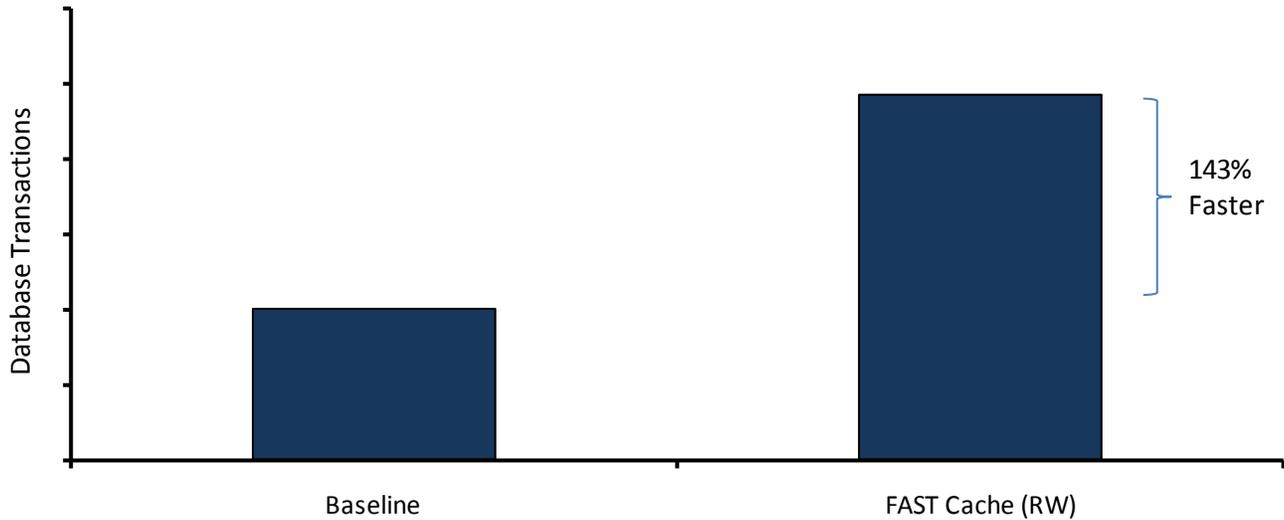


Table 1 represents the drive configurations and performance results of both FAST and FAST Cache testing performed by ESG Lab.

Table 1: Performance Advantage of FAST Automated Tiering and FAST Cache

	Capacity	EFD(Flash)	600 GB 15K FC	2 TB SATA II	Database Transactions	Latency
Baseline (FC Only)	27 TB	0	45	0	-	-
FAST	58 TB	5 (200 GB)	45	15	+108%	-65%
FAST Cache	27.584 TB	8 (73 GB)	45	-	+143%	-65%

What the Numbers Mean

- The capacity of an all-Fibre-Channel database environment was doubled using five 200 GB EFD drives and 15 2 TB SATA drives as OLTP performance was increased by 108%.
- An Oracle OLTP environment saw performance increase more than 143% using FAST Cache without adding any additional drives.
- Latency, which translates directly into delays experienced by users, reduced by 65% with flash drives using both FAST and FAST Cache.

In addition, ESG Lab audited results from a test performed with SATA drives used in place of Fibre Channel. The results showed the same performance gains as the Fibre Channel tests. Since FAST Cache offloads most of the IO to flash drives, it minimizes the reads/writes performed against the physical disks behind cache. This enables SATA drives to deliver performance numbers comparable to Fibre Channel configurations.

Overall, ESG Lab recorded improvements in both database transactions and response time with FAST and FAST Cache. Specifically, database transactions increased 108% with FAST and 143% with FAST Cache. Response times for both FAST and FAST Cache improved by 65%.

As seen in Table 2, an ESG Lab audit of cost of CX4 infrastructure indicates that a 54 TB configuration using EFD, FC, and SATA drives with FAST costs less to acquire than a 54 TB FC only configuration, provides better performance and consumes less power.

