EMC SYMMETRIX VMAX WITH ENGINUITY

EMC PRODUCT DESCRIPTION GUIDE

EMC²

TABLE OF CONTENTS

AUDIENCE

This product description guide is intended for any reader interested in understanding the hardware and software architecture of the EMC® Symmetrix® VMAX™ series with EMC Enginuity™. This paper will be of particular interest to system, application, database, and storage architects and anyone interested in deploying solutions on the Symmetrix VMAX platform. This document presumes an understanding of the Symmetrix DMX™-4 series. The value and necessity of all features are highlighted in sufficient detail to allow a reader of general technical experience to assimilate the material.

CHAPTER 1: INTRODUCTION

Enterprises today are looking at ways to reduce costs while providing better service levels to their customers. Server virtualization is driving a transformation to more efficient data centers. These virtual environments require lower costs, simplified management, higher scalability, more flexibility, and the ability to scale out storage. Building on a rich history of innovation that includes more than 500 patents, EMC has advanced the Symmetrix platform with the new Symmetrix VMAX series with Enginuity. It's no wonder that organizations of all sizes around the world have made Symmetrix the number-one market-share leader in high-end storage.

The Symmetrix VMAX series is the only storage system purpose-built for the virtual data center and enables businesses to:

- Reduce costs via scale-out and storage tiering
- Provide higher service levels for critical applications
- Leverage unprecedented performance and scale
- Achieve unmatched application availability
- Count on a secure information infrastructure
- Achieve highest levels of data security

STORAGE REQUIREMENTS FOR TODAY'S VIRTUAL DATA CENTER

Symmetrix is the original storage platform—the platform that revolutionized the storage industry and has proven its reputation as the gold standard for high-end storage. It continues to lead the industry in providing highly-available, high-performance storage for the world's most critical applications. Symmetrix innovation has created many of the industry-wide storage categories available today, such as external storage arrays, enterprise storage, and local and remote replication. Symmetrix has also delivered many industry firsts, including "in-the-box" tiered storage, advanced multisite replication, support for up to two petabytes of usable capacity in a single array, native enterprise Flash drive support for Tier 1 ultra high-performance requirements, and most recently, sub-LUN Fully Automated Storage Tiering for virtual pools (FAST VP) with continuous performance optimization for dynamic workload environments.

The IT landscape is changing amid a transition from the physical to the virtual. Virtualization is accelerating within the data center. Most IT organizations have successfully deployed virtualization within their IT owned applications, such as test, development, and smaller databases and applications. The next step in their journey is to virtualize their business production and Tier 1 applications, such as ERP, email and customer support applications. Organizations are shifting from managing infrastructures that focus on cost-functionality tradeoffs and physical devices, to managing policies in virtualized environments that deliver the right infrastructure services at the right cost.

VMware® is the clear leader in the server virtualization market delivering:

Infrastructure Services—The set of components that comprehensively virtualizes server, storage, and network resources, aggregates them, and allocates them precisely on demand to applications based on business priority.

Application Services—The set of components that provides built-in, service-level controls to all applications running on VMware, regardless of the application type or operating system.

EMC enables this transition with the Symmetrix VMAX series with Enginuity. The new Symmetrix VMAX system delivers the first high-end EMC Virtual Matrix Architecture™, which uses cost-effective, common building blocks called Symmetrix VMAX engines. These engines have Virtual Matrix™ Interconnects between Symmetrix VMAX directors to provide a simple way to scale out storage resources with massive levels of performance, capacity, and connectivity that can be shared across applications. Symmetrix systems continue to provide non-disruptive operations with advanced clustering software and redundant components. VMAX fully supports VMware's "vStorage APIs for Array Integration" (VAAI) initiative with support for APIs that enable VMware vSphere™ to offload certain operations to VMAX,

thereby accelerating tasks, supporting massive-scale environments, and freeing up server resources for other activities. VAAI support with Enginuity 5875 includes:

- Full Copy offloads replication to the array to enable up to 10x faster virtual machine deployments, clones, snapshots, and storage vMotion® operations. This can more efficiently support rapid growth.
- Block Zero initializes file system block and virtual drive space more rapidly, with as much as 10x less I/O for VMFS formatting and reallocation.
- Hardware Assisted Locking provides block-level locking to enable more efficient metadata updates and assists virtual desktop deployments, enabling up to 10x more virtual machines per datastore. Administrators are thereby able to manage thousands of desktops more efficiently.

Additionally, VMAX supports VMware vSphere Storage APIs for Storage Awareness (VASA) enabling unprecedented coordination between vSphere/vCenter and VMAX. No other storage product is as tightly integrated with the virtual data center as the Symmetrix VMAX series.

The Symmetrix VMAX integrates with virtual server environments with its scale-out architecture and software that optimize provisioning for VMware and Hyper-V virtual machines. VMAX administrators can automate and accelerate the most common, repetitive, and error-prone tasks. Auto-provisioning Groups help manage many server-storage links at once by creating groups of host initiators, front-end ports, and storage devices. These groups can be named and associated with one another in an application-specific view, and component changes/updates are automatically propagated through the associated views.

EMC PowerPath® Virtual Edition (PowerPath/VE) supports hypervisors, helping optimize server, storage, and path utilization to ensure Symmetrix VMAX systems provide predictable and consistent information access in VMware and Hyper-V virtual environments. In addition, the ProSphere™ family of storage resource management products delivers automated discovery and reporting with easy-to-use, end-to-end management and control of physical and virtual resources.

LOWEST COST-OF-OWNERSHIP

Today's economic environment is forcing customers in all industries and geographies to pursue cost savings and operational efficiencies. At the same time, information growth continues unabated at a 60 percent compound annual growth rate. The challenge is to manage that growth while still meeting today's economic imperatives.

Symmetrix helps achieve this by storing information more efficiently. The Symmetrix VMAX architecture enables users to consolidate multiple application tiers, server platforms, and connection types—all in the same array, without compromising performance, availability, or functionality. This has grown more compelling with the Symmetrix VMAX series. Enterprises can incrementally grow their Symmetrix VMAX systems to cost-effectively achieve up to three to four times the performance, twice the connectivity, and three times the usable capacity of Symmetrix DMX-4 systems.

Symmetrix DMX-4 and Symmetrix VMAX systems provide the industry's most complete range of tiering options to optimize storage environments. Customers can use Fully Automated Storage Tiering for virtual pools (FAST VP) to leverage EMC optimized Enterprise Flash drive technology, significantly increasing performance and reducing capacity, energy, and footprint costs by supporting workloads with fewer drives than are required with standard Fibre Channel technology. By automatically migrating selected, high-priority volumes to Flash drives and lower-priority volumes to SATA drives, organizations can improve performance where it matters, and lower overall system and energy costs.

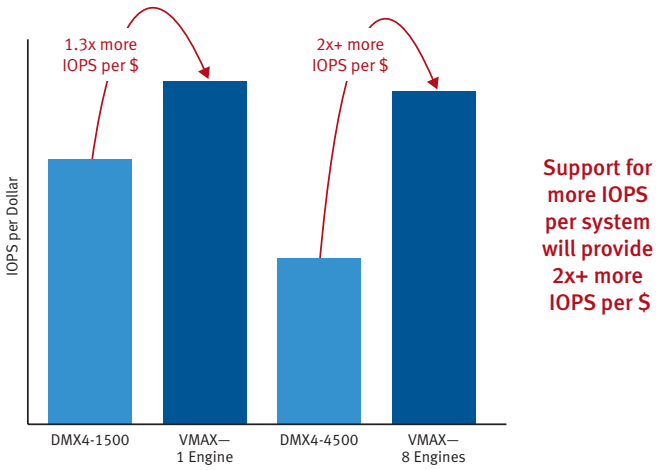
EMC continues to reduce the labor costs associated with managing Symmetrix systems. Symmetrix Management Console (SMC) makes storage management more efficient, enabling initial system discovery and configuration, including single-menu device creation and configuration. SMC also includes new, intuitive configuration wizards and templates, which streamline the configuration process for auto-provisioning groups, migrations, and replication.

Within SMC is the option to support, configure, and monitor Symmetrix Virtual Provisioning for Symmetrix DMX-3, DMX-4, and Symmetrix VMAX systems. Based on a technology known in the industry as "thin provisioning," Virtual Provisioning simplifies storage management and reduces labor costs in two critical ways. First, automated wide striping simplifies data layout. VP ensures that storage is allocated in small chunks across all of the physical drives in a VP pool, better performance than manual striping with standard provisioning, with far less planning required. No other storage product can be configured as easily or is easier to manage than the Symmetrix VMAX.

Second, Virtual Provisioning reduces the steps required to accommodate application growth. Administrators are able to create a volume size that allows for future capacity growth needs. The physical capacity is consumed when data is written to the volume. When more space is needed, administrators can simply add capacity to the VP pool. Unlike with standard provisioning, as long as a sufficiently large VP volume was created initially, the host relationship does not change, and there is no need to perform mapping and masking again. VMAX with Enginuity has further improved the efficiency of provisioning by enabling users to execute multiple configuration commands, such as the creation of different VP pools simultaneously.

UNPRECEDENTED PERFORMANCE AND SCALE

The Virtual Matrix Architecture is a new way to build storage systems that transcend the physical constraints of all existing architectures by scaling system resources through common building blocks. The building block is a Symmetrix VMAX engine that contains two Symmetrix VMAX directors, a cross-director communication path linking the two directors, and redundant interfaces to the Virtual Matrix Interconnect. Each Symmetrix VMAX director consolidates front-end, global memory, and back-end functions, enabling direct memory access to data for optimized I/O operations. The engines are interconnected via a set of multiple-active fabrics that provide scalable performance and high availability.



Comparing similar configurations, drive types, and RAID Protection levels

DMX-4 Compared to Symmetrix VMAX—Two Times the IOPS per $

Symmetrix VMAX engines can be added non-disruptively to provide linear scale-out of Symmetrix system resources. With the first release, Symmetrix VMAX systems can scale from one to eight engines. The Symmetrix VMAX system features multi-core CPUs to improve performance. Twice the cache memory and twice the front-end port connectivity of Symmetrix DMX-4 systems further enable Symmetrix users to reduce costs while increasing performance.

PREDICTABLE SERVICE-LEVEL OBJECTIVES FOR CONSOLIDATED WORKLOADS

Symmetrix further provides quality of service and resource optimization tools that dial-in the right levels of performance to meet specific application service levels. Dynamic Cache Partitioning isolates memory resources for workloads, making performance more predictable, while sharing underutilized cache as needed among partitions, to maximize overall performance. Symmetrix Priority Controls prioritize I/O by device group, providing preferential processing for higher priority applications.

UNMATCHED APPLICATION AVAILABILITY

For the highest level of information protection, Symmetrix DMX and Symmetrix VMAX systems are the only platforms in the industry that can deliver comprehensive solutions for local, remote, and multisite business continuity. All of these solutions are based on EMC TimeFinder® and SRDF® family technology—the most established and field-proven business continuity technologies in the industry today. Symmetrix continues to extend its leadership in business continuity. SRDF/Extended Distance Protection (SRDF/EDP) is a new two-site disaster restart solution available with VMAX that enables zero data loss at greater distances than previously were possible. No other storage product matches the Symmetrix system's market adoption for mission-critical environments.

SECURE INFORMATION INFRASTRUCTURE

Security has become a pressing and complex problem. Businesses must address regulatory requirements, gaps in their security measures, and a proliferation of controls and services. If not properly addressed, security shortfalls and/or inefficient solutions can lead to compromised SLAs, missed market opportunities, and excessive operating costs. It is imperative to adopt effective and simpler security implementations.

The Security Division of EMC

EMC understands that there are many aspects to helping customers deploy secure information infrastructures. Across the board, EMC products reflect a comprehensive, disciplined approach to security. EMC incorporates 80 consistent security considerations into all of our products at all phases of the product lifecycle—from design to implementation to deployment to operations. EMC's approach and the integration with RSA®, The Security Division of EMC, provide significant competitive advantages while providing customers with a solid, secure information infrastructure. No other storage platform has the built-in security capabilities available in the EMC Symmetrix family.

Key security capabilities of the Symmetrix platform include:

- **Symmetrix Data at Rest Encryption** encrypts data on all drives within a VMAX storage array. Data at rest encryption eliminates security risks when drives are removed from an array (because of normal drive replacement or possibly media theft) as well as when arrays are repurposed. There is a different encryption key for each drive in the VMAX, and the VMAX array does NOT require specialized encryption-enabled drives. The encryption process occurs on the Disk Adapter Serial Link hardware. This specialized hardware ensures there is no performance overhead associated with the VMAX encryption solution.
- **IPv6 and IPSec support** secures remotely replicated data that travels over public IP networks, and provides compliance with federal security regulations. It is provided on front-end Gigabit Ethernet and multi-protocol directors. IPv6 is supported with new 10 Gb/s Ethernet connectivity.

