Welcome to VMAX All Flash and VMAX3 Remote Replication Fundamentals.

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Course Overview

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<td>This course covers an introduction to Remote Replication. It includes an overview of the VMAX All Flash and VMAX3 Remote Replication architecture, features, and functionality. This course also provides a basic understanding of Symmetrix Remote Data Facility (SRDF) modes of operations, disaster recovery concepts and terminology.</td>
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<td>This course is intended for professionals who will be positioning, designing, deploying, managing, and supporting a solution using VMAX All Flash and VMAX3 systems. It is also suitable for anyone seeking to learn the basics of the remote replication products.</td>
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| Upon completion of this course, you should be able to:  
- Explain the remote replication business requirements and benefits  
- Define the architectural components and connectivity options  
- Identify the various remote replication modes  
- Describe remote replication management options  
- Explain the features of Open Replicator |

This course provides an introduction to VMAX3 Remote Replication. It includes an overview of the Remote Replication architecture, features, and functionality.
This module focuses on business challenges, and VMAX All Flash and VMAX3 remote replication benefits. It also provides an overview of the remote replication suite, the Symmetrix Remote Data Facility (SRDF) family of products.
The source(s) of outages play an important role in determining an information or data protection strategy.

Planned downtime, represented by normal housekeeping events, account for approximately eighty-five percent of all information outages. Planned downtime is often predictable, and manageable (but, sometimes things go wrong); so business continuity is assured even during regular maintenance windows the majority of time.

Replication technologies can also be applied to scheduled events, such as occasional migrations and more frequent data re-purposing for decision support, or test and development.

Unscheduled events account for most of the remaining fifteen percent of outages. Without preparation, an unplanned outage can severely impact the viability and profitability of a business.

Less than one percent of outages are caused by natural disasters, such as hurricanes and earthquakes, or major business events, such as mergers and acquisitions.
SRDF is a solution for mission critical enterprise storage systems. It represents the most reliable, scalable, and trusted solution to ensure continuance of business operations.

For cloud scale deployments, SRDF provides a mechanism to maintain consistency across many storage systems, so that recovery, the most important part of replication, is feasible no matter what the configuration is.

The right remote replication solution can limit exposure to planned and unplanned downtime by enabling operations at remote sites. SRDF provides an organization with efficient data replication tools to meet corporate or government standards, while still meeting Total Cost of Ownership requirements and lower RPO/RTO. SRDF offers data protection, and fast business restart in the event of a disaster.
SRDF is Dell-EMC’s remote replication technology that enables the remote mirroring of a data center with minimal impact to the performance of the production application. SRDF provides disaster recovery and data mobility solutions for the VMAX All Flash and VMAX3 storage arrays in both Open Systems and mainframe data centers.

The copy process between the sites is accomplished independently without the host. There are no limits to the distance between the source and the target copies. SRDF allows storage systems to be in the same room, different buildings, or hundreds to thousands of kilometers apart.

SRDF can integrate with other products such as Microsoft Failover Cluster, VMware Site Recovery Manager (SRM), and with TimeFinder.

SRDF products offer the ability to maintain multiple, host-independent, remotely mirrored copies of data.
The available VMAX3 remote replication options are:

- **Remote Replication Suite:**
  - SRDF/S
  - SRDF/A
  - SRDF/CE
  - SRDF/Star
  - Replicator for File
  - File Auto Recovery using SRDF/S

- **SRDF/Metro**

- **Data migration options free with HYPERMAX OS**
  - SRDF/DM
  - Open Replicator
The SRDF family of products offers a range of Symmetrix-based disaster recovery, parallel processing, and data migration solutions for Symmetrix family systems including all VMAX and DMX systems. SRDF solutions offer a range of topologies and modes of operations to meet different service level requirements.

SRDF/S (synchronous mode) maintains a real-time (synchronous) mirrored copy of production data (R1 devices) at a physically separated Symmetrix system (R2 devices). This can be used only for limited distance (up to 125 miles or 200 km).
SRDF/A (Asynchronous mode) mirrors data from the R1 devices while maintaining a dependent-write consistent copy of the data on the R2 devices at all times. The copy of the data at the secondary site is typically only seconds behind the primary site. SRDF/A can be used for unlimited distance.
SRDF/Data Mobility (SRDF/DM) enables fast data transfer from R1 to R2 devices over extended distances. SRDF/DM can be used for adaptive copy over unlimited distance. More information about Adaptive Copy mode will be presented later in this course.
SRDF/Metro can be deployed with either a single multi-pathed host or with a clustered host environment. It enables the hosts to read and write to both R1 and R2 devices.
This is an example of a media and entertainment industry customer with a large customer base where SRDF is implemented.

The aging tape infrastructure which was unable to meet backup and recovery requirements, frequent tape failures and costly overhead of tape: maintenance, offsite storage, media, and shipping fees led to the shift to a remote replication and recovery mechanism.

The primary site servers use VMAX SRDF; remotely replicated 990 km to a target site with another VMAX system. The approximate SRDF I/O traffic rates average about 25 MB/sec. The SRDF groups use SRDF/A mode for synchronization.

