IBM FlashSystem 7200 Product Guide

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Redpaper

IBM FlashSystem 7200 Family Product Guide

This IBM® Redbooks® Product Guide publication describes the IBM FlashSystem® 7200 solution, which is a comprehensive, all-flash, and NVMe-enabled enterprise storage solution that delivers the full capabilities of IBM FlashCore® technology. In addition, it provides a rich set of software-defined storage (SDS) features, including data reduction and de-duplication, dynamic tiering, thin-provisioning, snapshots, cloning, replication, data copy services, and IBM HyperSwap® for high availability (HA). Scale-out and scale-up configurations further enhance capacity and throughput for better availability

The success or failure of businesses often depends on how well organizations use their data assets for competitive advantage. Deeper insights from data require better information technology. As organizations modernize their IT infrastructure to boost innovation, they need a data storage system that can keep pace with highly virtualized environments, cloud computing, mobile and social systems of engagement, and in-depth and real-time analytics.

Making the correct decision about storage investment is critical. Organizations must have enough storage performance and agility to innovate because they need to implement cloud-based IT services, deploy a virtual desktop infrastructure (VDI), enhance fraud detection, and use new analytics capabilities. Concurrently, future storage investments must lower IT infrastructure costs while helping organizations derive the greatest possible value from their data assets.

IBM FlashSystem storage solutions can accelerate the transformation of modern organizations into an IBM Cognitive Business®. IBM FlashSystem all-flash storage arrays are engineered to support the organization's active data sets. IBM FlashSystem solutions offer a broad range of industry-leading storage virtualization and data management features that can provide improved storage system performance, efficiency, and reliability. Even better, IBM FlashSystem solutions can be less expensive than conventional enterprise storage solutions.

With the release of IBM FlashSystem 7200 V8.4.0, extra functions and features are available, including support for new larger IBM FlashCore Module NVMe type drives within the control enclosure and the optional Storage Class Memory (SCM) drives. New software features include GUI enhancements, an updated dashboard, remote support assistance (RSA), data de-duplication, and an IBM Storage Insights configuration.

Flash for less than the cost of disk

Integral to the IBM FlashSystem 7200 solution is the IBM FlashCore technology. The recent evolution of this technology saw the introduction of inline hardware compression and decompression with the IBM FlashSystem model AE3 enclosure.

IBM FlashSystem 7200 with IBM FlashCore Module NVMe type drives feature built-in hardware data compression as standard, and this data reduction is "always on". This compression is implemented in hardware by using FPGAs within each module and uses a modified dynamic GZIP algorithm. With this approach, the solution can deliver the level of performance that you expect without compression, with the added benefit of better utilization of the physical storage.

Compression and decompression are not apparent above the IBM FlashCore Module, except for management of space. Performance is not affected and scales linearly with the number of instances.

IBM FlashSystem 7200 Control Enclosure Data Reduction Pool compression can increase the effective capacity of your flash memory up to 5x, which decreases the cost for effective capacity up to 80%. Data Reduction Pool supports active data, unlike other data reduction solutions. The IBM FlashSystem 7200 Control Enclosure offers several features for Data Reduction Pool compression workloads. These features include 8 Intel core processors with up to 768 GB of memory per node, and a built-in compression accelerator for hardware-assisted compression. In addition, the IBM FlashSystem 7200 system with IBM FlashCore Module NVMe type drives applies compression to any data that is not compressed.

The IBM FlashSystem 7200 system also supports the new SCM type drives. SCM is a new storage media technology that offers high endurance, high IOPS, and ultra-low latencies. For more information, see "Storage Class Media" on page 12.