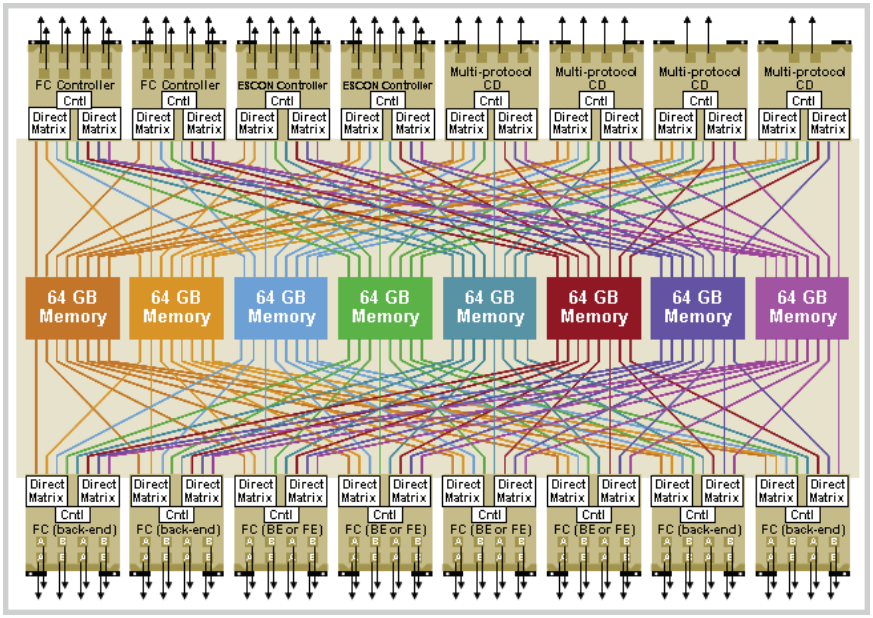
- **EMC Certified Data Erasure** of the full array or individual drives eliminates the risk of data exposure when organizations change infrastructure components. This includes a certifiable record that data has been overwritten three to seven times, ensuring data is unreadable and exceeds industry best practices. EMC Certified Data Erasure also helps satisfy regulations such as the Payment Card Industry Data Security Standard (PCI) and the Health Insurance Portability and Accountability Act (HIPAA).
- **The Symmetrix Audit Log** ensures that service and host-initiated actions on the Symmetrix are recorded in a secure log to assist with compliance efforts. Logged event contents cannot be altered, and only authorized users can access them. Status alerts provide additional integrity safeguards for the rotating log file.
- **Audit Integration with RSA enVision®** provides automated, policy-based, audit log management that helps meet compliance requirements. RSA enVision analyzes Symmetrix events and other events in the customer environment to understand and respond to security threats.
- **Symmetrix Service Credential, Secured by RSA,** prevents unauthorized service actions by integrating industry-leading RSA technology into Enginuity. This dynamic feature provides the highest level of confidence ensuring that only the right individuals are performing permissible activities, on permissible systems, at permissible times, with no action required by the customer.
- **Symmetrix Access Control** enables users to control server actions. Device masking ensures that only permissible host machines can see Symmetrix devices, while Symmetrix Access Control ensures those hosts can only perform permissible actions, such as local or remote replication. These aspects of Enginuity have been Common Criteria certified, providing ISO assurance of the rigor of EMC's security practices.

CHAPTER 2: THE SYMMETRIX VMAX ARCHITECTURE

THE SYMMETRIX HERITAGE

Over the years, Symmetrix has proven itself time and again in the world's most demanding environments. Symmetrix is engineered to work flawlessly, continue to run no matter what, and be serviced proactively and non-disruptively. The Virtual Matrix Architecture was designed to surmount the barriers to throughput, bandwidth, scalability, and response time that are inherent in other traditional high-end storage systems.

The core components of the Symmetrix Direct Matrix Architecture® consist of two back-end director boards, two memory boards, and two front-end boards. These components have been integrated into the VMAX engine.



Symmetrix DMX—Direct Matrix Architecture

THE SYMMETRIX VMAX STORAGE SYSTEM

Driven by constant data growth, today's storage platforms must efficiently accommodate much larger capacities and higher performance while leveraging the best of emerging technologies. What is required is an architecture that employs the latest scalable technology, takes advantage of the unprecedented performance and capacity of new drive technologies, and is driven by innovation that transcends the physical and management capabilities of today's systems, while preserving and building upon existing infrastructure investments and skill sets.

The Symmetrix VMAX Architecture provides a high-end, multi-dimensional storage subsystem that can scale beyond the confines of a single system footprint. The core element of this architecture is the Symmetrix VMAX engine, which includes a pair of highly-available directors with dual Virtual Matrix Interconnects.

The system grows by aggregating up to eight Symmetrix VMAX engines in a single system with fully shared connectivity, processing, memory, and storage capacity resources. Breaking through the physical barriers of today's architectures, the Virtual Matrix is the first architecture that is purposely built to ultimately scale across a data center, encompassing multiple system bays and dozens of Symmetrix VMAX engines.

The Symmetrix VMAX series delivers seamless scale-out growth from an entry level configuration to the world's largest storage system. The Symmetrix VMAX system is a high-end, scalable storage array with a system bay containing one to eight engines and separate rollup storage bays. The system scales from a single-engine configuration with one storage bay to either single-phase power or three-phase power.

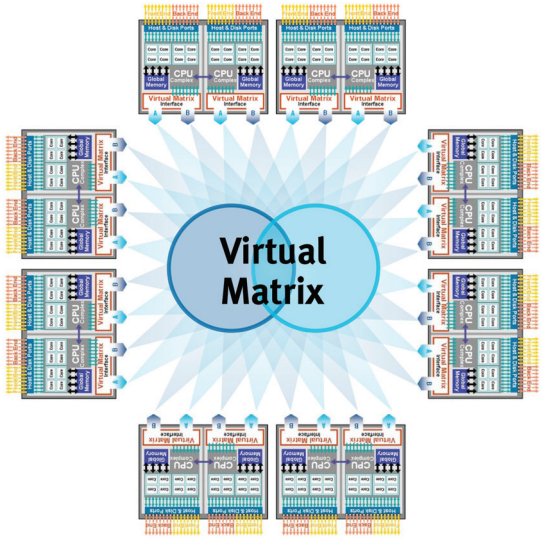
The Symmetrix VMAX SE (Single Engine) system is the entry point to the Symmetrix VMAX storage family. Symmetrix VMAX SE systems offer a single cabinet configuration containing both the engine and drives. Capacity can be increased online by adding a drive bay.

Symmetrix VMAX systems with the Enginuity operating system provide all the features of previous versions of Enginuity, as well as many important new features.

Symmetrix VMAX—the world's most scalable, high-end storage array

SYMMETRIX VMAX HARDWARE ARCHITECTURE

The synergy between Symmetrix hardware and software has made Symmetrix systems best-in-class for more than a decade. The combination of the Symmetrix multi-processing hardware architecture with the Enginuity operating environment produces a massively parallel storage system designed to multi-task numerous simultaneous events.



New Virtual Matrix Architecture revolutionizes high-end storage capabilities

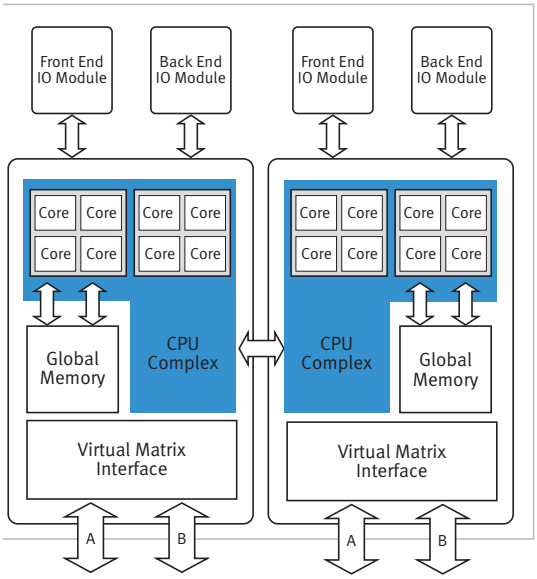
For example, when a new write operation is committed to memory, the new data is immediately available to all of the processors within every Symmetrix VMAX engine director-pair. While the data is protected in memory, the processors on all of the director-pairs can work autonomously on the new data to update a mirrored pair; send the update over an SRDF link; update a TimeFinder Clone BCV; report the current status of all events to the management software; and handle error detection and correction of a failed component.

All of these tasks can occur simultaneously, without de-staging to the drive and re-staging to a separate region in memory. This sophisticated functionality makes Symmetrix storage arrays best-in-class for high-end storage requirements.

The core architecture of the Symmetrix DMX system is carried over to the Symmetrix VMAX storage array.

THE SYMMETRIX VMAX ENGINE

The engine is the hardware foundation of the Symmetrix VMAX series. Today's Symmetrix system has the ability to non-disruptively scale from one to eight engines, enabling businesses to acquire storage capabilities as they are needed. Each engine provides physical memory, front-end host connectivity, back-end connectivity, and connections to other engines. The engines connect through the Virtual Matrix Interconnect to every other engine and to all of the global memory.



The Symmetrix VMAX Engine Dual Directors for High Availability

The engine contains two integrated, highly-available directors. Each director contains a CPU complex, protected global memory, and dual-interfaces to the Virtual Matrix Interconnect. In addition, a group of hot-pluggable modules is chosen for front-end and SRDF connectivity as well as back-end (drive) connections.

Each VMAX director employs dual Quad-core 2.33 GHz Intel Xeon processors, up to 64 GB of memory, and dual interfaces for redundant connectivity to the Virtual Matrix Interconnect fabrics.

An engine, comprised of two directors, supports 16 back-end Fibre Channel (4 Gb/s) connections that are used to connect to the VMAX storage bay. Customer configurable I/O modules provide connectivity for the front-end (host) and/or optional SRDF ports. These front-end I/O modules support:

- Up to 16 Fibre Channel connections (8 Gb/s) for host connectivity
- Up to four Fibre Channel (8 Gb/s) ports for SRDF connectivity
- Up to eight FICON (8 Gb/s) connections provide for mainframe connectivity
- Up to eight multi-mode Ethernet ports (10 Gb/s) with compression provide support for FcOE and iSCSI hosts
- Up to four ports (10 Gb/s) for SRDF connectivity

Redundant management modules provide environmental monitoring and system management intercommunications for each engine. Power and cooling subsystems are also redundant to provide continuous availability. Two standby power supplies (SPS) provide backup power for each engine in the event of an AC power interruption. This enables all data in cache memory to be safely written to the vault drives in the event of complete power loss.

GLOBAL MEMORY

The single most distinguishing feature of Symmetrix has been its global memory. In every Symmetrix, memory is a centrally shared resource that is accessible by every single processor and I/O stream in the system. Write requests received by front-end communications ports are stored in global memory for the back-end disk directors to deliver to drive; and host read requests are fulfilled by the disk directors by placing payloads in global memory for the front-end directors to deliver back to the requestor.

Over the years, the interconnect between memory and the I/O processors and the way that these processors communicate with each other both have changed, but the operational utility of global memory hasn't. One of the major changes introduced in the Symmetrix VMAX system design is a shift from a centralized to a distributed global memory model. From the viewpoint of a director, some global memory is local and some resides remotely with other directors. Directors have the ability to access local portions of global memory directly, and remote portions of global memory through the Virtual Matrix Interconnect. Each director contributes a portion of the total global memory space. Memory on each director stores the global memory data structures, which include a common area, track tables, and cache entries.

The Symmetrix VMAX array can be configured with up to 1 TB of global memory (512 GB protected). Memory is located on each director utilizing up to 8 DIMMS per director. Memory size considerations include the number of applications and replication requirements, as well as drive capacity, speed, and protection. Engines can be configured with 32, 64, or 128 GB of physical memory. Global memory has a maximum system bandwidth of 192 GB/s. Continuous global memory data integrity checking and error detection and correction with fault isolation are key to data and system integrity.

VIRTUAL MATRIX INTERCONNECT

The Virtual Matrix design is much more than just an interconnect. The Virtual Matrix Interconnect also extends onto the Symmetrix VMAX engines, encompassing the memory and the I/O paths.