Table 2: Price Performance Advantage of FAST Automated Tiering⁵

	Capacity	200 GB EFD(Flash)	600 GB 15K FC	2 TB SATA	CAPEX Savings	Performance Advantage
Monolithic (FC Only)	54 TB	0	90	0	-	-
FAST	54 TB	5	30	17	-15.4%	+5%

Why This Matters

Companies continuously face challenges in cost effectively meeting the capacity and performance requirements of applications —especially applications with strict performance requirements. Failure to meet these requirements can result in downtime leading to lost productivity and costly loss of services.

ESG Lab has confirmed that FAST and FAST Cache provide significant levels of storage efficiency, enabling broader use of enterprise flash drives for critical application data sets as well as automatic application of EFD, FC, and SATA drives to appropriate workloads with no user intervention. FAST can not only be used to dramatically increase performance, it can also be used to dramatically reduce total cost of ownership for a broad range of application environments.

⁵ Published list pricing data used to calculate savings can be found in the Appendix

Optimizing Virtual Server Environments

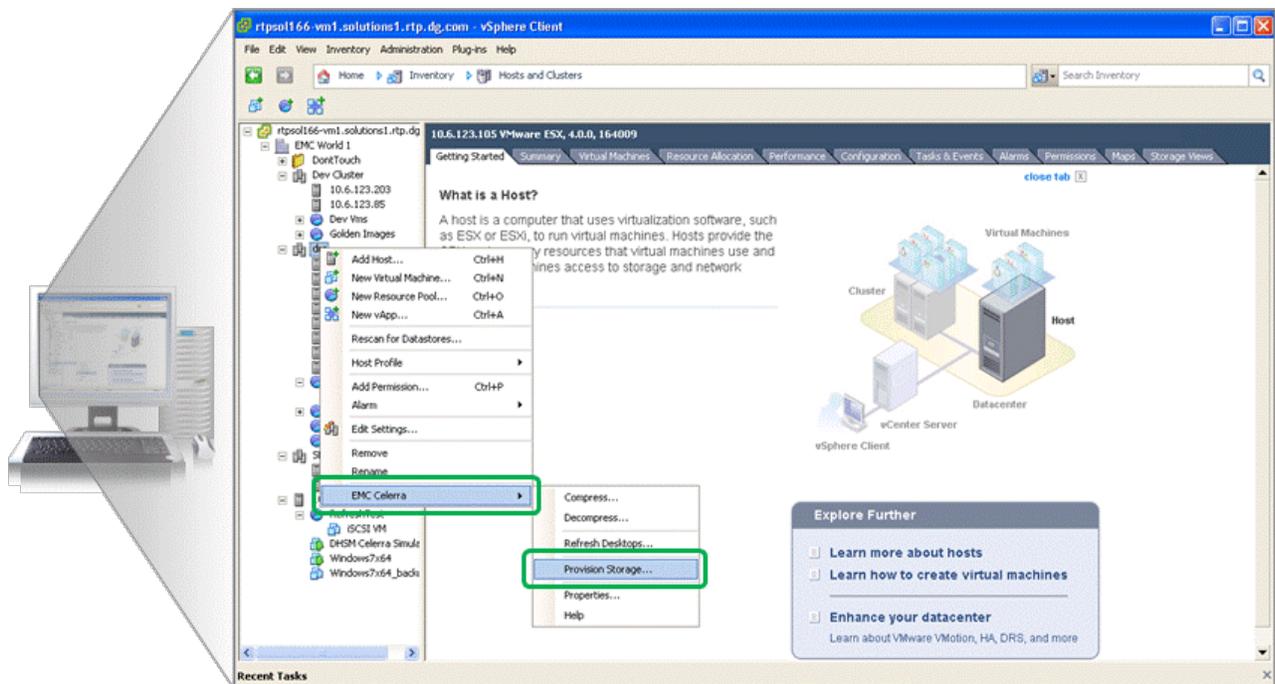
CLARiiON and Celerra storage systems support VMware's vStorage API for Array Integration (VAAI) for vCenter integration. This enables VMware administrators to easily provision and manage virtual machine storage. Improved integration hides the complexity of the underlying storage systems, but gives VMware administrators the ability to perform advanced administrative tasks including cloning volumes, creating pools and compression.