Agile integration

The IBM FlashSystem 7200 system has the following agile characteristics:

► Fully integrated system management
► Application-aware data services
► Advanced Encryption Standard (AES), data at rest encryption with all NVMe type drives and FCMs drives have FIPS 140-2
► In-line hardware compression with IBM FlashCore Module type drives
► Tier or mirror to storage
► Mixed workload consolidation
► Nondisruptive data migrations
► Concurrent code load

By accelerating physical and virtual applications, the IBM FlashSystem 7200 system can help organizations reduce costs, increase revenue, and improve customer satisfaction for all types of applications, including the following categories:

► Transactional
► Enterprise resource planning (ERP) and supply chain management
► Big data and analytics
► Server and desktop virtualization
► Cloud

AI-empowered

The IBM FlashSystem 7200 system has the following AI characteristics:

► AI-empowered storage analytics, storage resource management, and support platform

► AI-based data placement for optimal data center performance and zero-downtime data migration

► IBM Storage Insights: AI-empowered predictive analytics, storage resource management, and support platform delivered over the cloud

Multicloud enabled

Along with IBM Spectrum® Virtualize on premises, IBM Spectrum Virtualize for Public Cloud V8.4.0 can enable clients to migrate data to and from supported public cloud providers, including IBM Cloud™ and Amazon Web Services (AWS). Clients can create hybrid multicloud solutions for their traditional block data and workloads by using built-in IP replication capabilities.

IBM Spectrum Virtualize for Public Cloud is deployed on cloud Infrastructure as a Service (IaaS) from IBM Cloud or AWS on bare metal servers in IBM Cloud or on Amazon Elastic Compute Cloud (Amazon EC2) instances on AWS, and virtualizing AWS Amazon Elastic Block Store (EBS) storage. This ability enables clients to create clustered configurations as with on-premises, while bringing the optimization and virtualization capabilities of IBM Spectrum Virtualize to public cloud infrastructures. These capabilities include most of the key features of IBM Spectrum Virtualize, such as FlashCopy®, transparent cloud tiering, thin provisioning, Global Mirror, Metro Mirror, Global Mirror with change volumes, and IBM Easy Tier® to public cloud IaaS.

IBM Spectrum Virtualize on-premises and IBM Spectrum Virtualize for Public Cloud together enable a hybrid multicloud deployment with a single data management layer between on-premises and the cloud across heterogeneous storage pools that can exist in the data center. This hybrid multicloud approach provides the following significant features:

► Storage pooling and automated allocation with thin provisioning

► Easy Tier automated tiering

► Deduplication and compression to reduce cloud storage costs

► FlashCopy and remote mirror for local snapshots and remote replication

► Support for virtualized and containerized server environments, including:

  – VMware
  – MicrosoftHyper-V
  – IBM PowerVM®
  – Red Hat OpenShift
  – CRI-O
  – Kubernetes

For more information about IBM FlashSystems and Hybrid Multi-Cloud, see IBM FlashSystems and Hybrid Multicloud.

Advanced Data Services

The IBM FlashSystem 7200 system provides the following advanced data services:

- ► Business continuity with replication services
- ► Data protection with IBM FlashCopy services
- ► Higher storage efficiency with thin-provisioning
- ► Data reduction pools that provide compression with de-duplication
- ► IBM Easy Tier
- ► External virtualization
- ► IP quorum support
- ► N-Port ID Virtualization (NPIV) support
- ► VMware vSphere virtual volume (VVOL) support and space-efficient copies
- ► Transparent Cloud Tiering

FlashSystem 7200 Enclosure Overview

The IBM FlashSystem 7200 system the following types of enclosures:

- ► A *control enclosure* manages your storage systems, communicates with the host, and manages interfaces. It also can house up to 24 NVMe-capable flash drives. These drives can be industry-standard NVMe types or the exclusive IBM FlashCore Module NVMe type and up to 12 optional SCM class drives.

- ► An *expansion enclosure* increases the available capacity of an IBM FlashSystem 7200 cluster. It communicates with the control enclosure through a dual pair of 12 Gbps SAS connections. These expansion enclosures can house many flash (solid-state drive [SSD]) and HDD serial-attached SCSI (SAS) type drives, depending on which enclosure model is ordered.

Figure 1 shows the FlashSystem 7200 control enclosure front view with an NVMe drive partially removed.