The use of SRDF lowered costs and improved the recovery window by moving to a self-managed DR plan from a third-party disaster recovery service, reduced costs for tape-related expenses, reduced data storage and network bandwidth requirements, and thus simplified the business recovery plan for mainframe and open systems. The IT infrastructure of the entertainment industry requires DR protection for their mission critical applications with zero RPO; and SRDF provides the solution.
This module covered business challenges met by the VMAX All Flash and VMAX3 remote replication technologies. This module also provided an overview of the Symmetrix Remote Data Facility (SRDF) family of products. Additionally, a business use case was presented.
Module: SRDF Architecture

Upon completion of this module, you should be able to:

- Describe remote replication components
- Explain remote replication connectivity, topologies and key terminology

This module focuses on the remote replication architectural components and remote replication connectivity, topologies and terminology.
Lesson: SRDF Architectural Overview

This lesson covers the following topics:

- SRDF I/O flow
- SRDF devices
- SRDF architectural components
- SRDF director types
- SRDF groups and ports

This lesson covers SRDF I/O flow, devices, architectural components, director types, groups and ports.
SRDF replicates data between 2, 3 or 4 arrays located in the same room, on the same campus, or thousands of kilometers apart. Replicated volumes may include a single device, all devices on a system, or thousands of volumes across multiple systems.

In a typical SRDF configuration:

- A host at the production site is connected to the local array.
- SRDF device pairs are designated as the R1 side (local to the host) and R2 side (remote)
- R1 and R2 device pairs are connected over SRDF links.
- The production host writes I/O to the R1 side of the device pair at the primary site.
- SRDF mirrors the production I/O to the R2 side of the device pair at the secondary site(s).
An SRDF device is a Symmetrix logical device paired with another Symmetrix logical device that resides in a remote Symmetrix system. The systems on both sites are connected to each other through SRDF links. An SRDF pair consists of the primary SRDF device (R1) residing on one and the secondary SRDF device (R2) residing on another system.

At the primary site, a local host connects to a VMAX family array. The device containing the production data to be remotely mirrored is called the primary (R1) device, also referred to as the source device.

At the secondary site, a second host (optional) connects to the remote VMAX family array with the secondary (R2) device, also referred to as the target device, and contains the remotely mirrored data.

The R1 and R2 devices communicate through SRDF links. Under normal circumstances, the R1 device presents a Read/Write (R/W) status to the host that accesses the R1. The R2 device presents Write Disabled (WD) status to its host.
SRDF Architectural Components

- Data mirroring between physically separate VMAX systems
- Independent of Host operating system, DBMS and file-system
- Uses SRDF RA (Remote Adapter) Directors as a communication channel
- Track Tables enables differential resynchronization capabilities
  - Only changed data is copied in events such as link down or a power down

SRDF disaster recovery solutions use “active, remote” mirroring and dependent-write logic to create consistent copies of data. Dependent-write consistency ensures transactional consistency when the applications are restarted at the remote location. SRDF provides comprehensive business continuity and restart capabilities for planned and unplanned outages. This online, host-independent, mirrored data solution duplicates production site data on one or more physically separate target VMAX systems. What makes this technology a leader in the industry is its use of track tables. Track tables maintain the differential between source and target devices; track tables have a unique capability to send only changed information at the track level. This allows SRDF to operate in several modes that are addressed later in this course. SRDF compression is accomplished using an optional compression I/O module; compression can be set at the SRDF group level.
The SRDF family offers great flexibility in deployment depending on the business needs by offering fully tested, integrated and flexible hardware, software and communication options.

Dell-EMC offers native Gigabit Ethernet and Fibre channel capability for the VMAX All Flash and VMAX3 systems.

NOTE: In mainframe environments, FICON connectivity is also supported.
SRDF Groups and Ports

SRDF groups define the relationships between the local SRDF instance and the corresponding remote SRDF instance. All SRDF devices must be assigned to an SRDF group. Each SRDF group communicates with its partner SRDF group in another array across the SRDF links. Each SRDF group points to one (and only one) remote array. An SRDF group consists of one or more SRDF devices, and the ports over which those devices communicate. The SRDF group shares CPU processing power, ports, and a set of configurable attributes that apply to all the devices in the group. In HYPERMAX OS, all SRDF groups are dynamic.

RA ports are assigned to SRDF groups with SRDF management software. All SRDF devices must belong to an SRDF group. VMAX3 and VMAX arrays will support up to 250 SRDF groups per system. When a VMAX3 is connected to a VMAX, it supports 64 SRDF groups. All configured ports on an SRDF group have the same topology (Switched Fabric or Peer-to-Peer). All configured ports on a single RA must use the same protocol.
Lesson: SRDF Connectivity, Topologies, and Terminology

This lesson covers the following topics:

- SRDF topologies
- SRDF link configuration types
- SRDF dynamic operations
- SRDF terminology

This lesson covers SRDF topologies, link configuration types, dynamic operations, and key terminology.
The SRDF distance solutions are:

- Campus solution
- Extended Distance WAN solution

Campus solution is limited to transmit data over short distances using VMAX systems and SAN equipment; typically, the distance is shorter than 200 kilometers using channel extenders or long distance fiber-optic cables.

Extended Distance Wide Area Network provides SRDF connectivity over long distances using telecommunications networks, such as IP, SONET, or ATM.

The Extended Distance Wide Area Network solution enables units to be at trans-oceanic or trans-continental distances for all types of directors. Typically, OC3, ATM, T3, and E3 lines, or IP are offered by lease carriers. Fibre Channel SRDF can leverage write acceleration, sometimes referred to as Fast Write, a performance enhancement feature offered by distance extension and/or switch products.