ESG Lab Testing

ESG Lab tested the integration of CLARiiON and Celerra in a vCenter environment by examining the functionality of the plugins for CLARiiON and Celerra in vSphere. Using the navigation pane in vSphere, ESG Lab was able to right click on a VMware cluster and select EMC Celerra as one of the configuration options. From that selection, ESG Lab could quickly and easily provision storage from an available storage pool for a VMware cluster node as shown in Figure 10.

ESG Lab was also able to navigate to a VMware image and select an option under the EMC Celerra plugin to create a full or fast clone of the image. During the cloning process, ESG Lab was able to create a storage host pool to use for the new image.

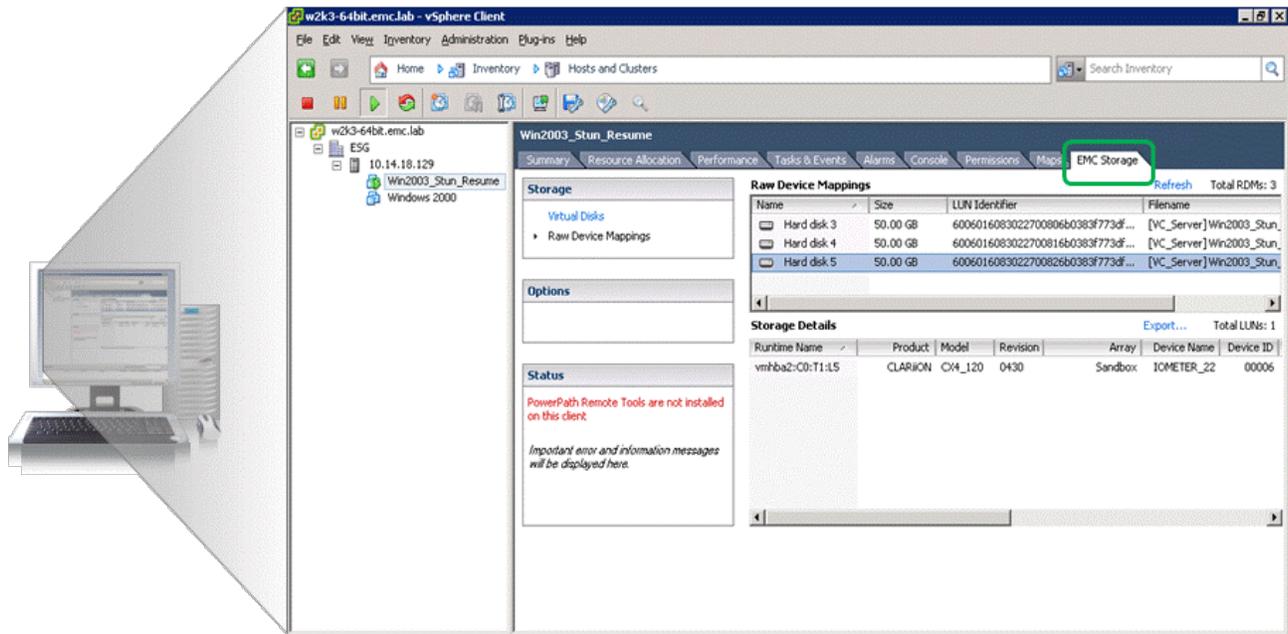
Figure 10. Provisioning Data Stores



ESG Lab also examined the plugin for CLARiiON with vSphere. The CLARiiON plugin presents a tab available directly from the vSphere home page. ESG Lab was able to log in to a vSphere environment and, from the CLARiiON page, provision new datastores and delete existing datastores.

In addition, ESG Lab looked at EMC's new unified vCenter plugin which is planned for general availability when the next version of VMware vSphere is released. Managing a storage environment was more intuitive as all the tasks are included as a tabbed page, much like the Unisphere interface. ESG Lab was able to navigate to a virtual machine and see the storage configuration for that image. Figure 11 shows the EMC Storage tab available from the VMware image configuration page.