Figure 1   IBM FlashSystem 7200 Control Enclosure with one NVMe drive partially removed

Control enclosures

Each control enclosure can have multiple attached expansion enclosures, which expand the available capacity of the whole system. The IBM FlashSystem 7200 solution supports up to four control enclosures and up to two chains of SAS expansion enclosures per control enclosure.

The IBM FlashSystem 7200 Control Enclosure supports up to 24 NVMe-capable flash drives in a 2U high form factor and consists of one machine type: 2076. The 2076 is available in two models: 824 and U7C.

Note: The 2076-U7C model is an IBM FlashSystem 7200 solution with a 3-year warranty, and is intended for the Storage Utility Offering space. This model is physically and functionally identical to the IBM FlashSystem 2076-824 model, except for target configurations and variable capacity billing. The variable capacity billing uses IBM Spectrum Control or IBM Storage Insights to monitor the system usage, which allows allocated storage use above a base subscription rate to be billed per terabyte per month. Allocated storage is identified as storage that is allocated to a specific host (and unusable to other hosts), whether data is written or not written. For thin-provisioning, the data that is written is considered used. For thick-provisioning, the total allocated volume space is considered used.

Expansion enclosures

The IBM FlashSystem 7200 expansion enclosures consist of one machine type and three 2076 models: 12G, 24G, and 92G.

New SAS-based small form factor (SFF) and large form factor (LFF) expansion enclosures support various flash and SSD MDisks in a storage pool, which can be used for IBM Easy Tier:

► IBM FlashSystem 7200 LFF expansion enclosure Model 12G offers drive options with SAS drives. Up to 240 drives of SAS expansions are supported per IBM FlashSystem 7200 Control Enclosure. The expansion enclosure is 2U high.

► IBM FlashSystem 7200 SFF expansion enclosure Model 24G offers drive options with SSD flash and SAS drives. Up to 480 drives of SAS expansions are supported per IBM FlashSystem 7200 Control Enclosure. The expansion enclosure is 2U high.

► IBM FlashSystem 7200 LFF expansion enclosure Model 92G offers drive options with SSD flash and SAS drives. Up to 784 drives of SAS expansions are supported per IBM FlashSystem 7200 Control Enclosure. The expansion enclosure is 5U high.

Note: Attachment and intermixing of existing IBM Storwize® V7000 expansion enclosures models 12F, 24F, and 92F with FlashSystem 7200 expansion enclosure models 12G, 24G, and 92G is supported by FlashSystem 7200 Model 824 and Storwize V7000 Models 524, 624, and 724.

The IBM FlashSystem 7200 Control Enclosure can be recognized by the nomenclature "IBM FlashSystem 7200" on the left side of the bezel cover, which covers the rack-mounting screws.

Figure 2 on page 8 shows the IBM FlashSystem 7200 bezel and NVMe drive.

Figure 2   IBM FlashSystem 7200 bezel and IBM FlashCore Module description

Labeling on the NVMe drive provides the drive type, capacity, type of drive, and FRU number. The example that is shown in Figure 2 is the IBM FlashCore Module NVMe 19.2 TB type.

Did you know

IBM FlashSystem 7200 runs Spectrum Virtualize V8.4.0, which provides the following functionality:

► Support for the IBM FlashCore Module NVMe type drives with IBM enhanced flash technology.

► The IBM FlashSystem 7200 Control Enclosure supports up to 24 ultra-low latency 2.5-inch (SFF) 4.8 TB, 9.6 TB, 19.2 TB, or 38.4 TB IBM FlashCore Module NVMe types or up to 24 NVMe 800 GB, 1.92 TB, 3.84 TB, 7.68 TB, or 15.36 TB industry-standard drives, or a mixture of both.

► It also supports up to 12 NVMe Storage Class Memory Drives in capacities 375 GB, 750 GB, 800 GB, and 1.6 TB.

► IBM FlashCore Module NVMe types provide automatic data compression and encryption without affecting the system performance.