When selecting the ideal business continuance solution, the selection is determined by the distances separating the data centers, the Recovery Point Objective and Recovery Time Objective, and how well the applications tolerate network latency. Shorter distances reduce network latency, which allows using synchronous disk replication and data center mirroring. The SRDF solution can be tailored to meet various Recovery Point Objectives/Recovery Time Objectives.
SRDF supports regular synchronous and asynchronous SRDF, between various VMAX family storage systems. It also supports concurrent SRDF, replicating to two systems concurrently. In a two site configuration, synchronous and asynchronous modes are supported. A three site configuration supports concurrent modes of synchronous or asynchronous. SRDF allows cascaded configurations in which data is propagated from one Symmetrix to the next. Cascaded SRDF is a three-way data mirroring topology. SRDF/Star is a three-site protection topology where data is replicated from source Site A to two other Symmetrix systems simultaneously (Site B and Site C).
There are three types of SRDF link configurations:

- **Unidirectional** - a one-way mirror relationship.
- **Bidirectional** - a two-way mirror relationship where data moves in both directions on the SRDF links. Bidirectional configuration is only recommended in Campus mode due to the overhead associated with the change of direction.
- **Dual-directional** – an extended distance solution with two unidirectional SRDF RA groups, primary and secondary, in each VMAX system.
Dynamic SRDF provides the capability to change SRDF Groups and device pairings, as needed. The two main operations are: creating dynamic SRDF groups and device pairs.

A dynamic SRDF group represents a SRDF logical link between two VMAX family arrays. After a Dynamic SRDF group has been created, the SRDF device pairs can be added.

An SRDF device is a logical device paired with another logical device that resides in a second array; the arrays are connected by SRDF links.

Dynamic SRDF enables the creation and deletion of SRDF pairs while the storage system is in operation. Once established, the new SRDF pairs can be synchronized and managed.

A requirement for Dynamic SRDF groups is ‘Switch’ connectivity (example: a SAN or GigE switch topology).

SRDF groups define the relationships between the local SRDF director/ports and the corresponding remote SRDF director/ports. Any SRDF device must be assigned to an SRDF group.

SRDF devices can dynamically swap “personality” between R1 and R2. After a personality swap, the R1 in the device pair becomes the R2 device and the R2 becomes the R1 device. Swapping R1/R2 personalities allows the application to be restarted at the remote site without interrupting replication if an application fails at the production site. After a swap, the R2 side (now R1) can control operations while being remotely mirrored at the primary (now R2) site. All volumes created on a VMAX All Flash or VMAX3 array will automatically be created as dynamic SRDF capable.

NOTE: An SRDF device pair (R1/R2) cannot include ProtectPoint devices.
SRDF Terminology

SRDF device pairs: An SRDF device is logically paired with another logical device that resides in a second array. The arrays are connected by SRDF links.

R1 devices: R1 devices are the member of the device pair at the source (production) site. R1 devices are generally Read/Write accessible to the host.

R2 devices: R2 devices are the members of the device pair at the target (remote) site.

Invalid tracks: tracks that are not synchronized, that is, they are tracks that are “owed” between the two devices in an SRDF pair.

R11 devices: R11 devices operate as the R1 device for two R2 devices. Links to both R2 devices are active. R11 devices are typically used in SRDF/Concurrent solutions.

R21 devices: R21 devices operate as:
- R2 devices to hosts connected to array containing the R1 device, and
- R1 device to hosts connected to the array containing the R2 device.
- R21 devices are typically used in cascaded 3-site solutions where data on the R1 site is synchronously mirrored to a secondary (R21) site, and then synchronously mirrored from the secondary (R21) site to a tertiary (R2) site.
SRDF Terminology cont....

**R22 devices:** Have two R1 devices, only one of which is active at a time. These are typically used in cascaded SRDF/Star and concurrent SRDF/Star solutions to decrease the complexity and time required to complete failover and failback operations.

**SRDF device states:** An SRDF device’s state is determined by a combination of two views; host interface view and SRDF view as shown in the image.

- Host interface view: the SRDF device state as seen by the host connected to the device.
- SRDF view: composed of the SRDF state and internal SRDF device state. These states indicate whether the device is available to send data across the SRDF links, and able to receive software commands.

**Dynamic device personalities:** SRDF devices can dynamically swap “personality” between R1 and R2.
This module covered VMAX3 remote replication architectural components and remote replication connectivity, topologies, and key terminology.
Module: SRDF Features and Capabilities

Upon completion of this module, you should be able to:

- Describe the remote replication key features and capabilities
- Describe SRDF multi-site solutions

This module focuses on remote replication features and capabilities. It also covers a description of SRDF multi-site solutions.
Lesson: Basic Features

This lesson covers the following topics:

- SRDF solutions
- SRDF/Synchronous operations
- SRDF/Adaptive Copy operations
- SRDF/Metro overview
- SRDF/Asynchronous operations
- SRDF/A DSE and resource pool
- SRDF Enginuity backward compatibility

This lesson covers SRDF solutions, SRDF/Synchronous operations, SRDF/Adaptive Copy operations, SRDF/Metro overview, SRDF/Asynchronous operations, SRDF/A DSE and resource pool, and SRDF Enginuity backward compatibility.
SRDF solutions address different service level requirements. The solution chosen determines:

- how R1 devices are remotely mirrored across the SRDF links
- how I/Os are processed
- when the host receives acknowledgment of a write operation relative to when the write is replicated
- when writes owed between partner devices are sent across the SRDF links
SRDF offers:

- **Synchronous Replication (SRDF/S)** – Host writes are written simultaneously to both arrays in real time before the application I/O completes. Acknowledgments are not sent to the host until the data is stored in cache on both arrays.