The Virtual Matrix Interconnect provides two active-active, non-blocking, serial RapidIO® private networks as the inter-node Virtual Matrix Interconnect. These fault-tolerant connections allow directors to access distributed global memory and other resources system-wide. The Virtual Matrix Interconnect utilizes the industry-standard, packet-switched serial RapidIO architecture as the communication mechanism among the directors. The RapidIO protocol and feature set has been augmented with EMC Symmetrix-specific atomic operations, enhanced priority management, enhanced error reporting, and error management features. Each fabric supports reads and writes to global memory and director-to-director messaging within the system with an aggregate interconnect fabric bandwidth of 80 GB/s.

This high-bandwidth, low-latency fabric interconnect has been adopted in a variety of applications including computer storage, automotive, military, and telecommunications. While serial RapidIO is a key component of the first release of the Symmetrix VMAX, the Virtual Matrix Architecture can support any type and number of redundant fabrics and any number of switching elements per fabric.

Fabric management is performed by designated directors within the system. All directors are capable of fabric management. The director appears as an entity connected to a specific port of the fabric. The director responds to in-band fabric management packets and interacts with the system fabric components. Fabric management operations include discovery and Initialization, path management, load balancing, failover, and fault Isolation.

In addition, an Ethernet fabric is configured within the system for troubleshooting and serviceability of the RapidIO fabrics and other system management communication. All directors can communicate over the redundant Ethernet network for system management purposes. This Ethernet fabric is not used for data movement.

SYMMETRIX VMAX SERIES: OVERTAKING THE FUTURE

Because service levels and the demands they impose upon IT organizations are steadily escalating with no end in sight, the future will, without a doubt, be far more challenging than the present. To fully overtake the future, a high-end storage infrastructure must do the following:

- Scale-up and scale-out to handle far greater demands than are presently placed upon it
- Incorporate future technology enhancements to address future service-level requirements

The Virtual Matrix Interconnect and Global Memory Architecture were specifically designed to accommodate escalating interconnect bandwidth and global memory throughput demands. Enginuity 5875 further optimizes performance by reducing the operations required to move data between global memory and back-end drives. This increases throughput by as much as two times for workloads such as data warehousing and business intelligence. In addition, by design, the architecture can absorb and leverage new processor technologies, interconnect protocols, storage media designs, and resource optimization strategies as they evolve. In the future, the Virtual Matrix Architecture will enable EMC to easily implement scalable performance enhancements with additional engines, global memory, new host interconnects, and distributed storage bays. As a result, the Symmetrix VMAX Architecture (and IT organizations that invest in Symmetrix VMAX systems) can take the future in stride.

SYMMETRIX VMAX SYSTEM: THE STORAGE

Designed for the latest in drive technologies, the Symmetrix VMAX system supports Flash, Fibre Channel, SAS and SATA drives. Each storage bay can hold up to 16 drive enclosures (DEs) for a maximum of 240 3.5-inch drives per storage bay. The maximum system configuration is 2400 drives utilizing 10 storage bays. DEs are storage modules that contain drives, link control cards, and power and cooling components. All DE components are fully redundant and hot swappable. Each houses up to 15 drives. Each DE provides physical redundant connections to two separate directors and redundant connections to "daisy-chained" DEs that extend the number of drives that are accessible per director port. The DE supports dual-ported, 4 Gb/s, back-end fibre interfaces.

Similar to the system bay, each storage bay has redundant power distribution panels (PDPs). Two standby power supplies (SPS) provide backup power for each set of four drive enclosures. If both AC power zones are interrupted or fail, the SPS modules can maintain power for two five-minute periods of AC loss, enabling the Symmetrix storage bay to shut down properly. All storage bays are fully pre-cabled and pre-tested from the factory to easily enable future growth.

The combination of flash and SATA drives result in lower storage costs

SUPPORTED DRIVE TYPES

VMAX systems support Enterprise Flash, rotating Fibre Channel, SAS, and SATA drive types. All drives use the same physical 3.5-inch drive carriers, however the SAS drives are 2.5" devices for high efficiency operations. Physical compatibility with existing drives is only part of the story. Enginuity software features provide the necessary performance and capacity management tools, including FAST VP, to intelligently and automatically place applications on drives with the most cost-effective characteristics. Customers can benefit from the very highest performance without interference from concurrently running, lower priority applications.

SUPPORTED DRIVE TYPES, SIZES, AND CAPACITIES

EMC is always qualifying new drive technologies. Please see the Symmetrix product page on EMC.com for the latest drive information.

Ultra-high performance: Enterprise Flash drives

High performance: Fibre Channel and SAS drives

High capacity: SATA drives

ENTERPRISE FLASH DRIVES

Enterprise Flash drives are suited for applications with drive-intensive activity that require the fastest data storage and retrieval. Flash drives improve performance in mixed workload environments because they improve response time for read-miss activity, even when workloads have relatively low read-miss ratios. Any workload that is I/O intensive can benefit from better read-miss response times. Examples include OLTP applications, Oracle and DB2 databases, Microsoft Exchange collaboration server, and SAP R/3.

A Symmetrix VMAX system with Flash drives can deliver single-millisecond application response times and up to 30 times more IOPS than traditional 15,000 RPM Fibre Channel disk drives. In addition, because there are no mechanical components, Flash drives require up to 98 percent less energy per IOPS than traditional disk drives. To satisfy enterprise-level drive requirements, NAND single-level cell Flash technology was made more robust with static and dynamic wear leveling functions, bad block remapping, and multi-bit error

correction. Because of these reliability enhancements and the fact that the drive has no moving parts, the life expectancy of the Flash solid-state device exceeds that of hard disk drives.

All Symmetrix drives, including Flash, have a dual-ported design and use the same 3.5-inch, form-factor drive carriers. All drives are managed in the same manner. The Symmetrix VMAX system supports up to 2,400 Enterprise Flash drives per system.

One natural question that comes up is about reliability of Flash drive technology. Similar to the case of performance, this is an area in which Flash drives deliver. There is comprehensive validation that includes environmental, manufacturing processes, quality, performance, reliability, and availability with all EMC Flash drives. These drives are guaranteed, and Enginuity monitors their operational status just like every other drive in the system. EMC backs this technology with worldwide service and support. Leveraging NAND reliability and intelligent wear leveling (the practice of writes and rewrites moving to new NAND blocks onto over-provisioned internal raw capacity) ensures that these drives will have a life expectancy of over five years.

FIBRE CHANNEL DRIVES

Symmetrix VMAX systems use industry-standard 10 K and 15 K rpm 4 Gb/s Fibre Channel disk drives and supports Fibre Channel loops ranging from 15 drives to 75 drives each.

SAS DRIVES

Symmetrix VMAX arrays use industry-standard 10 K rpm 2.5" SAS disk drives and support FC loops ranging from 15 drives to 75 drives each. These SAS drives are designed to lower energy consumption by up to 40 percent compared with 3.5" FC drives in order to provide customers with the absolute lower cost of ownership (TCO).

SATA DRIVES

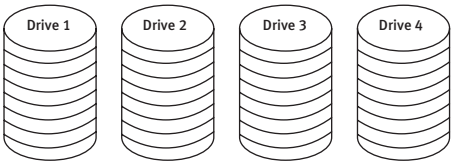
SATA drives provide an option for high-density storage. These drives can provide up to 70 percent of the storage capacity of a typical enterprise. These drives provide high density at a lower cost per terabyte. SATA drives can coexist in the same drive enclosure as other drives, but because of performance differences, they should not be mixed in RAID volume protection strategies.

EMC continually adds new and higher capacity drives. The most recent information about drive types and capacities is posted on EMC.com and EMC Powerlink®.

Building on strengths and capabilities, Symmetrix provides advanced functionality to optimize storage tiering through a suite of software-based tiering capabilities. This includes key capabilities such as QoS management and optimization tools that dial-in the right levels of performance to meet specific application service levels. FAST advances these capabilities by automatically migrating volumes—and now sub-volume quantities—of data between drive types, based on user-specified policies and changing performance requirements.

HYPERVOLUMES

Symmetrix logical volumes are configured from slices of physical drives called hypervolumes. The Symmetrix systems support as many as 512 hypervolumes per physical drive, which improves space efficiency and utilization. The logical-to-physical relationship specified when hypervolumes are configured can apply to all devices in the system or can be customized for specific devices.



Example: Drives are configured with eight hypervolumes per physical drive. A maximum of 512 hypervolumes can be configured on each physical drive.

METAVOLUMES

A metavolume is two or more Symmetrix hypervolumes presented to the host as a single addressable disk. Creating metavolumes provides the ability to define host volumes larger than the current Enginuity maximum size of approximately 240 GB. Metavolume creation also stripes the volume across back-end directors, which increases performance. Symmetrix metavolumes can contain a maximum of 255 devices and can be a maximum of 16 TB in size. The maximum number of volumes that a Symmetrix system can support is 64,000 volumes. Configuring metavolumes also reduces the number of host-visible devices, because each metavolume is counted as a single logical volume. Devices that are members of the metavolume, however, are counted toward the maximum number of host-supported logical volumes.

Metavolumes provide two ways to access data:

- **Concatenated volumes**—Organizes addresses for the first byte of data at the beginning of the first volume and continues sequentially to the end of the volume. Data is written sequentially, beginning with the first metavolume and extended to the next once the first is full.
- **Striped volumes**—Organizes addresses by joining multiple hypervolumes to form a single volume. Instead of addressing sequentially, striped volumes use addresses that are interleaved between hypervolumes. Data striping benefits configurations with random reads by avoiding stacking multiple reads on a single drive and controller. Data striping creates a large volume and balances the I/O activity among the drives and the Symmetrix system controllers.

LARGE VOLUME SUPPORT

The largest individual logical volume size has increased to 240 GB (for open systems environments) from about 60 GB in the previous Enginuity release. This simplifies storage management by reducing the need to create several metavolumes, and more easily accommodates high capacity and high growth application requirements. Large volumes also reduce the risk that organizations will exceed their systems' volume addressing limits.

Example: drives are configured with eight hypervolumes per physical drive. A maximum of 512 hypervolumes can be configured on each physical drive.

SUMMARY

Emerging high-end storage requirements drive the need for unprecedented levels of performance, availability, and functionality at a time when IT budgets are being tightly controlled. The Symmetrix VMAX Architecture is EMC's response to this challenge. The Virtual Matrix Architecture and shared global memory ensure the highest possible I/O throughput and scalability to meet the data center requirements of tomorrow.

The Symmetrix Virtual Matrix Architecture carries forth the essential characteristics that have made Symmetrix systems the standard for high-end storage for more than a decade. The Symmetrix global memory design moves I/O from server to drive in the most efficient manner possible. The Enginuity operating system for Symmetrix prioritizes multiple simultaneous events within the system, and guarantees quality of service (QoS) for the most important events. Enginuity provides the intelligence to derive maximum functionality from the Symmetrix architecture.

The two major design points for the Symmetrix VMAX Architecture are the Virtual Matrix Interconnect and the Global Memory Architecture. The Symmetrix VMAX system provides twice the cache memory, twice the front-end port connectivity, and three times the usable capacity of the Symmetrix DMX-4 models. These innovations more fully leverage the inherent capabilities of the scalable hardware design and event-driven storage operating environment.

The Virtual Matrix Interconnect provides dual-active connections to all directors within the system providing internal aggregate bandwidth of up to 80 GB/s. These fault-tolerant connections allow directors to access distributed global memory and other resources.

The combination of the Virtual Matrix Interconnect and the Global Memory Architecture has redefined high-end storage capabilities for performance, availability, and functionality.

The Symmetrix VMAX Architecture is "future ready." It can, without modification, handle far greater demands than are presently placed upon it, and readily incorporate, future technology enhancements as service-level requirements continue to rise.

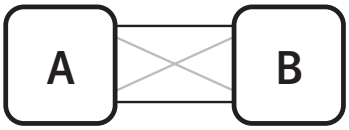
CHAPTER 3: AVAILABILITY AND SYSTEM INTEGRITY

SYMMETRIX: THE GOLD STANDARD IN STORAGE FOR ENTERPRISES LARGE AND SMALL

As service levels for critical applications continue to rise, so too do requirements for information availability and data integrity. Symmetrix is the gold standard for mission-critical applications. It has proven itself time and again, over more than two decades, in some of the world's most demanding environments, including the data centers of the largest financial, insurance, and telecommunications companies. Symmetrix was engineered from the beginning to work flawlessly, to continue to run no matter what, and to be serviced proactively and non-disruptively. The Symmetrix VMAX series raises the availability bar even higher with the world's most advanced, fault-tolerant design, featuring full redundancy, proactive monitoring, error detection, and correction.