- ► The models 12G, 92G, and 24G SAS expansion enclosures can be used with the IBM FlashSystem 7200 control expansion.

- ► The IBM FlashSystem 7200 system can use IBM Security Key Lifecycle Manager (SKLM) or USB key encryption. Up to four SKLM key servers are supported. It also offers hardware-based AES 256 data-at-rest encryption by using USB key and SKLM key server-based encryption, with no affect on performance.

- ► Remote Support Assistance (RSA) enables IBM support personnel to access the system to complete troubleshooting tasks.

- ► Consistency protection for Global Mirror and Metro Mirror replication.

- ► Management GUI support for host clusters, including private and shared volume mappings.

- ► Throttling allows customers to control resources that are used when the system is processing I/Os on hosts, host clusters, volumes, copy offload operations, and storage pools.

- ► Transparent Cloud Tiering is a function of IBM Spectrum Virtualize that uses IBM FlashCopy mechanisms to produce a point-in-time snapshot of the data.

- ► Provides flexible interface types, including Fibre Channel (FC) and Ethernet (iWARP and RoCE protocols) to easily integrate into SAN and iSCSI network environments.

- ► IBM Storage Insights offers some key capabilities that helps clients meet the demands that are put on IT by helping to build the connective fabric between IBM, storage, and the user. IBM Storage Insights provides advanced customer service, and monitors the performance, capacity, and health of each device.

Current release functions

This section describes several new functions and features that are available in the current IBM FlashSystem 7200 release.

New in IBM FlashSystem 7200 Software V8.4.0

The following functions are included in IBM FlashSystem 7200 Software V8.4.0:

- ► 3 Site Data Replication for HyperSwap. 3 Site Data Replication for HyperSwap supports the following use cases:
  - – Disaster scenarios
  - – Site maintenance
  - – Link failure cases
- ► Security updates:
  - – IBM is releasing a new set of options to allow a security administrator to create policies for passwords, account lockout, session time-out.
  - – Create a single system-wide policy that applies to all local accounts (session time-outs also apply to remote accounts).
  - – Configurable CLI time-out.
  - – HTTP proxy server for cloud callhome and Storage Replication Adapter (SRA) log upload.

- NVME drive security updates (new events and sense data to better identify and resolve NVMe drive encryption errors) and secure data deletion.

► UI modernization updates:
   - Modernized syslog servers panel.
   - New host dialog.
   - New Add Storage experience.
   - Modernized remote copy experience (2-site and 3-site).

► DRAID-1:
   - 2 member drives per array (0 rebuild area)
   - 3 - 16 member drives per array (1 rebuild area)
   - System recommendation is to create DRAID-1 in arrays up to 6 drives

► Data reduction child pools:
   - User can create child pools in data reduction parent pools
   - Data reduction child pools are created without a quota and can consume entire parent capacity

► DRP
   - Redirect-on-write for DRP snapshots adds a redirect-on-write (RoW) alternative to the existing copy-on-write (CoW) capabilities.
   - Comprestimator always on.
   - RAID Reconstruct Read (3R) leveraging RAID capabilities, DRP asks for a specific data block reconstruction when detecting a potential corruption.

► Miscellaneous:
   - Updates to max configuration limits.
   - 8.4.0 mirrored vDisks fast format enhancements.
   - 8.4.0 FC-NVMe enhancements.
   - 8.4.0 improved handling of memory errors.
   - SCM restrictions lifted. See "Storage Class Media" on page 12.
   - As of Spectrum Virtualize 8.4.0.2 and SI/ Spectrum Control 5.3.7 or later data collection can be done with Monitor (least privileged) role. As each node writes a statistics file it will automatically be uploaded to the config node.
   - 8.4.0 DNS support enhancements.

IBM FlashSystem 7200 Software V8.3.1

The following functions are available in IBM FlashSystem 7200 Software V8.3.1:

► Support for IBM FlashSystem 7200 enclosures with new larger NVMe drives.