- **Asynchronous Replication (SRDF/A)** – Host writes are collected for a configurable interval into “delta sets”. Delta sets are transferred to the remote array in timed cycles. It maintains a dependent-write consistent copy at a remote secondary site.

- **SRDF Data Mobility (SRDF/DM)** – Data from the source devices is transferred to the remote devices without waiting for an acknowledgment, using Adaptive Copy mode.

- **SRDF Consistency Groups (SRDF/CG)** – The dependent-write consistency of devices within a group is preserved by monitoring data propagation from source devices to their corresponding target devices. If consistency is enabled and SRDF detects any write I/O to an R1 device that cannot communicate with its R2 device, SRDF suspends the remote mirroring for all devices in the consistency group before completing the intercepted I/O and returning control to the application. These operational solutions can be changed dynamically using EMC software and the operational method can be specified on a per device basis or as a device group.

- **SRDF/Metro** – Unlike in traditional SRDF, R1 and R2 devices are both Read/Write accessible to hosts in SRDF/Metro. Hosts can write to both the R1 and R2 side of the device pair and R2 devices assume the same external device identity (geometry, device WWN) as their R1. This shared identity causes the R1 and R2 devices to appear to hosts(s) as a single virtual device across the two arrays.

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**SRDF Solutions (cont.)**

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<th>Microsoft Failover Cluster integration</th>
<th>SRDF/Cluster Enabler (CE)</th>
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<td>Combines SRDF and TimeFinder to provide a long distance disaster restart solutions</td>
<td>SRDF/Automated Replication (AR)</td>
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<td>Three-site disaster recovery solution where data is mirrored from the primary site concurrently to two R2 devices</td>
<td>Concurrent SRDF</td>
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<td>Three-site disaster recovery solution where data from a primary site is synchronously replicated to a secondary site and then asynchronously replicated to a tertiary site</td>
<td>Cascaded SRDF</td>
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<td>Maintains protection and business continuity in a three-site configuration with the option of remote mirroring between secondary and tertiary sites when primary site fails</td>
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- **SRDF/Cluster Enabler (CE)** – Combines Microsoft Failover Clusters and SRDF to provide a wizard that is used in conjunction with the Microsoft Cluster Administrator to configure and administer the SRDF-enabled cluster. SRDF/CE implements both SRDF/Synchronous (SRDF/S) and SRDF/Asynchronous (SRDF/A) solutions of transfer.

- **SRDF/Automated Replication (AR)** – An automated remote replication solution that uses both SRDF and TimeFinder to provide a long distance disaster restart solution for UNIX and Windows environments. SRDF/Automated Replication is the most affordable of the listed solutions because it can be configured to run on lower bandwidth networks than the other solutions. The network cost is reduced and the time for resynchronization is improved.

- **Concurrent SRDF** – Maintains two data copies. Usually, one copy running in SRDF/S mode is maintained at a nearby location and offers zero data loss if the primary site fails. The second copy operating in SRDF/A mode offers an out of region recovery site with an RPO of seconds to minutes.

- **Cascaded SRDF** – This three-site cascaded configuration uses a bunker site and combines Synchronous and Asynchronous modes. Data from a primary site is synchronously replicated to a secondary site and then asynchronously replicated to a tertiary site. The major benefit provided with a cascading configuration is its inherent capability to continue replicating from the secondary site to the tertiary sites when the primary site goes down.

- **SRDF/Star** – SRDF/Star is a three-site disaster recovery solution consisting of primary (production), secondary, and tertiary sites. The secondary site synchronously mirrors the data from the primary site, and the tertiary site asynchronously mirrors the production data. When an outage occurs at the primary site, SRDF/Star allows the user to quickly move operations and re-establish remote mirroring between the remaining sites.
SRDF/Synchronous Operations

SRDF Synchronous mode is primarily used in SRDF campus environments. In this mode of operation, the Target VMAX3 maintains a real-time mirror image of the data sent from the Source.

Data on the source (R1) and target (R2) devices are always fully synchronized at the completion of an I/O sequence through a first in first out (FIFO) model. All data movement is at the block level with synchronized mirroring.

With Synchronous SRDF, writes from the host to are sent to the R1 device(s). Those writes are mirrored across the SRDF links to the R2 device(s). The remote array acknowledges receipt of the data, then the local array acknowledges receipt of the data to the host, completing the I/O transfer. This means that the logical device is busy at the primary host, including read-following-write operations throughout the very quick SRDF operation.
SRDF Adaptive Copy modes facilitate data sharing and migration. These modes allow the R1 and R2 devices to be out of synchronization by up to a user-configured maximum skew value. The maximum number of I/Os that the R2 can be out of synchronization is known as the maximum skew value. If the maximum skew value is exceeded, SRDF starts the synchronization process to transfer updates from the R1 to the R2 devices. The default value is equal to the entire logical device.

SRDF Adaptive Copy Disk mode is designed for bulk data transfer. Host write tasks accumulate on the primary device as invalid tracks rather than in global memory. A background process sends the outstanding write requests to the corresponding secondary device.
With SRDF/Metro, R1 and R2 devices are both Read/Write accessible to hosts. Hosts can write to both the R1 and R2 side of the device pair, and R2 devices assume the same external device identity as their R1. This shared identity causes the R1 and R2 devices to appear to hosts(s) as a single virtual device across the two arrays.