Figure 11. New vSphere Integration



ESG Lab also examined VMware-aware Unisphere, which allows a storage administrator to look into a virtual infrastructure. Unisphere talks directly to ESX APIs and provides end to end mapping from ESX, to LUN, to virtual machine mappings. ESG Lab was able to monitor the state of storage requirements, including alert messages from ESX when storage is full.

Why This Matters

As virtual infrastructures grow, the requirement for storage space grows exponentially. According to ESG research over half (54%) of current server virtualization users estimate their organization has experienced a net increase in total storage volume since their organization implemented a server virtualization solution⁶. Bringing these two worlds together in a familiar interface for both virtual infrastructure and storage administrators allows common storage functions to be offloaded, reducing wait times for storage needs. It also allows storage administrators to be more proactive in identifying requirements in a rapidly growing virtual infrastructure.

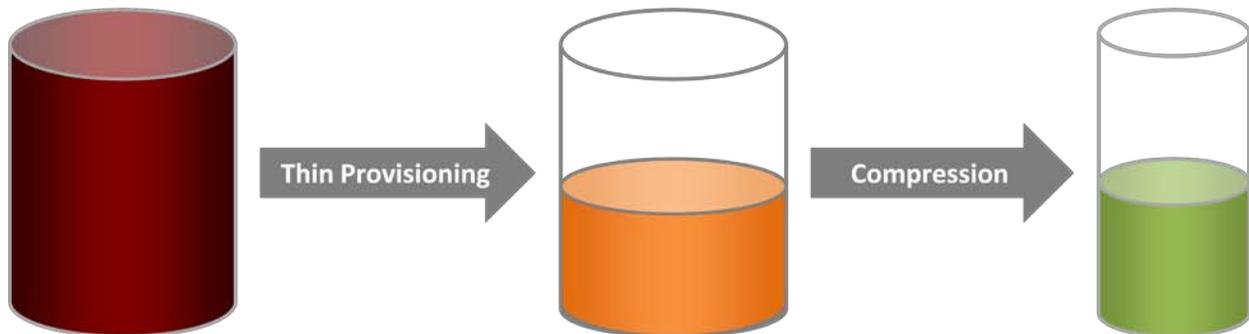
From the vSphere client, ESG Lab was able to create a virtual image and provision storage for the image without the need for a storage administrator to complete the task. Likewise, the entire virtual storage infrastructure and the mappings to CLARiiON and Celerra storage were visible through the vSphere client.

⁶ Source: ESG Research report, [The Impact of Server Virtualization on Storage](#), December 2007.

Storage Efficient Compression

EMC's block data compression feature allows administrators to compress inactive data in live volumes and reclaim storage capacity. This builds on the capacity reduction provided by Virtual Provisioning (a.k.a., thin provisioning). Virtual Provisioning frees up allocated but unused LUN capacity that can be returned to the common storage pool. Compression provides additional benefits as it recognizes repeating patterns in allocated and used application data. Compression is supported on both full and thin provisioned LUNs. If the LUN is fully provisioned and part of a RAID group, the LUN is migrated to a storage pool at the same time it is compressed and the free space is returned to the RAID group. Fully provisioned LUNs that are compressed are automatically converted to thin provisioned LUNs.