► RSA provides a secure connection for remote support with audit logging.

► Management GUI enhancements.

► Ownership groups.

   An ownership group defines a subset of users and objects within the system. You can create ownership groups to further restrict access to specific resources that are defined in the ownership group.

- ► Priority flow control.

  Priority flow control (PFC) is an Ethernet protocol that supports the ability to select the priority of different types of traffic within the network.

- ► Support for expanding distributed arrays (DRAID).

- ► Support for pool-level volume protection.

  Volume protection prevents active volumes or host mappings from being deleted inadvertently if the system detects recent I/O activity.

- ► Support for SNMP protocol version 3 enhanced security features.

- ► Support for enhanced auditing features for syslog servers.

- ► Enhanced password security.

  The user must change the default password to a different password on first login or system set-up.

- ► Improvements to the terms and definitions that relate to capacity were updated.

- ► Support for the new Storage Class Memory (SCM) technology with implementation by using new drives from Intel and Samsung, which can enchain workload throughput, with or without using EasyTier.

- ► Three-site replication:

  - – Three-site replication provides enhanced disaster tolerance for IBM Spectrum Virtualize systems, which allows coordination of data between three disparate sites for failover and failback.

  - – At the time of this writing, three-site replication requires the submission of a request through the SCORE system to help manage and ensure that the requirements and configuration details are met.

- ► Secure Drive Erase, which is the ability to completely erase any customer data from a NVMe, SAS SSD, or HDD before it is removed from the control and expansion enclosure.

Highlights

In this section, we describe the IBM FlashSystem 7200 highlights.

IBM FlashCore technology

At the heart of the IBM FlashSystem 7200 system is IBM FlashCore technology (if the IBM FlashCore Module NVMe type drives are ordered), which consists of the following key elements:

- ► Hardware-accelerated architecture that is engineered for flash, with a hardware-only data path.

- ► The IBM FlashSystem data compression and decompression algorithm is a Modified dynamic GZIP algorithm. Because it is implemented completely in hardware, no processor intervention is required.

- ► IBM FlashCore Modules, which are designed for low latency, density, and reliability.

- ► IBM Advanced Flash Management, which improves flash endurance over standard implementations without sacrificing latency.

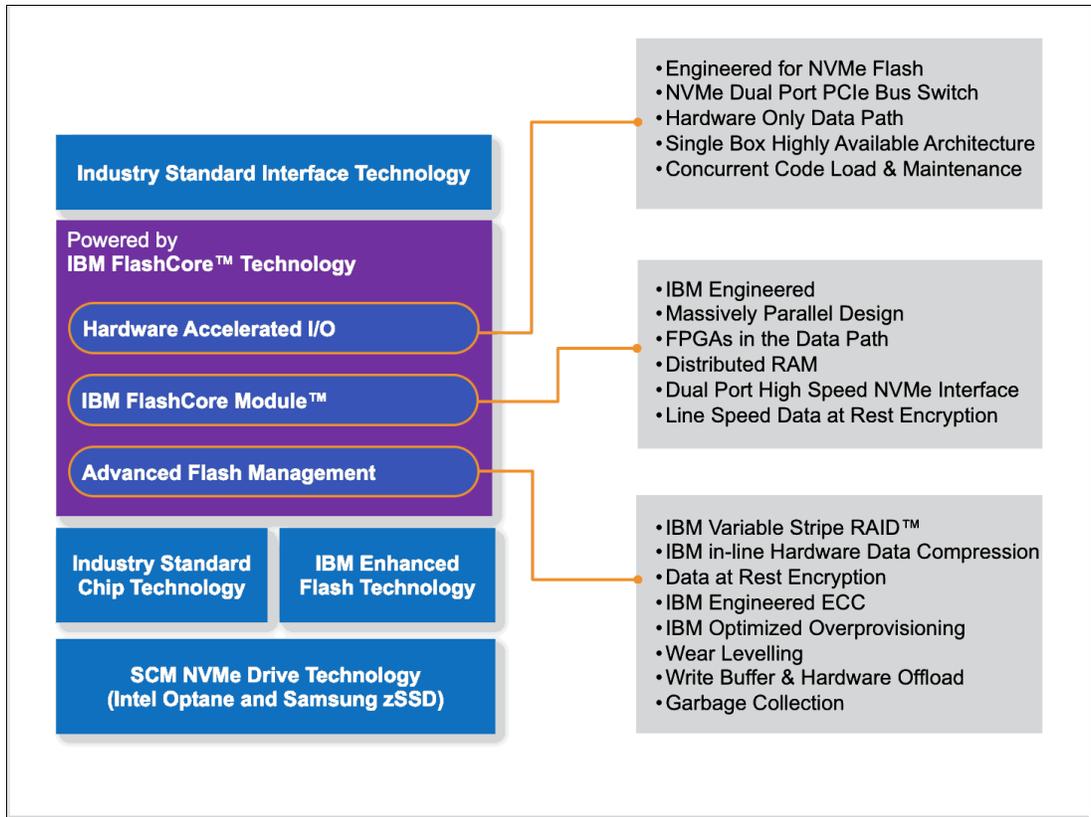Figure 3 on page 12 shows IBM FlashCore technology.