SRDF/Metro can be deployed with either a single multi-path host or with a clustered host environment. For single host configurations, multi-pathing software directs parallel reads and writes to each array. For clustered host configurations, host I/Os can be issued by multiple hosts accessing both sides of the SRDF device pair. In both configurations, writes to the R1 or R2 devices are synchronously copied to the paired device. Any write conflicts are resolved by the SRDF/Metro software to maintain consistent images on the SRDF device pairs.

**SRDF/Metro resiliency Bias and Witness:** If an SRDF/Metro device pair becomes Not Ready (NR) on the SRDF link, SRDF/Metro must respond by choosing one side of the device pair to remain accessible to hosts, while maintaining the other side of the device pair inaccessible. There are two options which enable this, Bias and 3rd Party Witness. Both of these options prevent data inconsistencies between the SRDF device pair. Bias is a native function of an SRDF/Metro configuration. The 3rd Party Witness is an optional component of SRDF/Metro. It allows a 3rd party (example: a VMAX or VMAX3 system) to act as an external arbiter to avoid split-brain results in cases where the bias functionality alone may not result in continued host availability of a surviving non-biased array.
SRDF/Asynchronous (SRDF/A) mode maintains a dependent-write consistent copy between the R1 and R2 devices across any distance with no impact on the application. Host writes are collected for a configurable interval into “delta sets”. Delta sets are transferred to the remote array in timed cycles.

At the source-site, delta sets include ‘Capture’ and ‘Transmit’; At the target-site, delta sets include ‘Receive’ and ‘Apply’. The data flow of SRDF/A can be summarized in simple steps:

- **Capture** captures all incoming writes to the source devices involved in the SRDF/A group. When a minimum time elapses, a new capture cycle starts. There may be more than one capture at the primary VMAX3.

- **Transmit** transfers its contents from the source to the target system.

- **Receive** on the target system receives the data being transferred by the source-site Transmit delta set.

- The **Apply** cycle writes the delta set to the target device to create a consistent recoverable remote copy. This completes the delta set cycle.
SRDF/A Multi-Cycle Mode (MCM)

- Allows more than two delta sets on primary site
- Cycle are more granular with incremental updates
- Cycle switch occurs at minimum cycle time

SRDF/A Multi-Cycle Mode (MCM) creates multiple SRDF/A cycles on the R1 side at regular intervals, which provides smaller incremental updates to R2; cycle switch occurs at minimum cycle times. Both sites must be VMAX All Flash or VMAX3 arrays. SRDF/A operations may vary depending on whether the SRDF session mode is single or multi-session with Multi-Session Consistency (MSC) option enabled.
SRDF/A Multi-Cycle Mode (MCM) allows more than two capture cycles on the R1 side. When the minimum cycle time elapses, the data from the capture cycle is added to the transmit queue and a new capture cycle occurs. The transmit queue is a feature of SRDF/A and it provides a location for R1 captured cycle data to be placed so that a new capture cycle can occur.

The Capture cycle occurs even if no data is transmitted across the link. If no data is transmitted across the link, the capture cycle data is again added to the transmit queue. The transmit queue holds the data until it is transmitted across the link. The Transmit cycle transfers the data in the oldest capture cycle to the R2 first and then repeats the process.

The benefit of this technique is that controlled amounts of data on the R1 side is captured; each capture cycle occurs at regular intervals and does not contain large amounts of data waiting for a cycle to occur. Another benefit is, data that is sent across the SRDF link is smaller in size and does not overwhelm the R2 side. The R2 side will still have two delta sets, the Receive and the Apply.
MCM supports Single Session Consistency (SSC) and Multi Session Consistency (MSC).

For single SRDF/A sessions (SSC), cycle switching is controlled by HYPERMAX OS. Each session is controlled independently, whether it is in the same or multiple arrays.

For multiple SRDF/A sessions (MSC) mode, multiple primary SRDF groups and multiple secondary SRDF groups are in the same SRDF/A MSC session. MSC combines and co-ordinates cycle switching for more than one VMAX system, and the cycle switching is controlled at the host level by SRDF/A software to maintain consistency.
SRDF/A Delta Set Extension

- Allows offloading of SRDF/A delta sets from cache to specially configured device pools:
  - Delta Set Extension (DSE) pools
- Intended to make SRDF/A resilient to temporary increases in write workloads or loss of link
- R2 side available for personality swap

SRDF/A Delta Set Extension (DSE) provides a mechanism for augmenting the cache-based delta set buffering mechanism of SRDF/A with a disk-based buffering ability. This extended delta set buffering ability allows SRDF/A to be maintained through larger and/or longer SRDF/A throughput imbalances than would be possible with cache-based delta set buffering alone.

In previous versions of Enginuity, SRDF/A Delta Set Extension extended the space available for an SRDF/A session’s cycles by spilling its cycle data from cache to a user configurable DSE pool. Now, SRDF/A spills tracks to the Storage Resource Pool (SRP) designated for use by DSE. When running SRDF/A MCM, smaller cycles on the R2 side eliminate the need for DSE on the R2 side.
The **SRDF/A Write Pacing** feature helps to secure the availability of an SRDF/A session by preventing conditions that can cause cache overflow on both the R1 and R2 sides. SRDF/A detects when the SRDF I/O service rates are lower than the host I/O rates; it then takes corrective action to slow host I/O rates to match the SRDF I/O service rates. SRDF/A write pacing helps control the amount of cache used by SRDF/A. This can prevent cache from being exhausted on the R1 side of the SRDF link, thereby keeping the SRDF/A sessions continued.