SYMMETRIX COMPONENT-LEVEL PROTECTION AND REDUNDANCY

All critical components are fully redundant, including Symmetrix VMAX directors, Virtual Matrix data paths, power supplies, standby power supplies, and all Fibre Channel back-end components.



VMAX—Built-in High Availability

NON-DISRUPTIVE OPERATIONS AND UPGRADES

Enginuity, the intelligent operating environment for the Symmetrix VMAX system, manages and ensures the optimal flow and integrity of information through the different hardware components of the Symmetrix VMAX system. Enginuity manages all Symmetrix operations—from monitoring and optimizing internal data flow, to ensuring the fastest response to users' requests for information, to protecting and replicating data.

Non-disruptive Enginuity upgrades from one version to the next, and interim updates are available for the Symmetrix DMX and VMAX families, and take advantage of their multiprocessing and redundant architecture. Release levels can be loaded online without interruption to data availability or access.

Enginuity upgrades and updates, performed at the customer site by the EMC customer engineer (CE), provide enhancements to performance algorithms, error recovery, reporting techniques, diagnostics, and code fixes. During an online upgrade, the EMC customer engineer downloads the newest version of Enginuity to the Symmetrix service processor.

The Symmetrix system does not require manual intervention to perform this function. All directors remain online to the host, thus maintaining uninterrupted application access. The Symmetrix system will load the new version of Enginuity at selected windows of opportunity within each director hardware resource until all directors have been loaded.

Once the new version of Enginuity is loaded, internal processing is synchronized, and the new code becomes operational. During an online load within a code family (or interim upgrade), the full version is loaded and consists of the same base code plus any additional patches.

The ability to perform non-disruptive Enginuity upgrades is critical to providing uncompromising levels of system availability and data access. In addition to non-disruptive microcode upgrades, Enginuity also supports a wide range of non-disruptive operations, enabling Symmetrix to support mission-critical environments for applications that require uninterrupted access to information and uncompromising service levels.

Other examples of non-disruptive operations that storage administrators can perform include configuration updates and modifications to production or business continuity data volumes. This may include reconfiguring or moving existing storage resources to support new host platforms, or the ability to dynamically add or remove SRDF groups, or convert clone capacity into standard devices. With Symmetrix VMAX, non-disruptive configuration updates are completed faster and can be run in parallel (up to four changes).

SYMMETRIX VMAX SERIES ERROR DETECTION AND REMOTE SUPPORT

Symmetrix VMAX system hardware is the most reliable storage system in the industry. However, all hardware is subject to occasional failures. The unique methods used by Symmetrix to proactively detect and prevent these failures from impacting customer operations set it apart from all other storage solutions in providing continuous data integrity and high availability.

SERVICE PROCESSOR FUNCTIONALITY

MANAGEMENT INTEGRATION

Symmetrix Management Console, the Symmetrix device management tool, can now be loaded directly on the service processor. This frees up server resources and allows any web browser with proper security credentials to manage the system from anywhere in the enterprise.

EMC REMOTE SUPPORT

Through the service processor, the Enginuity operating environment for Symmetrix proactively monitors all end-to-end I/O operations for errors and faults. By tracking these errors during normal operation, Enginuity can recognize patterns of error activity and predict a potential failure. This proactive error-tracking capability can remove a suspect component from service before a failure occurs.

The service processor enables EMC's remote support capabilities, which include remote notification and remote diagnostics and repair. Remote notification enables EMC to monitor the health of the Symmetrix. If operational statistics fall outside a well-defined set of tolerances, or if certain error conditions are encountered, the service processor will automatically contact a support center to report its findings. Additionally, EMC periodically establishes proactive remote support connections to verify that the system is responding and able to communicate with EMC. When an EMC support engineer is assigned to a service request or support ticket, he or she remotely accesses the service processor of the system in question to gather operational data and logs.

GLOBAL MEMORY PROTECTION AND REDUNDANCY

Symmetrix utilizes global memory mirroring to protect the system from memory component failures. A single logical image of memory is actually two physical images for redundancy and availability. Symmetrix systems preserve the integrity of data stored in cache by conducting ongoing data checks and corrections and by proactively monitoring the hardware where data is cached. Symmetrix system cache integrity checks include additional Error Checking and Correction (ECC) which provides a level of ECC available only in Symmetrix systems. In addition, Symmetrix periodic memory-correction routines proactively verify all locations in cache memory.

SYSTEM-WIDE ERROR CHECKING AND CORRECTION CODE

The Symmetrix VMAX series drive format is 520-byte blocks for all drives except the IBM i, which uses 528-byte blocks. The system utilizes these additional bytes to provide protection of the data record. The system uses these bytes to check the data and, if possible, to correct it. If the system detects an uncorrectable error, it informs the host that it has encountered bad data to avoid affecting data integrity. Symmetrix systems always perform this level of error checking and correction when they transmit data and addresses. However, Symmetrix VMAX systems add bits to the data record to ensure that the information transmitted

belongs to the record specified. This protection information is generated as data enters the Symmetrix VMAX from a host, and is checked every time data in the Symmetrix VMAX cache is accessed—when it is written to cache, by front or back end, when it is moved between cache locations, and when it is sent to or received from any disk or Flash drive. This second level of protection, available only in Symmetrix systems, further ensures data integrity by preventing incorrect data from being transferred.

PHYSICAL MEMORY ERROR CORRECTION AND ERROR VERIFICATION

Symmetrix VMAX systems always correct single-bit errors and report an error code once the single-bit errors reach a predefined threshold. When a multibit error occurs, the Symmetrix system fences the physical memory segment (removes it from service) and retrieves the data from mirrored memory (if it was unwritten) from the drive. In the unlikely event that physical memory replacement is required, the Symmetrix system notifies EMC support, and a replacement is ordered.

DATA PROTECTION AND ERROR CHECKING

The Symmetrix VMAX series supports various data integrity mechanisms to reduce the possibility of data corruption in the system and to provide fault isolation. These data checking mechanisms are hardware- and/or software-based solutions. Symmetrix system byte and block-level error checks provide data checking at every point and ensure that only the correct information is exchanged.

Symmetrix VMAX Data Record Format

BYTE-LEVEL ERROR CHECKING

All data paths and control paths have byte-level error generation and checking that verifies data integrity at the byte or word level. All data and command I/Os passed through the system fabric and within each I/O module and director include parity bits on busses and CRCs on serial data paths to check integrity.

BLOCK-LEVEL CRC ERROR CHECKING

Symmetrix VMAX systems provide block-level CRC error checking based on the industry-standard T10 Data Integrity Field (DIF) Block. CRC error checking provides a data protection word for every block written, and also includes additional checking information to ensure that the data read back is what was written. The system checks block-level CRC every time data is transferred within the Symmetrix system.

GLOBAL MEMORY PROTECTION FROM POWER FAILURE

The Symmetrix VMAX system uses pre-configured Power Vault drives to destage data from global memory during a sudden power-down or an unexpected power outage. Global memory data integrity is protected if power is lost using standby power supplies. Symmetrix then writes the data from global memory onto designated drive storage called Power Vault devices. Vaulted images are fully redundant where the contents of global memory are saved two times to independent drives. The Symmetrix VMAX then completes the power-down sequence. Once power is restored, the Symmetrix VMAX system startup program initializes the hardware and the environmental system, restores global memory contents from the Power Vault devices while checking data integrity, and re-initializes the global data memory. The system resumes normal operation when the standby power supplies are sufficiently recharged to support another vault. If any condition is not safe, the system will not resume the normal status and will call customer support for diagnosis and repair. This allows EMC Customer Support to communicate with the Symmetrix VMAX system and restore normal system operations. Under normal conditions, the SPS batteries can support two consecutive vaults; this ensures on power restore after the first power failure, that the system will be

able to resume I/O immediately, that it and can still vault if there is a second power failure, enabling customer operations to resume without risking data loss.

DRIVE INTEGRITY MONITORING AND CORRECTION

Symmetrix VMAX systems proactively protect data from drive read and write errors. Drive status conditions are continuously monitored for errors or warnings of impending issues. The system validates the data at transfer and also uses idle time to read data and monitor drives. During data and drive monitoring, the director checks the data correction bits for validity.

If a drive read error occurs, the director:

1. Reads all data on that track to Symmetrix system physical memory.

2. Tests the drive track for errors.

3. Rewrites the data from physical memory back to the drive.

The system maps around any bad block(s) detected during the test, thereby avoiding defects in the media. If necessary, the system can reallocate a maximum of 32 blocks of data on that track. To further safeguard the data, each drive (both hard disk and flash-based) has several spare cylinders available. If the number of bad blocks per track exceeds 32 blocks, the director rewrites the data to an available spare cylinder. The director increments an error counter for each bad block detected. If the error threshold is reached and/or the spare pool is close to being consumed on either a hard drive or a flash drive, the Symmetrix service processor automatically contacts EMC Customer Support to arrange for corrective action or replacement.

RAID DATA PROTECTION OPTIONS

Symmetrix systems provide a range of RAID protection options to meet different performance, availability, and cost requirements. RAID protection options are configured at the physical drive level. Symmetrix systems support varying levels of protection including RAID 1, CKD RAID 10, RAID 5 (3+1 and 7+1), and RAID 6 (6+2 and 14+2). RAID 6 protection allows for failure of two drives per RAID group, which makes it ideal for large SATA drives. Different levels of RAID protection can be easily configured with different datasets within a Symmetrix VMAX system. EMC strongly recommends that you use one or more of the RAID data protection schemes for all data volumes.

SYMMETRIX RAID OPTIONS

RAID Option	Provides the Following	Configuration Considerations
Mirroring (RAID 1)	The highest level of performance and availability for all mission-critical and business-critical applications. Maintains a duplicate copy of a volume on two drives: • If a drive in the mirrored pair fails, the Symmetrix system automatically uses the mirrored partner without interruption of data availability. • When the drive is (non-disruptively) replaced, the Symmetrix system re-establishes the mirrored pair and automatically re-synchronizes the data with the drive. • When a drive fails, there is always a full copy of the data available for host use (no rebuild is required to provide the data to the host). • While both drives in a mirrored pair are operational, Symmetrix will employ its Dynamic Mirror Sharing Policy to utilize both drives to support read I/O requests, thereby increasing the effective performance over other RAID protection types.	Withstands a drive failure within the mirrored pair. A drive rebuild is a simple copy from the remaining drive to the newly replaced drive. The number of required drives is twice the amount required to store data (usable storage capacity of a mirrored array is 50 percent).
Symmetrix RAID 10	A combination of RAID 1 (mirrored) and RAID 0 (striping with no data protection) used for mainframe environments. RAID 10 allows four Symmetrix system devices (each one-fourth the size of the original IBM device) to appear as one IBM device to the host, accessible by way of one host address. Any four devices can be chosen to define a group provided they are equally sized, the same type (for example, all 3390), and have the same mirror configuration.	Withstands a drive failure within the mirrored pair. A drive rebuild is a simple copy from the remaining drive to the newly replaced drive. The number of required drives is twice the amount required to store data (usable storage capacity of a mirrored array is 50 percent).
RAID 5	Distributed parity and striped data across all drives in the array. A dedicated parity drive is not required. Options include: • RAID 5 (3+1)—Consists of four drives with data and parity striped across each device. • RAID 5 (7+1)—Consists of eight drives with data and parity striped across each device.	RAID 5 (3+1) provides 75 percent usable data storage capacity. RAID (7+1) provides 87.5 percent usable storage capacity. Withstands failure of a single drive within the RAID 5 group.
RAID 6	Striped drives with double distributed parity (horizontal and diagonal). Options include: • RAID 6 (6+2)—Consists of eight drives with dual parity and data striped across each device. • RAID 6 (14+2)—Consists of 16 drives with dual parity and data striped across each device. • Affords the highest availability and resiliency to drive failures, protecting against data loss during both single- and dual-drive failures.	RAID 6 (6+2) provides 75 percent usable data storage capacity. RAID 6 (14+2) provides 87.5 percent usable storage capacity. Withstands failure of two drives within the RAID 6 group.