Figure 3   IBM FlashCore technology

For more information about IBM FlashCore technology, see IBM FlashSystem 900 - Overview.

Storage Class Media

Storage Class Memory (SCM) is an industry-wide statement for non-volatile memory devices that perform faster (~10µs) than traditional NAND SSDs (100µs), but slower than DRAM (100ns).

The technology pricing sits between DRAM and traditional NAND. Price is significantly more expensive than traditional NAND drives.

At the time of this writing, the following major vendors are available:

► Intel (3D Xpoint memory technology in Optane drives)
► Samsung (zNAND memory technology in zSSD drives)

The IBM FlashSystem 7200 system supports the new low-latency, high-speed SCM drives in any of the slots of the control enclosure. The control enclosure can contain up to 12 SCM drives.

Note: Storage Class Memory (SCM) and other NVM Express (NVMe) drive types can be installed in any drive slot. However, the highest capacity drives must be installed in the lowest available drive slots.

SCM and Easy Tier

Because of their faster speed, SCM drives are placed in a new top tier of Easy Tier. This new tier is ranked higher than the existing tier0_flash that is used for NVMe NAND drives that are supported today. The Easy tier levels are:

► Storage Class Memory

– Storage Class Memory tier exists when the pool contains drives that use persistent memory technologies that improve endurance and speed of current flash storage device technologies.

► Tier 0 flash

– Tier 0 flash tier exists when the pool contains high performance flash drives.

► Tier 1 flash

– Tier 1 flash tier exists when the pool contains tier 1 flash drives. Tier 1 flash drives typically offer larger capacities, but slightly lower performance and write endurance characteristics.

► Enterprise tier

– Enterprise tier exists when the pool contains enterprise-class MDisks, which are disk drives that are optimized for performance.

► Nearline tier

– Nearline tier exists when the pool contains nearline-class MDisks, which are disk drives that are optimized for capacity.

Hot data is placed in the SCM tier when Easy Tier is enabled. DRP and VG extent allocation was tuned to use SCM drives, specially for metadata (directory volume lookups). This is one of the main use cases for SCM drives in an IBM FlashSystem 7200 system.

SCM and RAID configurations

SCM Drives feature the following rules concerning RAID supported configurations:

► Distributed DRAID 1 with two drives (including distributed spare capacity) or more and is the best practice recommendation and configuration.

► Distributed DRAID 5 with four drives (including distributed spare capacity) or more is supported

► Distributed DRAID 6 with six drives (including distributed spare capacity) or more is supported

► Traditional TRAID 1 and 10 with two drives is supported; however, no spare is available, and performance might be limited.

► SCM drives have their own SCM technology type and drive class.