VMAX3 introduces **Enhanced Group-level Pacing**. The Enhanced Group-level Pacing throttles host I/Os to the DSE spillover rate for an SRDF/A session. When DSE is activated for an SRDF/A session, host-issued write I/Os are throttled so their rate does not exceed the rate at which DSE can offload the SRDF/A session’s cycle data. The system paces at the spillover rate until the usable configured capacity for DSE on the SRP reaches its limit, at that point, the system then either drops SRDF/A, or paces to the link rate option. All existing pacing features are supported and can be utilized to keep SRDF/A sessions active. Enhanced Group-level Pacing is supported between VMAX3 and VMAX arrays.
SRDF FAST coordination is enabled at the array-level by default. Performance metrics are periodically transmitted from R1 to R2 across the SRDF link. The R1 metrics are merged with R2 metrics; this instructs FAST to factor the R1 device statistics into the move decisions that are made on the R2 device. Service Level Objectives (SLOs) associated with R1 and R2 devices can be different.
Meta devices do not exist on VMAX3 arrays; however, there is support for creating SRDF pairs between VMAX Meta devices and VMAX3 Non-meta devices. Device pairs consisting of a larger R2 than R1, with one meta and one non-meta are supported, regardless of whether the R2 is the meta or the non-meta device. R2 larger than R1 is a one-way replication since a restore from a larger to smaller SRDF device is not supported. SRDF also supports thick to thin replication. All volumes created on a VMAX3 array are automatically created as dynamic SRDF capable.

SRDF does support hardware and software compression, but this requires a separate I/O module if hardware-based compression is desired.
The track size on VMAX3 is 128K. When creating an RDF pair between a device on a VMAX array, whose track size is 64K, and a device on a VMAX3 array, compatibility problems arise if the device on the legacy VMAX array has an odd number of cylinders. If the device on the VMAX array becomes the R1 then the resulting RDF pair ends up as an R2 larger than R1 relationship and the RDF support is limited.

If the device on the VMAX array becomes the R2 then RDF device pair results in an R1 larger than the R2 relationship, which is not an allowed configuration.

The **Geometry Compatible Mode (GCM)** of operation allows full RDF support in an environment where a device on a legacy VMAX array, with an odd number of cylinders, is paired with a device on a VMAX3 array. A volume with GCM attribute set is referred to as a GCM device and its size is referred to as the device’s GCM size.
Lesson: SRDF Multi-site Solutions

This lesson covers the following topics:

- Concurrent SRDF
- Cascaded SRDF
- SRDF/Star

This lesson covers SRDF multi-site solutions such as Concurrent SRDF, Cascaded SRDF, and SRDF/Star.
Concurrent SRDF is a three-site disaster recovery solution that uses R11 devices which replicate to two R2 devices. The two R2 devices operate independently but concurrently using any combination of SRDF modes:

- Concurrent SRDF/S to both R2 devices if the R11 site is within synchronous distance of the two R2 sites
- Concurrent SRDF/A to sites located at extended distance from the workload site

The R11 device can be restored from either of the R2 devices. The user can also restore both the R11 and one R2 device from the second R2 device. Concurrent SRDF can be used to replace an existing R11 or R2 device with a new device. To replace an R11 or R2 device, migrate data from the existing device to a new device using Adaptive Copy Disk mode, and then replace the existing device with the newly populated device. Concurrent SRDF topologies are supported on Fibre Channel and Gigabit Ethernet.

The image on the slide shows:

- R11 -> R2 in Site B in synchronous mode
- R11 -> R2 in Site C in adaptive copy mode
Cascaded SRDF provides a zero data loss solution at long distances in the event of a primary site failure. In cascaded SRDF configurations, data from a primary (R1) site is synchronously mirrored to a secondary (R21) site and then asynchronously mirrored from the secondary (R21) site to a tertiary (R2) site. If the primary site fails, Cascaded SRDF can continue mirroring with minimal user intervention, from the secondary site to the tertiary site. This enables a faster recovery at the tertiary site.

The benefits of Cascaded SRDF are:

- Tight integration with TimeFinder product family
- Geographically dispersed secondary and tertiary sites
SRDF/Star

- Three-site disaster recovery solution
- Remote mirroring between secondary and tertiary sites when primary site fails
- Operates in concurrent or cascaded modes

SRDF/Star is a three-site disaster recovery solution consisting of primary (production), secondary, and tertiary sites. The secondary site synchronously mirrors the data from the primary site and the tertiary site asynchronously mirrors the production data. When an outage occurs at the primary site, SRDF/Star allows the user to quickly move operations and re-establish remote mirroring between the remaining sites. When conditions permit, the user can quickly rejoin the primary site to the solution, resuming the SRDF/Star operations. SRDF/Star operates in concurrent mode or cascaded mode to address different recovery and availability objectives.
In Concurrent SRDF/Star, the data is concurrently mirrored from the primary site to two R2 devices. Both the secondary and tertiary sites, are potential recovery sites. Differential resynchronization is used between the secondary and the tertiary sites.