PERMANENT SPARING

Permanent sparing is an automated, self-healing process that replaces a failing drive with a spare standby drive. A configuration change is automatically made converting the new drive into the permanent replacement. A Symmetrix system initiates sparing when certain errors are detected, thereby reducing the amount of time that a failed or failing drive remains active in the system. Sparing replaces a failing drive with a spare drive through a permanent configuration change. Sparing is used in conjunction with data protection RAID 1, RAID 5, RAID 6, and SRDF. The Symmetrix VMAX system features immediate sparing of drives for the highest system availability. Suggested standard practice for hard drive sparing include two spare drives per 100 drives, per drive type, with a minimum of eight spare drives in a system. Best practice is to have at least eight of each drive type as spares in every system.

SYMMETRIX DATA AT REST ENCRYPTION

Symmetrix Data at Rest Encryption utilizes Data Encryption Keys to encrypt/protect data on drives within a VMAX array. Symmetrix Data Encryption reduces security risks when drives are removed from an array (because of normal drive replacement or possibly media theft) and when arrays are repurposed. Compliance with industry encryption or confidentiality requirements can also be satisfied with this solution. The data protection mechanism is a "set-and-forget" feature for the entire VMAX array that is enabled at array installation.

Encryption keys are managed from a key server and secure repository that resides on the VMAX service processor, with no key management required of the end user. Three copies of the encryption keys are kept on the VMAX for redundancy and recoverability, and all three key copies are themselves securely encrypted. There is a different encryption key for each drive in the VMAX, and the VMAX array does not require specialized encryption enabled drives. Enterprise Flash drives, Fibre Channel, and SATA drive types are all supported.

The encryption process occurs on Disk Adapter Serial Link hardware (SLIC). The encryption chip has been designed to fully support the back-end bandwidth in an identical fashion to existing non-encrypting back-end SLICs. This specialized hardware ensures that there is no performance overhead associated with the VMAX encryption solution. Encryption on the drive is performed using the 256 bit AES-XTS fixed-block cipher standard and is fully transparent to all applications and Symmetrix functionality (all data leaving the array is unencrypted for maximum data protection; host-based, application-based, and/or I/O channel-based security should also be deployed). Encrypted drives are only readable when installed into the proper position in the correct VMAX array—every drive in every array will have its own unique key. Encryption keys are managed by an embedded RSA Key Manager and cannot be removed, relocated, or even viewed for maximum protection. All data formats are supported (open system: FBA, mainframe: CKD, and iSeries), and the encryption is compatible with every drive type that Symmetrix VMAX supports (Flash, Fibre Channel, SAS, and SATA).

BUSINESS CONTINUITY SOFTWARE

EMC Symmetrix has been the leader in providing the most robust suite of software for business continuity for more than a decade. The TimeFinder and Symmetrix Remote Data Facility (SRDF) families of local and remote replication solutions deliver the most comprehensive and robust suite of replication solutions available in the marketplace, providing high performance, a wide range of deployment options, and an industry-proven architecture. The TimeFinder and SRDF solutions enable organizations to balance performance, availability, functionality, and economic requirements to achieve required service levels for local and remote disaster recovery and business continuity. More detail on the TimeFinder and SRDF families is provided in the next chapter.

SUMMARY

Binding service-level agreements commit IT organizations to deliver stipulated, measurable support metrics such as application performance, end-user response time, and system availability. Even in the absence of such SLAs, IT executives universally recognize that downtime can have disastrous ramifications in lost revenue, dissatisfied customers, and missed opportunities. For more than two decades, Symmetrix systems have been the gold standard for data integrity and availability in enterprises of all sizes. The Symmetrix VMAX architecture raises the bar even higher with enhanced availability features in every aspect of system design. With key enhancements to a proven architecture, Symmetrix VMAX systems are the logical choice for enterprises requiring only the most uncompromising levels of data and system availability for their high-end storage environments.

CHAPTER 4: THE ENGINUITY OPERATING ENVIRONMENT

The EMC Enginuity operating environment for Symmetrix provides the intelligence that controls all components in an EMC Symmetrix storage array. Enginuity is an intelligent, multi-tasking, preemptive storage operating environment (SOE) that controls storage data flow.

It is wholly devoted to storage operations and optimized for the service levels required in high-end environments. While it shares many traits with the operating systems typically used to run large host computers, Enginuity is more specialized and specifically optimized for storage-based functions. It is driven by realtime events related to the input and output of data. It applies self-optimizing intelligence to deliver the ultimate performance, availability, and data integrity required in a platform for advanced storage functionality.

Foundation—Enginuity is the core intelligence to manage multiple shared resources across Symmetrix systems. It ensures investment protection and consistency over time in technology and operational processes. It provides built-in security capabilities while insulating powerful storage applications from technology changes.

Performance—Utilizing patented intelligent adaptive algorithms to manage data flow across channels, memory, and drives, Enginuity dynamically controls events in complex and highly variable environments to maximize application performance under any load.

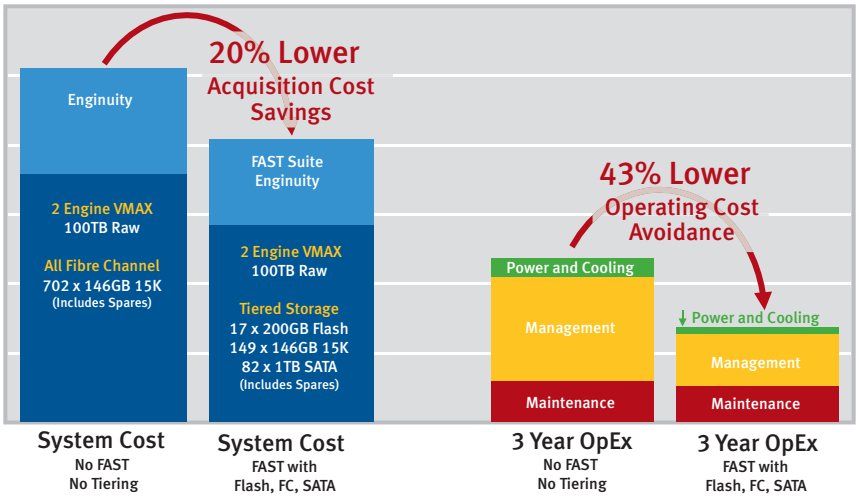
Availability—Enginuity manages data integrity through continuous checking of all data and hardware—from host, to memory, to drive, and back again. This includes trend analysis and early detection as well as automatic failover and escalation when a problem does occur.

Open integration—EMC maintains the industry's broadest, deepest, and most exhaustive storage networking interoperability program for hardware and software. In addition, by using openly available application programming interfaces (APIs) and supporting SMI-S industry standards, EMC has enabled hundreds of independent software vendor applications to run on Symmetrix. Even the latest Symmetrix VMAX systems are ready from the start, accessible through robust APIs and assured interoperability.

TIERED STORAGE OPTIMIZATION

FULLY AUTOMATED STORAGE TIERING (FAST)

Fully Automated Storage Tiering lowers overall storage costs while simplifying management of storage infrastructure. EMC's FAST technology automates the dynamic allocation and relocation of data across storage tiers based on the changing performance requirements of applications. FAST helps customers maximize the benefits of in-the-box tiered storage by optimizing cost and performance requirements to put the right data, on the right tier, at the right time.



Symmetrix VMAX with FAST Suite lowers acquisition and operational costs

Symmetrix: 100 TB Example—Lowering Costs with FAST

FAST for full LUN proactively monitors workloads and automatically moves heavily used data to higher performing Enterprise Flash drives and the less frequently accessed data to higher capacity drives (SATA). FAST does this dynamically and non-disruptively without affecting business continuity and availability.

FAST VP monitors VP LUN utilization and moves the busiest thin extents to appropriate VP pools located on various drive technologies. It also moves underutilized thin extents to pools located on high-capacity drives. Because the unit of analysis and movement is measured in thin extents, this sub LUN optimization is precise and efficient.

With FAST, and especially FAST VP, customers can reduce their storage total-cost-of-ownership in multiple dimensions:

- **Reduced acquisition costs for performance** ($/IOPS) by using a small number of Enterprise Flash drives (EFDs) to deliver IOPS levels that today require large numbers of short-stroked hard drives (HDDs) at response times far lower than attainable by HDDs
- **Reduced acquisition costs for capacity** ($/GB) by utilizing more SATA capacity for infrequently used data
- **Reduced operating costs** because the combination of EFDs and SATA enables customers to meet their capacity and performance requirements by using significantly fewer drives and reduced power, cooling, and floor space requirements
- **Reduced management costs** because storage administrators, server administrators, and database administrators each spend less time monitoring and optimizing their IT infrastructures, due to the automation provided by FAST

DYNAMIC CACHE PARTITIONING

Dynamic Cache Partitioning is a Symmetrix feature that allows the allocation of portions of cache to specific application groups, making performance more predictable. A maximum of eight separate cache-partitioned groups can be configured. Cache-partitioned groups are monitored by the Symmetrix system to ensure that they do not consume more cache than they are allotted. Cache partitions can either be dynamic or static. Dynamic cache partitions allow the temporary donation of unused cache to other partitions after a specified donation time. Static partitions remain fixed in size and are often charged back to that particular application.

SYMMETRIX PRIORITY CONTROLS

Symmetrix Priority Controls enhance tiered storage management by allowing prioritization of host application read I/O and SRDF/S transfers by assigning a priority level to specific device groups. Symmetrix Priority Controls allow up to 16 user-defined priority levels. The task's priority level determines the task's position in the queue. During non-peak periods and periods of lower utilization, all queued requests are satisfied in a timely manner, even if they are assigned a low priority. It is only when the drive or SRDF/S transfer is "in demand" that service differentiation occurs.

ENHANCED VIRTUAL LUN TECHNOLOGY

Enhanced Virtual LUN technology, a feature of Symmetrix Optimizer, enables users to non-disruptively relocate volumes to different tiers and different RAID types transparently to the host, and without impact to local or remote replication. Migrations can be performed with traditional fully allocated volumes to either existing or new volumes. Once the data transfer has been completed, the physical space previously associated with the migrated volume will be returned to a free state. With existing volumes, the data is erased from the physical space and left configured for re-use. Migrations can also be performed with thin (virtually provisioned) volumes. VP volume movement occurs from one VP pool to another VP pool. Migrations between VP pools can also include changes to RAID scheme and drive type.

Open systems, mainframe, and IBM i (formerly iSeries) volumes, as well as metavolumes, can be migrated with Virtual LUN technology. There is no architectural limit to the number of volumes or the number of parallel operations that can be active, but Enginuity enforces a resource consumption cap to assist balancing this task with other workloads. Enginuity enables up to 16 concurrent migrations without significantly impacting system performance.

With Virtual LUN technology, users can maintain a storage consolidation strategy with the assurance that they can dynamically reallocate resources based on changing requirements. The ability to move data in this manner creates great flexibility in achieving price/performance ratios throughout the data lifecycle.

SYMMETRIX VIRTUAL PROVISIONING

One of the biggest challenges facing storage administrators today is provisioning storage for new applications. First, to meet performance requirements, administrators typically invest significant time planning the layout of the volumes. Then they allocate space based on the anticipated future growth of the applications. This is done to mitigate recurring operational functions, such as incrementally increasing storage allocation or adding new storage as existing space is consumed. Using this approach results in more physical storage being allocated to the application than is needed for a significant amount of time, resulting in higher storage costs. This over-provisioning of physical storage also leads to increased power, cooling, and floor space requirements. Even with the most careful planning, it often will be necessary to provision additional storage for the application in the future, which is a time-consuming and cumbersome process.

Symmetrix Virtual Provisioning, sometimes referred to as thin provisioning, simplifies storage management. Data layout becomes faster and easier as automated wide striping provides similar or potentially better performance with less planning and labor. Virtual Provisioning also reduces the steps required to accommodate future growth when additional capacity is required. Administrators simply add capacity to the virtually provisioned storage pool without needing to step through the mapping and masking process again, provided a sufficiently large VP volume was created at the outset.

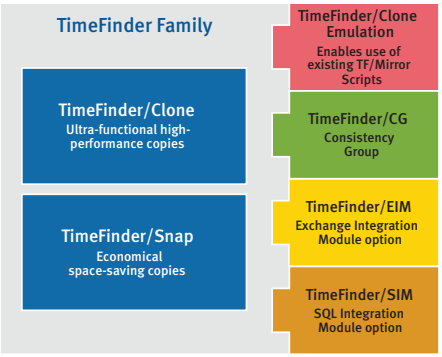
Virtual Provisioning also improves capacity utilization by allowing more storage to be presented to an application than is physically available. More importantly, Virtual Provisioning can allocate physical storage only when data is actually written to the volume. This enables greater flexibility in predicting future growth, reduces the initial costs of provisioning storage to an application, and can reduce the inherent waste in over-allocation of space and the administrative management of subsequent storage allocations. Costs can be reduced further with wide striping because hot spots are reduced and drive resources are used more efficiently, enabling users to meet performance requirements with higher capacity, more economical drives.