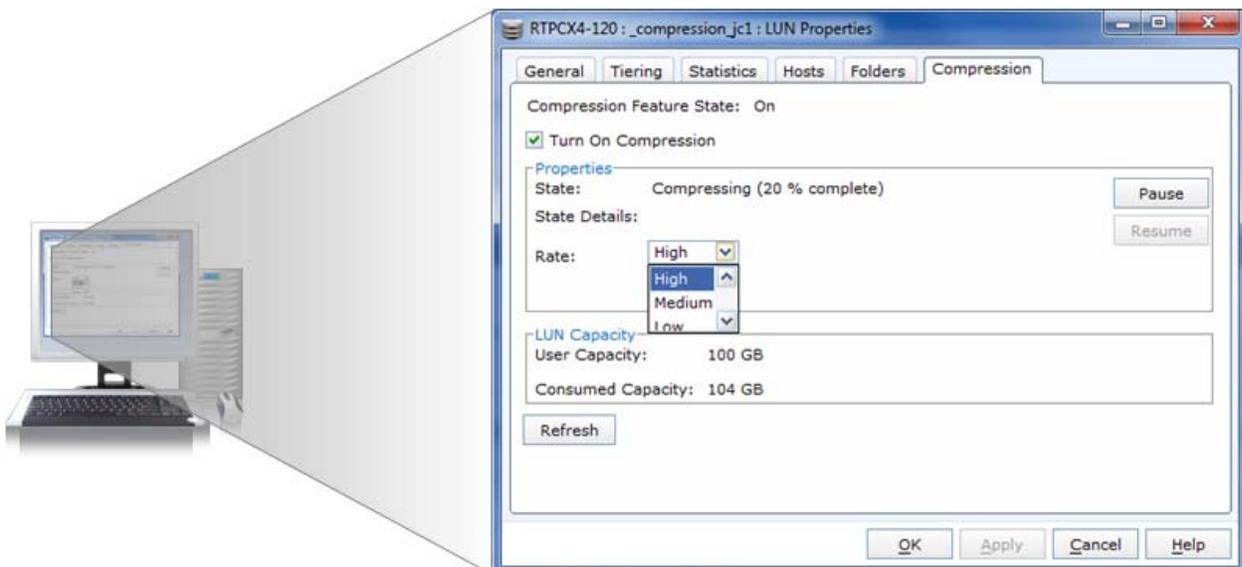
Figure 12. Storage Efficient Compression



ESG Lab Testing

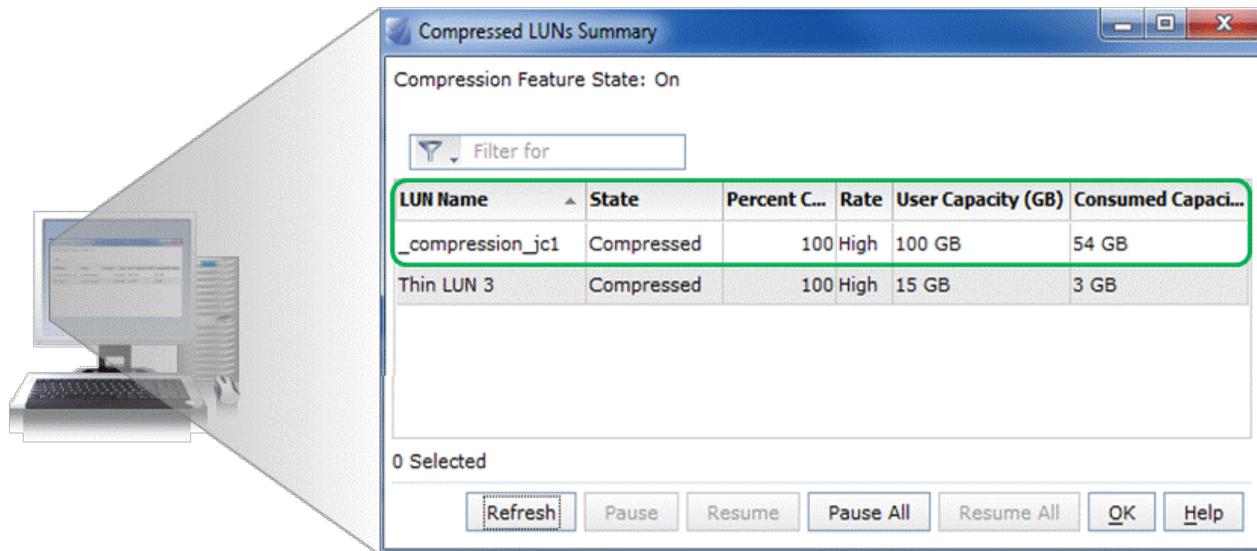
ESG Lab tested the results of compression on a CLARiiON by selecting a 100 GB LUN with 75 GB of mixed data types in an NTFS file system. The data set was derived from production EMC IT department's data and included a mix of media, Office, binary, and text files. ESG Lab configured compression by navigating to the compression tab under the LUN properties page. The compression properties were simple to configure and included the option to specify the rate of compression depending on the requirements for availability during the compression process. ESG Lab chose to use high compression for this test.