Differential synchronization between two remote sites:

- Allows SRDF/Star to rapidly re-establish cross-site mirroring in the event of the primary site failure
- Reduces the time required to remotely mirror the new production site

In Concurrent SRDF/Star solutions, production data on R11 devices replicate to two R2 devices in two remote sites, where:

- Site B is a secondary site using SRDF/S links from Site A
- Site C is a tertiary site using SRDF/A links from Site A
- The recovery links, normally inactive, are SRDF/A between Site B and Site C
In Cascaded SRDF/Star, the data is first mirrored from the primary site to the secondary site, and then from the secondary to a tertiary site. Both, the secondary and tertiary sites, are potential recovery sites. Differential resynchronization is used between the primary and the tertiary site.

In Cascaded SRDF/Star solutions, the synchronous secondary site is always more current than the asynchronous tertiary site. If the synchronous secondary site fails, the Cascaded SRDF/Star solution can incrementally establish an SRDF/A session between the primary site and the asynchronous tertiary site. Cascaded SRDF/Star can determine when the current active R1 cycle (capture) contents reach the active R2 cycle (apply) over the long-distance SRDF/A links. This minimizes the amount of data that must be moved between Site B and Site C to fully synchronize them.
Module Summary

Key points covered in this module:

- Remote replication key features and capabilities
- Multi-site SRDF solutions

This module covered remote replication features and capabilities. It also covered a description of SRDF multi-site solutions.
Module: Remote Replication Management Overview

Upon completion of this module, you should be able to:

• Describe remote replication management options
• Explain the different SRDF management operations

This module focuses on remote replication management options and SRDF management operations.
In Open Systems environments, the Dell-EMC Solutions Enabler suite provides a command line interface (SYMCLI) to manage replication operations from the command line, or within scripts. These commands are used to monitor device configuration and status, and perform control operations on the replication features. Alternatively Unisphere for VMAX can also be used.

Versions that can be used to perform operations are:

- Solutions Enabler - 8.0.1 and above
- Unisphere for VMAX - 8.0.1.4 and above

Unisphere for VMAX is an advanced Graphical User Interface (GUI) that provides a common Dell-EMC user experience across storage platforms. With Unisphere for VMAX, VMAX3 users can easily provision, manage, monitor, and analyze VMAX3 arrays from one console, significantly reducing the storage administration time. It provides the ability to monitor and manage SRDF and TimeFinder replication operations.
Unisphere for VMAX is the graphical management console for the VMAX. Unisphere offers navigation and streamlined operations to simplify and reduce the time required to manage the data center. Unisphere provides a user interface for the configuration and management of VMAX3 arrays and can be used to operate and monitor SRDF remote mirroring functions. Additionally, it provides health indicators for SRDF/A cache usage, cycle time, and throughput at user-configurable polling intervals. Unisphere is contextual and simple to navigate. With Unisphere, users can easily and rapidly manage and monitor all SRDF features. Open Replicator can also be managed with Unisphere.
In a mainframe environment, the Mainframe Enablers software suite provide functionality for working with SRDF.
The common SRDF dynamic operations include:

- Create Dynamic groups - makes a new logical connection in a physical cable. SRDF Groups may be dynamically added, deleted and/or modified.

- Create Dynamic SRDF device pairs - allows the user to pair Primary (R1) and Secondary (R2) devices.

- Swap device personality switches the R1 and R2 personalities, at its completion the remote site will have the R1 devices.

The software can also delete all the above groups and devices.

Also, the device states can be changed to:

- Set Synchronous mode
- Set Asynchronous mode
- Set Adaptive Copy mode

Change R1 and R2 states:

- Read/Write (Write Enabled) — The R1 device is available for Read/Write operations; this is the default R1 device state.
- Read Only (Write Disabled) — Write Protected from all write operations to that device.
- Not Ready — Not Ready to the host for read and write operations to that device.

There are many other operations that can be performed, for more information read the Solutions Enabler SRDF CLI product guide.
Some of the VMAX3 Recovery operations are:

**Failover** - A Failover moves production applications from the primary site to the secondary site when a disaster occurs on the primary site or in order to test the recovery solution.

**Failback** – This brings production applications back to the primary site after a disaster is resolved.

**Update** – Begins transfer of accumulated invalid tracks from remote devices to the local devices while production work continues on the remote devices.

**Split** – Suspends links between SRDF source and target volumes. The source devices continue to be Read/Write enabled and the target devices are set to Read/Write enabled. This enables read and write operations on the target volumes.

**Establish** – After a Split, the Establish command allows a target device to synchronize with the data from the source device.
Here is an example of managing SRDF operations via storage groups. In this example, we have two storage groups. To perform SRDF related operations, select a storage group from the Data Protection > SRDF > Storage Group listing and then choose the appropriate action.
Module Summary

Key points covered in this module:

• Remote replication management options
• SRDF management operations

This module covered Remote replication management options and VMAX3 SRDF management operations.
Module: Dell-EMC Open Replicator Overview

Upon completion of this module, you should be able to:

- Describe Open Replicator
- Explain Open Replicator Pull operations
- Describe VMAX3 Open Replicator support
- Describe Open Replicator management software

This module focuses on Dell-EMC Open Replicator and its operations.
Open Replicator provides a method for copying device data from various types of arrays within a Storage Area Network (SAN). Dell-EMC Open Replicator is a tool that can be used to migrate data from legacy Symmetrix, CLARiiON, or VNX arrays, and certain third-party storage arrays to a VMAX All Flash or VMAX3 array.