Users can non-disruptively rebalance workloads in order to extend VP pool capacity in small increments, as needed, protecting performance and minimizing TCO. In addition, VP pools can be shrunk non-disruptively, efficiently reusing the space. Mobility is now greatly improved with "thick-to-thin" replication with TimeFinder/Clone, which replicates standard volumes to VP volumes "sparsely" to ensure only host-written tracks are copied. This reduces capacity requirements and TCO. In addition, space reclamation returns all-zero chunks (also known as extents) to VP pools from volumes that have been copied over by other tools such as Open Replicator and SRDF.

Virtually provisioned volumes are built using the same familiar methods of managing and replicating Symmetrix systems that customers use today. For Symmetrix VMAX systems, virtually provisioned pools support all tiers and RAID levels with simultaneous local and remote replication including TimeFinder, SRDF, Open Replicator, and Open Migrator. Virtual Provisioning can be managed flexibly by either the command line interface or Symmetrix Management Console. Virtual Provisioning is also supported by the ProSphere family. As an example, ProSphere StorageScope™ could monitor and forecast the consumption of virtually provisioned drive space.

BUSINESS CONTINUITY SOLUTIONS—LOCAL AND REMOTE REPLICATION

The EMC TimeFinder and Symmetrix Remote Data Facility (SRDF) families of software are the most powerful suites of local and remote storage replication solutions available in the industry. They enable business continuity volumes for parallel processing activities like backup, testing and development, and local restore, as well as remotely replicated copies to guard against primary site disasters and outages. In fact, the TimeFinder and SRDF families are the most widely deployed set of local and remote replication solutions in the industry and are installed in tens of thousands of demanding environments worldwide.



LOCAL REPLICATION—THE TIMEFINDER FAMILY

The EMC TimeFinder family of software provides a local copy of data, independent of the host and operating system, application, and database. The TimeFinder family of local copy software is the most field-proven, widely deployed, array-based, point-in-time solution in the world with tens of thousands of licenses shipped. Leveraging the industry-leading, high-end Symmetrix system, TimeFinder offers the most choice and flexibility to meet any service-level requirement, all while enabling you to control or reduce costs for increased competitive advantage.

- **TimeFinder/Clone**: Creates a high-performance, full-volume, independent host-addressable, local point-in-time copy of a Symmetrix production device. This allows up to 16 active clones of a single production device, all of which are immediately available for both read and write access. These Clone BCVs support all RAID protection types, including RAID 5 and/or RAID 6 protection schemes.
- **TimeFinder/Snap**: Creates a high-performance, space-saving, independent host-addressable, logical, local, point-in-time copy of a Symmetrix production device, and allows up to 128 active snapshot copies of a single production device which are immediately available for both read and write access. These Snap BCVs support all RAID protection types, including RAID 5 and/or RAID 6 protection schemes. Snap copies can also be taken from another Snap source, adding even more space savings and flexibility to this track-sharing technology.
- **TimeFinder/Consistency Groups**: Ensures dependent-write consistency of the application data when creating a point-in-time image across multiple devices associated with an application within a single Symmetrix system or applications that also span multiple Symmetrix systems.
- **TimeFinder/Exchange Integration Module and TimeFinder SQL Integration Module**: Integrates the TimeFinder family with Microsoft Exchange and SQL applications for automated backup and restore.

THE EMC SRDF FAMILY OF REMOTE REPLICATION SOLUTIONS

The EMC Symmetrix Remote Data Facility (SRDF) family of software is the most powerful suite of remote storage replication solutions available for disaster recovery and business continuity. Fully leveraging the industry-leading, high-end Symmetrix hardware architecture, it offers unmatched deployment flexibility and massive scalability to deliver a wide range of distance replication capabilities to meet mixed service-level requirements with minimal operational impact. The field-proven SRDF family is the most widely deployed set of high-end replication solutions, with tens of thousands of installations in the most demanding environments. In addition, only the SRDF family can provide cross-volume and storage system consistency, tight integration with industry-leading applications, and simplified usage through automated management.

The SRDF family of solutions provides a host-independent, data replication solution that duplicates production data on one or more physically separate target Symmetrix systems—across the room, across the globe, or anywhere in between. Many SRDF enhancements are available with Symmetrix VMAX systems such as an increase to 250 SRDF groups from the previous maximum of 128.

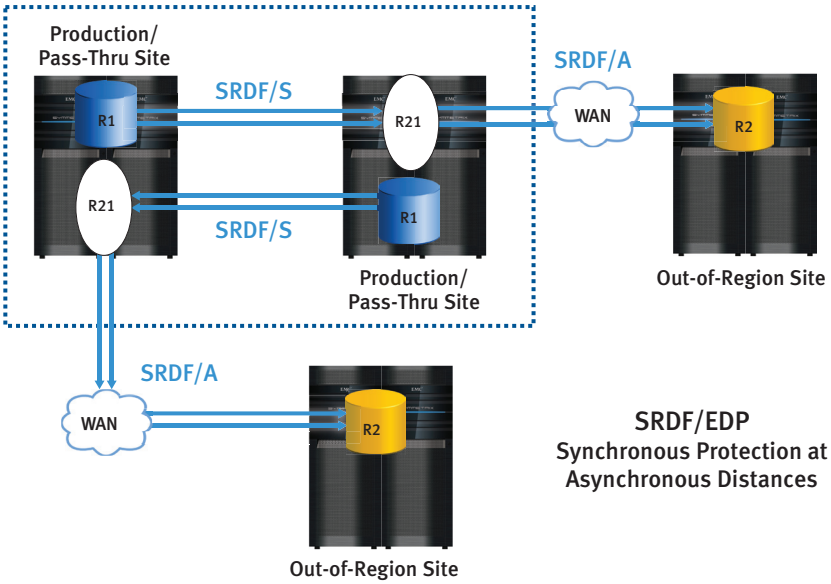
Use the SRDF family to:

- Realize 365x24x7 revenue generation and customer service capabilities for increased competitive advantage
- Recover business data from disruptive outages in minutes
- Perform scheduled backups, data warehouse loading, and application testing without disrupting operations

- Migrate data between sites quickly and non-disruptively, supporting data center consolidation and site workload reallocation
- Test disaster recovery plans without business interruptions or manually intensive recovery drills

EMC SRDF BASE PRODUCTS

- **SRDF/Synchronous (SRDF/S)**: Maintains a realtime synchronized mirror of a Symmetrix production data device to a secondary site Symmetrix data device, providing a recovery-point-objective of zero data loss.
- **SRDF/Asynchronous (SRDF/A)**: Maintains a near-realtime synchronized mirror of a Symmetrix production data device to a secondary site Symmetrix data device, providing a recovery-point-objective that could be as minimal as a few seconds.
- **SRDF/Data Mobility (SRDF/DM)**: Provides for the transfer of a Symmetrix production data device to a secondary Symmetrix data device that can be at any distance, permitting information to be periodically mirrored for disaster restart, information sharing for decision support or data warehousing activities, or for data migration.



SRDF/Extended Distance Protection—Bi-directional Topology

EMC SRDF ADVANCED TOPOLOGIES AND CAPABILITIES

- SRDF/Extended Distance Protection (SRDF/EDP)—new with Symmetrix VMAX series: SRDF/EDP is a new two-site disaster recovery solution that enables customers to achieve a zero recovery-point-objective in the event of a primary site failure. SRDF/EDP is a configuration similar to Cascaded SRDF which replicates data from a primary site (site A) to a secondary site (site B) in Synchronous mode, and then "cascades" it from the secondary site to an out-of-region, extended-distance, tertiary site (site C) in Asynchronous mode of replication. In SRDF/EDP, the secondary site B system does not contain a full data copy; instead it only retains the changed tracks received from site A that are buffered in cache and then sent to site C. The volumes configured in site B are called Driveless R21 volumes, which have dual roles of primary (R1) and secondary (R2) volumes, similar to the Cascaded SRDF R21 volumes. These volumes have no local drive space allocated to store user data.
- Concurrent SRDF/A—new with Symmetrix VMAX series: Concurrent SRDF/A expands the SRDF multisite topology offering by allowing two separate asynchronous links from a Symmetrix VMAX to Symmetrix systems located at remote data centers. This configuration exploits the core benefits of SRDF/A for improved application response times while replicating at extended distances. VMAX offers the flexibility to change Concurrent SRDF/S

and SRDF/A disaster restart topologies to Concurrent SRDF/A and SRDF/A. Such flexibility is designed to:
  – Meet performance goals during planned and known workload spike periods
  – Offer a new migration option for data center relocation
  – Provide additional disaster restart protection

- **SRDF/Star**: In SRDF Cascaded, Concurrent, or EDP topologies, SRDF/Star enables the differential resynchronization of the remaining two surviving sites in the event the primary production site suffers an unplanned outage. This differential resynchronization capability eliminates the need for full-copy operations and enables the environment to reach a protected state in a shorter time period.

- **SRDF/Automated Replication (SRDF/AR)**: Enables rapid disaster restart over any distance with a two-site, single-hop option using SRDF/DM in combination with TimeFinder or a three-site, multi-hop option used in combination with SRDF/S, SRDF/DM, and TimeFinder.

- **SRDF/Cluster Enabler (SRDF/CE)**: Enables automated or semi-automated site failover using SRDF/S or SRDF/A with Microsoft Failover Clusters. SRDF/CE enables Windows Server 2003 and Windows Server 2008 Enterprise and Datacenter editions running Microsoft Failover Clusters to operate across a single pair of SRDF-connected Symmetrix arrays as geographically distributed clusters.

- **SRDF/Consistency Groups (SRDF/CG)**: Ensures application-dependent write consistency of the application data being remotely mirrored by SRDF in the event of a rolling disaster—across multiple Symmetrix systems or across multiple devices within a Symmetrix—providing for a business point of consistency for remote site disaster restart for all identified applications associated with a business function.

- **EMC GDDR AutoSwap™ with SRDF/S**: Ensures continuous availability in z/OS and z/VM environments. AutoSwap transparently moves application workloads from drives in one Symmetrix system to drives in another with no disruption to operations.

GEOGRAPHICALLY DISPERSED DISASTER RESTART

Geographically Dispersed Disaster Restart (GDDR) is an automated solution for disaster restart in mainframe environments, including host systems, applications, and EMC Symmetrix systems. It offers protection automation for both planned and unplanned outages by automatically restarting a remote system's hosts, applications, and storage.

GDDR is used in three-site and two-site scenarios. It is a mandatory requirement for all three-site SRDF/Star deployments to automate disaster restart. GDDR effectively mitigates against human error in scripts and operations, eliminates single points of failure in the disaster restart process, and offers a proven and tested solution with an overall lower total-cost-of-ownership (TCO).

GDDR manages and is responsible for the multiple work streams involved in restart during planned and unplanned outages. GDDR includes an expert system used to dynamically determine the sequence of operations for both planned and unplanned state transitions. GDDR actions are dynamically determined based on the customer's chosen configuration and the detected or planned event in progress. With GDDR, mainframe customers have a proven product/solution that is regression tested and ensures the restart process works as planned when an outage occurs.

CHAPTER 5: DATA MIGRATION OPTIONS

Data migration can be defined as the one-time movement of data from a source to a target, whereby the data will subsequently only be accessed at the target. The key to this definition is that for any particular piece of data, this is a one-time movement. This one-time movement differentiates data migration from data replication which enables applications to continue to access the source data after the target copy is created. Also, the one-time movement differentiates data migration from data mobility which entails ongoing incremental data updates.

After a migration operation, applications that access the data must reference the data in its new location. Therefore, part of the migration solution is the methodology used to point applications to the new data location, also known as application cutover. Few applications have been designed with the ability to continue processing during the application cutover process. EMC has developed software tools and methodologies to make the migration transparent to applications.

Data Migration for Technology Refresh

There are many types and reasons for data migration:

- Moving data from one storage device to another
- Moving applications from one storage device to another
- Migrating operating systems files from one storage device to another
- Consolidating data or database instances
- Migrating database instances
- Migrating data centers containing storage infrastructure from one physical location to another

Additional factors and options to consider when planning and executing a data migration include the business impact and the type of data to be migrated, the site location(s), the number of systems and applications, and the total amount of data, as well as time considerations and schedules.

EMC has several tools and services to satisfy different data migration goals.