Figure 13. Compression Configuration



Compression of a 100 GB LUN completed in 1 hour and 40 minutes. Examining the results of the compression, as shown in Figure 14, ESG Lab observed that the LUN capacity was reduced from 100 GB to 54 GB, a savings in space of almost 50%. As expected, after compression, the LUN had been converted from a thick to a thin LUN.

Figure 14. Compression Complete



Compressed LUNs Summary

Compression Feature State: On

Filter for

LUN Name	State	Percent C...	Rate	User Capacity (GB)	Consumed Capaci...
_compression_jc1	Compressed	100	High	100 GB	54 GB
Thin LUN 3	Compressed	100	High	15 GB	3 GB

0 Selected

Refresh Pause Resume Pause All Resume All OK Help

Why This Matters

As storage needs grow, managing requirements efficiently becomes a necessity. The costs of adding more storage to meet those needs can be excessive. Adding compression capabilities to the already efficient thin LUN technology reduces the requirements for more storage as unused storage can be returned to the pool to be used by other applications, keeping costs down as storage needs grow.

The “set it and forget it” feature of compression reduces the administrative costs of maintaining an efficient storage environment.

ESG Lab successfully compressed a 100 GB LUN by 46%, returning 46 GB of storage to the free storage pool.

ESG Lab Validation Highlights

- ☑ ESG Lab confirmed that Unisphere provides a simple and intuitive management interface for multiple EMC storage systems.
- ☑ vCenter plugins for CLARiiON, Celerra and RecoverPoint were used to perform routine storage management tasks from a VMware management console. A unified plug-in, with planned availability in the next version of VMware vSphere, provided an intuitive interface for centralized storage management.
- ☑ With simple “set it and forget it” compression capability, ESG Lab observed a 46% reduction in CLARiiON disk capacity for common office files collected from EMC’s production IT environment.
- ☑ A 108% performance increase was recorded using FAST Sub-LUN tiering. These results were consistent with both Fibre Channel and SATA drives.
- ☑ A 143% performance improvement was recorded with FAST Cache as compared to traditional Fibre Channel storage.

Issues to Consider

- ☑ The current VMware vCenter plugins for Celerra, CLARiiON and RecoverPoint have difference in capabilities and a different look and feel. The unified plugin that ESG Lab tested (planned for general availability when the next version of VMware vSphere is released) has an intuitive and consistent look and feel.
- ☑ While the energy efficiency of the CLARiiON product line has been dramatically improved, full policy-based drive spin-down could be used to magnify the savings (currently, drives spin down after 30 minutes of disk inactivity)—particularly for large near-line archives that are infrequently accessed. While this technology is currently available in the CLARiiON CX4 and EMC Disk Library product, it is not yet supported within the Celerra line. EMC has advised ESG Lab that policy-based drive spin-down is planned for a future code release.
- ☑ While the management of EMC’s block and file storage tested by ESG Lab for this report is unified, the underlying hardware and software architectures are still separate and distinct. To be fair, EMC has made tremendous strides toward truly unified storage architecture, based on discussion with EMC, ESG Labs believes unification of midrange storage is on the roadmap.

The Bigger Truth

IT professionals are being tasked with justifying storage strategy even as senior managers struggle with budgets hamstrung by financial crisis. How can organizations keep pace with capacity growth of 50% or more annually while staying within budget? How will storage investments be protected—now and in the future? How can more capacity be managed with better performance and service levels with existing staff? Will storage investments complement—or complicate—virtual server consolidation initiatives? How will IT create a winning strategy that works for both the team *and* the organization?

ESG is not only impressed with EMC's ability to continually increase the capacity, performance, and capabilities of its full product line, but also by its focus on continuously improving manageability. In 2008, ESG Lab examined the fourth generation CLARiiON CX4 and confirmed that EMC stuck with its game plan of continuously simplifying routine management tasks, even as a number of innovative technologies were introduced into the CX4 product line which lowered the cost of ownership for CLARiiON customers.

EMC Unified Storage builds on EMC's heritage of providing a rich set of comprehensive availability and protection options, adding advanced storage efficiency and integrated, consistent management for both SAN and NAS storage.