The Open Replicator operations are controlled from a local host attached to a VMAX All Flash or VMAX3 array. Data copying is accomplished as part of the storage system process and does not require host resources. The data can be copied online between the VMAX All Flash or VMAX3 array and remote devices, allowing host applications such as a databases or file servers, to remain operational during the copy process.
In **Pull** operations, the VMAX volume can be in a live state during the copy process, which makes either restoring remotely vaulted volumes or migrating from other storage platforms very fast and efficient. The local hosts and applications can begin to access the data as soon as the session begins, even before the data copy process has completed. Hot pull is a way to perform migrations with minimal application down time. Copy operations are either hot (online) or cold (offline).

Rather than using the terms “source” and “target,” which might be confusing in the Open Replicator context, we use the terms “control” and “remote,” where the control device always resides on the array running Open Replicator. The remote device, also called “Donor,” is passive and does not require any software.

On pull operations, the remote devices should not be updated by the array hosts for the duration of the copy process.

At activation, all control tracks are marked protected, and then,

- Background copy is initiated between Remote and Control.

- A read or write from the control device causes the track to be pulled over before access is permitted (CopyOnAccess behavior).

- Copying continues until complete if –**copy** option is specified.
Open Replicator hot pull permits host access of the Control devices while data transfer is in progress. After a hot pull session is activated, data on the Control device is pulled from the Remote device before a new read or write to the Control device is permitted.

The default behavior is to start a background copy as soon as the session is activated. An attempt to read or write data that has not already been transferred causes a priority data move from the Remote to the Control device before the write is allowed. This process is known as “Copy On First Access”.

The **nocopy** option results in Control data not being copied in the background, but data is copied when a new read or write is directed against the Control device (using Copy On First Access).

The donor update option permits new writes to the Control device to be pushed to the Remote device. This option results in the remote site containing the most current data. Differential option is not allowed. If the data pull is unexpectedly aborted because of a failure of network connectivity, the data that was written to the Control device between the times when the session was activated is not lost.
The “donor update” option is used to protect against potential data loss due to a SAN failure or other connectivity issues during a hot pull operation. When enabled, this feature causes all writes to the control device from the host to be immediately copied to the remote device. Because the data is fully copied to the remote and control devices, if a failure occurs, the session can be safely terminated and created again to fully recover from any mid-copy failure.

Open Replicator includes a feature that protects against potential data loss due to a SAN failure or other connectivity problems during an active Open Replicator live pull session. The donor update feature enables arrays to propagate (update) writes to the local device back to the remote device (donor) as data is being pulled from the remote device. Upon restarting, the remote device contains the most recent data.
With VMAX3, support for Open Replicator has moved to the Enginuity Data Services (EDS) array module to manage data movements. Therefore, the mapping requirements are far simpler than in the older version with regard to hot pulls. This new underlying support has resulted in changes to Solutions Enabler (SE) ORS (Open Replicator Support) functionality in several areas. VMAX3 supports a maximum of 512 ORS sessions. Only ORS pull sessions are supported and there can be only be one remote device for pull sessions.

VMAX3 Open Replicator does not support SRDF and TimeFinder devices. The functions related to the setting of port throughput ceilings and the reporting of port throughput utilization have changed to reflect the changes to directors and the number of ports.

The Open Replicator Pace feature allows throttling to limit SAN bandwidth usage of the copy process. With VMAX3, Open Replicator Pace is not used; the devices involved in TimeFinder or SRDF replication cannot be used for ORS on a VMAX3.

Federated Live Migration (FLM) is not supported.

NOTE: The feature by which ORS throughput values are controlled has been changed from the symrcopy to symqos.
Open Replicator Session (ORS) Considerations

Enginuity Data Services emulation: uses directors and ports for data transfer

For an Open Replicator Session:
- One zoned remote port is required for cold
- Two zoned remote ports are required for hot

Restrictions lifted:
- Not all mapped ports need access to remote device
- Map and unmap of Control device is now supported

Enginuity Data Services (EDS) emulation dynamically finds directors and ports that can access an ORS’ remote devices and uses these directors and ports for the data transfer. Open Replicator requires at least one zoned remote port for cold sessions and at least two zoned remote ports from at least two different directors for hot sessions. In previous versions of VMAX3, to start a hot pull Open Replicator session, all the ports the control device was mapped to, had to have access to the remote device. This restriction has been removed with the new zoning requirements.

With the previous version of Open Replicator, devices were blocked from being explicitly mapped and unmapped from ports; in order to map a control device to a port, it had to be in a masking view. Control devices do not have to be in a masking view and can now be mapped and unmapped.
Open Replicator software includes Solutions Enabler that uses the “symrcopy” command. For more information, see the EMC Solutions Enabler 8.0 documentation at www.support.emc.com.

Unisphere for VMAX has all the options to manage the Open Replicator operations listed under "Data Protection".
Module Summary

Key points covered in this module:

- Open Replicator
- Open Replicator Pull operations
- VMAX3 Open Replicator support
- Open Replicator management software

This module covered Open Replicator; its operation, support, and management.
This course covered SRDF remote replication for VMAX All Flash and VMAX3 storage arrays. It included an overview of the remote replication architecture, features, and functionality.

This concludes the training. Proceed to the course assessment on the next slide.