OPEN REPLICATOR

EMC Open Replicator for Symmetrix enables remote point-in-time copies to be used for data mobility, remote vaulting, and migration between EMC Symmetrix and qualified storage arrays with full or incremental copy capabilities. Open Replicator can pull data from source volumes on qualified remote arrays to a Symmetrix target volume or push live source Symmetrix volumes to a target volume on a qualified array with incremental updates. These online data migrations provide minimal disruptions to host applications.

The Symmetrix system, where Open Replicator is being managed, and its devices are referred to as the "control" side of the copy operation. Other Symmetrix arrays, EMC CLARiiON® arrays, or third-party arrays on the SAN are referred to as the "remote" array and devices. Open Replicator has two modes of operation: cold (offline) and hot (online). Online or offline refers to the state of the Symmetrix-resident devices (control devices). In both scenarios, the remote devices should be offline to the host connected to the remote array. Open Replicator supports two types of copy operations—"push" and "pull." A push operation copies data from the control device to the remote device. I/O is permitted against

the source volume during the push operation. A pull operation copies data to the control device from the remote device. With Enginuity 5875 for VMAX, zero space reclamation for Open Replicator (OR) improves space efficiency by stripping out the all-zero blocks as they are being copied into a VP device when migrating from Symmetrix DMX, CLARiiON, and third-party arrays to VMAX.

SRDF/DATA MOBILITY (SRDF/DM) AND ADAPTIVE COPY

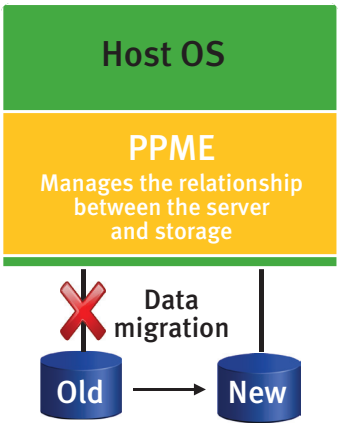
The SRDF/DM product offering permits operation in SRDF adaptive copy mode only, and is designed for data replication or migration between two or more Symmetrix systems. SRDF/DM transfers data from primary volumes to secondary volumes permitting information to be shared, content to be distributed, and access to be local to additional processing environments. Adaptive copy mode enables applications using that volume to avoid propagation delays while data is transferred to the remote site. SRDF/DM supports all Symmetrix systems, and all Enginuity levels that support SRDF, and can be used for local or remote transfers.

Adaptive copy modes facilitate data sharing and migration. These modes enable the primary and secondary volumes to be more than one I/O out of synchronization. There are two adaptive copying modes: adaptive copy write-pending (AW) mode and adaptive copy drive (AD) mode. Both modes enable write tasks to accumulate on the local system before being sent to the remote system.

With adaptive copy write-pending mode, write tasks accumulate in Symmetrix global memory. A background process moves, or destages, the write-pending tasks to the primary volume and its corresponding secondary volume on the other side of the SRDF link. The advantage of this mode is that it is faster to read data from global memory than from the drive, thus improving overall system performance. An additional advantage is that the unit of transfer across the SRDF link is the updated blocks rather than an entire track, which results in more efficient use of SRDF link bandwidth. The disadvantage is that global memory is temporarily consumed by the data until it is transferred across the link. Consequently, adaptive copy write-pending mode should only be used when detailed information about the host write workload is fully understood.

EMC POWERPATH MIGRATION ENABLER (PPME)

PowerPath Migration Enabler (PPME) is a host-based migration product that migrates data between storage systems. PPME takes advantage of PowerPath technology and works in conjunction with another underlying technology, such as Open Replicator or EMC Invista®, to actually migrate the data. PPME provides a host-based solution with virtually no impact to host resources by utilizing array-based or SAN-based replication. PPME benefits data migrations in three significant ways: by greatly reducing or eliminating application disruption due to the migration, reducing migration risk, and simplifying migration operations. PowerPath Migration Enabler is independent of PowerPath multipathing technology and does not require that PowerPath is used for multipathing.



PowerPath Migration Enabler—Non-disruptive Data Migration

BENEFITS OF USING PPME

As discussed previously, redirecting the application(s) to point to the migrated data in its new location will require an application outage unless this is done transparently to the application or PPME is utilized. PPME enables a transparent operation, so the cutover to the migrated data does not require an application outage. Depending on the host type and the use of pseudo- or native-named devices, this complete elimination may not always be possible. Additionally, if PowerPath 5.0 is not already installed on the host, a planned application outage must occur for the reboot necessary to install or upgrade PowerPath.

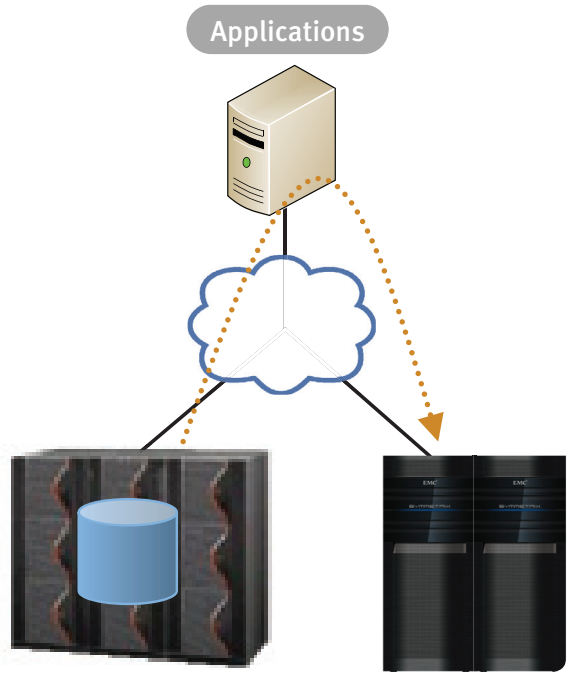
Even if PPME cannot entirely eliminate application outages, it greatly minimizes them and reduces data migration risk. For example, the interruption for installing PowerPath 5.0 can be scheduled to take place during normal maintenance windows prior to the actual migration process. Complex migrations almost always will require certain setup activities for the migration, like updating HBA drivers, to be conducted during scheduled maintenance windows when the host will need to be rebooted. There is a great difference between this type of small activity as part of a maintenance window and more risky procedures that have to be conducted when PPME is not used. One example of a risky procedure not needed when PPME is used is the potentially catastrophic cutover outage in which a machine is shut down, a few configuration changes are made, and hopefully the machine comes back up without issue. With PPME, the cutover task is fully verified before being performed and can sometimes be conducted fully online. I/O redirection enables administrators to preview deployment without committing to it. With PPME, in all cases the data remains accessible to host applications during the migration itself.

Eliminating or even just reducing application downtime during a migration greatly simplifies the planning for large-scale migrations. Migration window flexibility is important to the administrators themselves as this simplifies the migration planning process. They do not have to rely on others to follow their directions, nor do they need to work off their shifts when migrations need to be done. The pressure to correctly complete critical and complex migration tasks during outages or off-hours is reduced or eliminated.

PPME greatly simplifies migration operations, hiding the complexities of underlying migration products and integrating with the host. This simplification is even more important in providing a common interface across heterogeneous hosts, eliminating the host-specific knowledge required to perform key migration tasks. The simplicity that PPME brings to migration operations may even enable less-skilled and less-expensive staff to execute the work.

OPEN MIGRATOR/LM

EMC Open Migrator/LM enables online data migration of Microsoft Windows, UNIX, or Linux volumes between any source and EMC storage. Open Migrator/LM host-based software boosts the efficiency of the entire information infrastructure by automating and simplifying data migration. Whether consolidating servers, upgrading storage, or tuning performance, volumes stay online and are fully available to critical applications during migration. In addition, host applications continue operating at peak performance.



Online Migrations with EMC Open Migrator/LM

FEDERATED LIVE MIGRATION

Federated Live Migration enables data movement from an older Symmetrix to a Symmetrix VMAX system running without downtime to applications, and no requirement to load virtualization software. This feature moves data between the Symmetrix arrays and PowerPath, or other multi-pathing solutions, to manage host access to the arrays while the migration is taking place. Federated Live Migration permits a device in the VMAX array to “impersonate” a device in an old Symmetrix array, making it assume the complete identity and geometry of the old device, and then performing a hot pull, donor update operation. Impersonation can be maintained indefinitely or removed at a time convenient for the host.

Federated Live Migration handles data movement between arrays, however it does not automatically set up the required SAN zones. Zoning from the application hosts to the new storage array and from the old storage array to the new storage array is a user manual task, as is removing old zones when the migration is complete.

CHAPTER 6: MANAGEMENT AND OPERATIONS

The Symmetrix VMAX system provides a management abstraction whereby physical resources are optimized to provide optimal levels of performance, capacity utilization, and seamless mobility. Inherent in the Symmetrix VMAX Architecture is the ability to scale-out and consolidate storage for heterogeneous environments. This could mean that a typical Symmetrix VMAX array could have thousands of virtual LUNs serving hundreds of applications.

To simplify management and operations in Symmetrix VMAX system environments, EMC has four offerings:

- **Symmetrix Management Console (SMC)** is an intuitive, web-based interface used to discover, monitor, configure, and control Symmetrix arrays. SMC provides a web interface to use many of the Solutions Enabler command line interface (CLI) operations. The SMC is purpose-built to manage the scale-out architecture of the Symmetrix VMAX system, and an SMC instance can manage up to 10 Symmetrix arrays.
- **Symmetrix Performance Analyzer (SPA)** is launched from the Symmetrix Management Console and provides a view of the key performance indicators for the Symmetrix arrays. SPA is a tool that can be used to effectively manage storage growth and forecast the resources required to support the growth.
- **EMC z/OS Storage Manager (EzSM)** provides a host view of storage using the familiar ISPF screens in mainframe environments. With EzSM, the storage administrator can view all storage arrays that are connected to the mainframe host, regardless of their physical locations. EzSM manages TimeFinder and SRDF replication as well as views Symmetrix configuration.
- **EMC Virtual Storage Integrator (VSI) for VMware vSphere** provides the user with a view of the relationships between VMware virtual machines, disk files, datastores, and underlying EMC storage devices on the Symmetrix VMAX.

SYMMETRIX MANAGEMENT CONSOLE

SMC provides ease-of-use functionality to manage the overall scalability, mobility, tiering, and consolidation capabilities of the Symmetrix VMAX series. Some new functionality introduced to support Symmetrix VMAX scale-out architecture includes the following:

- Storage templates are a re-usable set of storage requirements that simplifies Symmetrix VMAX series storage provisioning by eliminating repetitive tasks. For example, in a typical organization, specific applications might have common requirements for storage. A payroll application might require storage of 40 GB, RAID-5 3+1, FBA emulation, and FC drives with Dynamic SRDF. The storage template will allow the storage administrator to set this template up and continue re-using it as needed. Additionally, once the template is set up, an administrator can request the SMC to "Find Existing," "Create," or "Best Effort" storage. The SMC will automatically search through the array and find the storage as per the storage template. This functionality reduces complexity and the overall effort in creating storage for new applications on demand. With storage templates, dozens of low-level Symmetrix commands occur automatically.
- SMC wizards streamline the tasks of configuring some key features on the Symmetrix VMAX array. Features such as FAST, auto-provisioning groups, virtual LUN migration, (SRDF), and SRDF Migration have wizards that walk the user through the setup. For example, auto-provisioning groups enable a storage administrator to set up a masking view associating hosts, storage ports, and storage groups. Once the masking view is set up, the mapping and masking is automatically executed by the Symmetrix VMAX array at a group level. The masking wizard in SMC walks administrators through the process of creating a masking view by helping them identify the hosts, storage ports, and storage groups. For FAST, an SMC FAST wizard is provided to create storage types and FAST policies and associate to the respective applications (storage groups).