ESG Lab was able to manage storage area network (SAN), network-attached storage (NAS), and storage efficiency technologies simply and intuitively using the EMC Unisphere storage management interface. VM-aware storage management, vCenter plugins, and VAAI provided comprehensive storage management from within the vSphere management environment.

While ESG lab confirmed that EMC has made significant advances with the unified management of CLARiiON, Celerra and RecoverPoint EMC still offers multiple separate architectures for block, NAS, and object storage. EMC has been listening to their customers and has been making significant progress toward a comprehensive, unified architecture starting at the component level, using the same disks, shelves, and controllers in the CLARiiON, Celerra, VMAX and VPLEX product lines. While there is still work to be done to get the rest of the way there, EMC has taken great steps in the right direction.

EMC Unified Storage includes a number of innovative technologies which lower the cost of ownership for EMC customers. ESG Lab used block data compression to compress inactive data and reclaim valuable storage capacity. FAST Cache leverages enterprise flash drives to avoid the wasted cost of over-provisioned disk capacity for applications with extreme performance requirements. ESG Lab hands-on testing has confirmed that FAST sub-LUN automated tiering can use a combination of EFD, FC, and SATA drives to provide exactly the same capacity as a large pool of Fibre Channel drives at a lower cost of acquisition and with better performance.

With EMC Unified Storage, EMC has dramatically enhanced simplicity, performance, and storage efficiency for consolidated, virtualized environments. While the speeds and feeds are impressive, ESG Lab is most impressed by the continuous improvements in manageability and the long list of valuable new capabilities that have been built into the offering. From the speed and automated operation of FAST to the dramatic manageability improvements of Unisphere and VM-aware technology, the breadth and depth of the features built into EMC Unified Storage can be used to meet the precise needs of any organization. If your organization is struggling to keep up with data growth while providing ever higher levels of performance and availability with stagnant or shrinking budgets, ESG Lab recommends that you consider EMC Unified Storage as the foundation for your own winning storage strategy.

Appendix

Table 3. ESG Lab Test Bed

Primary Test Bed	
EMC CLARiiON Arrays	
CX4-960 Rev. FLARE 30 (Beta) 4 x 4 Gbps FC HBAs	45 x 600 GB 15K Fibre Channel drives
CX4-480 Rev. FLARE 30 (Beta) 2 x 4 Gbps FC HBAs	15 x 600 GB 15K Fibre Channel drives
CX4-480 Rev. FLARE 30 (Beta) 2 x 4 Gbps FC HBAs	112 x 600 GB 15K Fibre Channel drives
Host Servers	
Dell PE2850 2.8 GHz CPU; 8 GB RAM	Windows 2003 SP2 2 x 4 Gbps Fibre Channel HBAs
Dell PE2850 2.8 GHz CPU; 8 GB RAM	VMware ESX Server 3.x 2 x Windows 2003 Guest OS virtual servers 2 x 4 Gbps Fibre Channel HBAs
Dell PE2850 2.8 GHz CPU; 8 GB RAM	VMware ESX Server 3.x 1 Windows 2003 Guest OS virtual servers 2 x 4 Gbps Fibre Channel HBAs
FC SAN Switches	
2 x EMC Connectrix DS5000B - 4 Gbps	
FAST and FAST Cache Test Beds	
EMC CLARiiON Arrays	
FAST: CX4-960 Rev. FLARE 30 (Beta) 4 x 4 Gbps FC HBAs	5 x 200 GB Flash drives 45 x 600 GB 15K Fibre Channel drives 15 x 2 TB SATA II drives
CX4-960 Rev. FLARE 30 (Beta) 4 x 4 Gbps FC HBAs	8 x 73 GB Flash drives 45 x 600 GB 15K Fibre Channel drives
Host Servers	
Dell PowerEdge R900 4 x Intel Quad-Core 2.4 GHz CPU; 32 GB RAM 6 x 4 Gbps FC HBAs	Oracle Enterprise Linux Oracle 11gR2
FC SAN Switches	
2 x EMC Connectrix DS5000B - 4 Gbps	



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