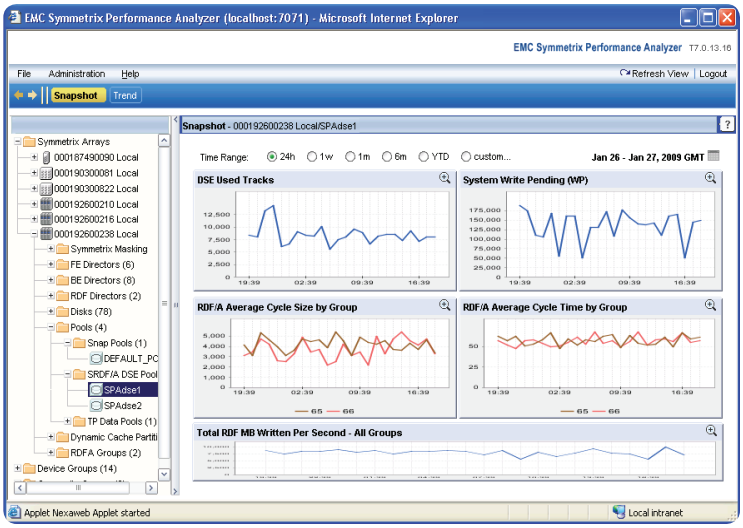
- The device filtering capability enables a storage administrator to create filters in order to search for devices. A single Symmetrix VMAX series instance can have thousands of devices or elements. When an administrator wants to search for a specific device in the array, the device filter will help the administrator identify the properties of the device, and it will automatically identify devices that meet that criteria. This functionality tremendously narrows the search for target devices eliminating the need to search through thousands of devices.
- SMC offers the ability to initiate a health check script on the VMAX array. SMC can provide extensive hardware verification prior to activities such as configuration changes or migrations, enabling scheduled activities to proceed with confidence in the hardware baseline. This SMC health check offers instant gratification for confirmation of array health status with no reliance on EMC support staff.
- With SMC, the commonly used tasks in managing a Symmetrix VMAX or DMX series are available for quick access in a single pane or task menu. This greatly simplifies access to these commonly used tasks and provides an additional level of ease-of-use when managing in large and complex data center environments. The tasks are categorized under the main headings of Setup, Administration, Security, Report, User Preference, and Wizard.

SMC is capable of supporting mixed host environments from open systems to mainframe. SMC can run on the service processor managing the single instance of the array, providing a flexible deployment option in mainframe environments. Additionally, with SMC, the the storage administrator can download Enginuity software directly from EMC Powerlink to service processor, and search the EMC Knowledgebase for uptime bulletins and release notes.

In addition to the newly introduced functionality, SMC enables initial system discovery and configuration scaling to manage up to 10 Symmetrix arrays. The navigation to manage multiple arrays is provided in a simple tree view with the ability to expand the view as needed to drill down to the various elements. SMC also has monitoring capabilities that enable the storage administrator to monitor replication and QOS functionality. Other software functionality managed by SMC includes Dynamic Cache Partitioning (DCP), Symmetrix Priority Controls (SPC), and Symmetrix Optimizer.

SYMMETRIX PERFORMANCE ANALYZER

Symmetrix Performance Analyzer is launched from the Symmetrix Management Console and provides a view of the key performance indicators for the Symmetrix arrays. SPA can collect data in real time and has a diagnostic mode to drill down to device-level performance views. SPA provides snapshot and trend views and enables the administrator to choose the time period of interest for analysis, i.e., 24 hours, one week, one month, etc. SPA provides a view of various group levels such as masking view, composite group, storage group, device groups, and disk groups. SPA is a tool that can be used to effectively manage storage growth and forecast the resources required to support that growth including array resources used on internal replication. SPA can trend future performance against historical performance and set thresholds and forecast points to predict future performance. SPA can be deployed both in open systems and mainframe environments. Additionally, for FAST, SPA can monitor storage type and storage group performance.



Symmetrix Performance Analyzer—Advanced Performance Monitoring and Forecasting

EMC Z/OS STORAGE MANAGER

EMC z/OS Storage Manager (EzSM) is a mainframe services management tool that monitors and reports on Symmetrix mainframe storage from the z/OS operating system perspective. EzSM offers mainframe storage managers and operations staff a single location/console to manage Symmetrix storage resources, monitor local and remote replication, and review detailed array configuration information from a mainframe host view. EzSM aids in efficiently planning storage resources by utilizing the mainframe's Interactive System Productivity Facility (ISPF) Interface.

EzSM enables customers to discover and monitor the volumes in a Symmetrix, set polices and alerts for DASD volumes (such as space alerts), display summarized Symmetrix configuration information, identify all the DASD volumes on a physical drive, and monitor and manage TimeFinder and SRDF. The flexibility of EzSM is enhanced with support for plug-ins for future storage and data management capabilities. With EzSM, a mainframe storage administrator can accomplish tasks in seconds that previously took hours or even days, increasing efficiency and ease of use, improving information access, and simplifying storage management.

EMC VIRTUAL STORAGE INTEGRATOR

The Virtual Storage Integrator (VSI) has several features that enable the ease-of-integration of Symmetrix VMAX into virtual environments. The features are as follows:

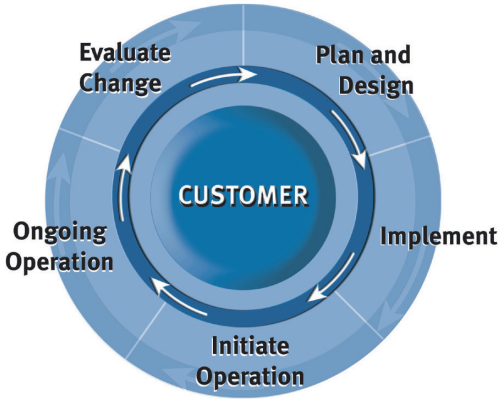
- The Storage Viewer feature extends the vSphere Client to facilitate the discovery and identification of EMC Symmetrix storage devices that are allocated to VMware ESX/ESXi hosts and virtual machines. Storage Viewer presents the underlying storage details to the virtual datacenter administrator, merging the data of several different storage mapping tools into a few seamless vSphere Client views.
- The EMC Storage Pool Management (SPM) feature simplifies the task of provisioning Symmetrix storage in VMware environments. In virtual computing environments, IT is offered as a service, user requirements change dynamically, and the underlying infrastructure is transparent to the end user. EMC Virtual Storage Integrator (VSI) and Symmetrix Management Console (SMC), together manage storage as a shared resource pool that accelerates storage provisioning, so the IT service is available to the end-user faster.

CHAPTER 7: EMC SERVICES

EMC GLOBAL SERVICES

MAXIMIZE SYMMETRIX VMAX SERIES' BENEFITS WITH EMC GLOBAL SERVICES

EMC delivers a full complement of services for EMC Symmetrix VMAX system hardware and software to ensure that your Symmetrix VMAX system performs as expected in your environment, while minimizing risk to your business and budget. Expert planning, design, and implementation services help you quickly realize the value of your hardware and software in your environment, no matter how simple or complex. After implementation, EMC's data migration services can help you plan, design, and safely migrate your critical data over any distance to your new system. EMC will also help you integrate your new system into your information architecture and applications, such as Microsoft Exchange and SQL, Oracle databases and applications, and SAP, and manage your new environment when it is complete. Extensively trained professional services personnel and project management teams, leveraging EMC's extensive storage deployment best practices and guided by our proven methodology, accelerate the business results you need without straining the resources you have.



IT Lifecycle—EMC Global Services delivers results throughout the IT lifecycle: Plan, Build, Manage, and Support.

More than ever before, organizations are demanding maximum value from their information assets and investments. EMC Global Services provides the strategic guidance and technology expertise organizations need to address their business and information infrastructure challenges. EMC Global Services is committed to exceptional total customer experience through service excellence. Staffed with over 14,000 professional- and support-service experts worldwide, plus a global network of alliance partners, EMC Global Services delivers proven methodologies, instills industry best practices, and shares industry-leading experience and knowledge. EMC Global Services feature rigorously tested and qualified solutions that reduce risk, lower costs, and speed time-to-value. Call upon EMC Global Services to address the full spectrum of requirements across the information lifecycle including: strategic, advisory, architectural, implementation, management, and support services.

PROVEN METHODOLOGIES

Every EMC Global Services engagement is guided by a proven methodology, the Global Delivery Model (GDM). The GDM ensures rapid, flawless implementation in every engagement around the world. EMC is committed to complete customer satisfaction. To this end, all EMC Global Services technologists undergo comprehensive training and certification in the industry's most advanced storage technology and implementation methodologies. As the leader in networked storage, EMC has the expertise and project management skills to ensure maximum value and minimal disruption during any networked storage engagement.

EMC CONSULTING SERVICES

EMC Consulting helps customers deploy virtualized data center architectures and next-generation information infrastructures, integrating Symmetrix VMAX systems into data center strategies to meet growing business demands for flexibility and improved service levels. We help customers understand the people, process, and technology dimensions of virtual data centers, including:

- Managing ROI and benefit expectations of business and application stakeholders
- Enhancing the IT service catalog to express service-level benefits of Symmetrix VMAX systems
- Developing reference architectures and aligning application requirements based on tiers of service
- Designing and deploying operational processes optimized for virtual data centers

As part of EMC Corporation, the world's leading developer and provider of information infrastructure technology and solutions, EMC Consulting provides strategic guidance and technology expertise to help organizations exploit information to its maximum potential. With worldwide expertise across organizations' businesses, applications, and infrastructures, as well as deep industry understanding, EMC Consulting guides and delivers revolutionary thinking to help clients realize their ambitions in an information economy. EMC Consulting drives execution for its clients, including more than half of the Global Fortune 500 companies, to transform information into actionable strategies and tangible business results.

EMC RESIDENCY SERVICES

Residency Services provide experienced, specialized information infrastructure professionals at your site for a defined period of time to furnish the skills, technical knowledge, and the expertise you need to assist in day-to-day infrastructure operations, management, and support. Services span the information lifecycle—from everyday operational storage tasks like provisioning and problem management to developing a long-term, ongoing information infrastructure strategy. All Residency Services are designed to yield operational benefits while reducing costs. EMC infrastructure professionals leverage EMC's best practices library, EMC Knowledgebase, and extensive storage/application expertise to materially improve your infrastructure's operation. EMC's Residency Services portfolio includes Operational Residencies, Technology Residencies, Support Residencies, and Managed Residencies. Residents are skilled in technology areas such as SAN, NAS, CAS, open systems, Microsoft environments, and virtualization, as well as backup, recovery, and archive.

Benefits of EMC's Residency Services include:

- Improved operational efficiency
- Greater and faster return on storage and information assets
- Narrowed staff, skill, and/or experience gaps without additional headcount
- Increased internal customer satisfaction
- Expanded management and support
- Improved planning and operational insight

EMC SERVICE AND SUPPORT

All EMC storage platforms are backed by the world's leading services and support organization. The EMC support infrastructure includes more than 4,700 technical experts and more than 80 strategic authorized services network partners serving customers in more than 75 countries, with more than 35 strategically located support centers delivering "follow-the-sun" support.

REMOTE SUPPORT

EMC Symmetrix systems are equipped with automatic phone-home capabilities, so EMC service experts can monitor a system 24x7. By dialing back into the EMC system, they can

take action quickly, analyzing events and abnormalities, and resolving most issues before they affect business. Advanced remote support means a proactive and pre-emptive approach unmatched in the industry.

SOFTWARE SUPPORT

An all-inclusive software support and maintenance program ensures optimum availability of mission-critical information. EMC software specialists provide 24x7 telephone support to meet the needs of the most complex multivendor environment. Other EMC e-services like EMC Powerlink and EMC Knowledgebase make information, solutions, and software upgrades instantly accessible.

CHANGE CONTROL

EMC's industry-leading change control process leverages the outstanding connectivity, flexibility, and upgradeability engineered into every Symmetrix VMAX system. EMC experts meticulously plan and orchestrate changes to the EMC solution—from standard microcode upgrades to massive data center relocations.

INSTALLATION SUPPORT

EMC specialists configure and install Symmetrix VMAX systems according to customer specifications and business requirements. They create file systems and set access rights as required; export file systems to the network; mount file systems on individual machines; and provide channel and network connectivity.

ONLINE SUPPORT WITH POWERLINK

EMC provides online information to customers and partners through our Powerlink web portal. The latest information, specifications, white papers, customer bulletins, and much more can be found here.

POST-SALE WARRANTY AND PRODUCT SUPPORT

Post-sale warranty coverage of Symmetrix VMAX systems includes EMC's basic three-year hardware and 90-day software warranty plan with 24x7 coverage. Post-warranty service offerings include 24x7 coverage, technical support, and service and maintenance contracts.

WORLDWIDE ORGANIZATION, LOCAL SUPPORT

The EMC Customer Support Center, headquartered in the United States, directly supports EMC hardware and software products. Use the following numbers to contact EMC and obtain technical support:

- U.S.: (800) 782-4362 (SVC-4EMC)
- Canada: (800) 543-4782 (543-4SVC)
- Worldwide: 1 + (508) 497-7901 (or contact the nearest EMC office)

CONTACT US

To learn more about how EMC products, services, and solutions can help solve your business and IT challenges, contact your local representative or authorized reseller, or visit us at www.EMC.com.

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