► SCM and Standard NVMe (or SAS) cannot intermix in the same array.

► Easy Tier tier_scm arrays can take lower tech types as spare drives when no tier_scm drives are available.

► Lower tier arrays can accept tier_scm drives as superior drives.

SCM drive formatting and UNMAPS

Because of its media technology, SCM drive formats take longer than a typical NVMe drive. The drive formats can take up to 15 minutes, so the user needs to be patient and wait until it completes.

SCM drive formats occur when one of the following conditions exist:

- ► Drive is replaced
- ► Enclosure is managed
- ► Array/mdisk is removed

> **Note:** Intel Optane drives do not support UNMAPs because it is not beneficial for these drives. Instead, the system writes zeros to deallocate drive sectors.

IBM FlashWatch overview

IBM FlashWatch is a new offering from IBM to complement the purchase of the IBM FlashSystem 7200. It provides the following features that are included in the purchase of the product (IBM FlashWatch features three main focus areas):

- ► Acquisition:
  - – High Availability Guarantee:
    - • Proven 99.9999% availability
    - • Optional 100% commitment when using HyperSwap
  - – Data Reduction Guarantee
    - • 2:1 self-certified
    - • Up to 5:1 with workload profiling
  - – All-inclusive Licensing

    All storage functions included in licensing cost for internal storage
- ► Operation:
  - – Comprehensive Care

    Up to 7 years of 24x7 support, with three years Technical Advisor, enhanced response times, and managed code upgrades
  - – Cloud Analytics

    Storage Insights included at no extra cost to proactively manage your environment
  - – Flash Endurance Guarantee

    Flash media is covered for all workloads while under warranty or maintenance
- ► Migration:
  - – IBM Flash Momentum - Storage Upgrade Program

    Replace your controller and storage every three years with full flexibility
  - – Cloud-like Pricing

    Storage Utility pricing features monthly payments for only the storage that you use
  - – No Cost Migration

    A total of 90 days no-cost data migration from over 500 storage controllers, IBM, and non-IBM

For more information about the IBM FlashWatch offering, see IBM FlashWatch FAQ.

The IBM FlashWatch offering is applicable across the Spectrum Virtualize family, with the Product Matrix in the FAQ detailing the elements that are applicable against which product.

IBM Storage Insights

IBM Storage Insights is another part of the monitoring capability of the IBM FlashSystem 7200 system and supplements the views available in the GUI.

IBM strongly recommends that all customers install and use this no-charge, cloud-based IBM application because it provides a single dashboard that gives you a clear view of all your IBM block storage. You can make better decisions by seeing trends in performance and capacity.

With storage health information, you can focus on areas that need attention, and when IBM support is needed. IBM Storage Insights simplifies uploading logs, speeds resolution with online configuration data, and provides an overview of open tickets all in one place.

IBM Storage Insights includes the following features:

► A unified view of IBM systems:

– Provides a single view to see all your system's characteristics

– See all of your IBM storage inventory

– Provides a live event feed so that you know in real time what is going on with your storage so that you can act fast

► IBM Storage Insights collects telemetry data and call home data and provides real-time system reporting of capacity and performance

► Overall storage monitoring looking at:

– The overall health of the system

– Monitoring of the configuration to see whether it meets preferred practices

– System resource management determines which system is overtaxed and provides proactive recommendations to fix it

► IBM Storage Insights provides advanced customer service with an event filter that you can use to accomplish the following tasks:

– You and IBM Support can view support tickets, open and close them, and track trends.

– You can use the autolog collection capability to collect the logs and send them to IBM before IBM Support reviews the problem. This capability can save as much as 50% of the time to resolve the case.

In addition to the no-charge version of IBM Storage Insights, IBM offers IBM Storage Insights Pro, which is a subscription service that provides longer historical views of data, more reporting and optimization options, and supports IBM file and block storage with EMC VNX and VMAX.

Customer dashboard

Figure 4 shows a view of the IBM Storage Insights main dashboard and the systems that it monitors.
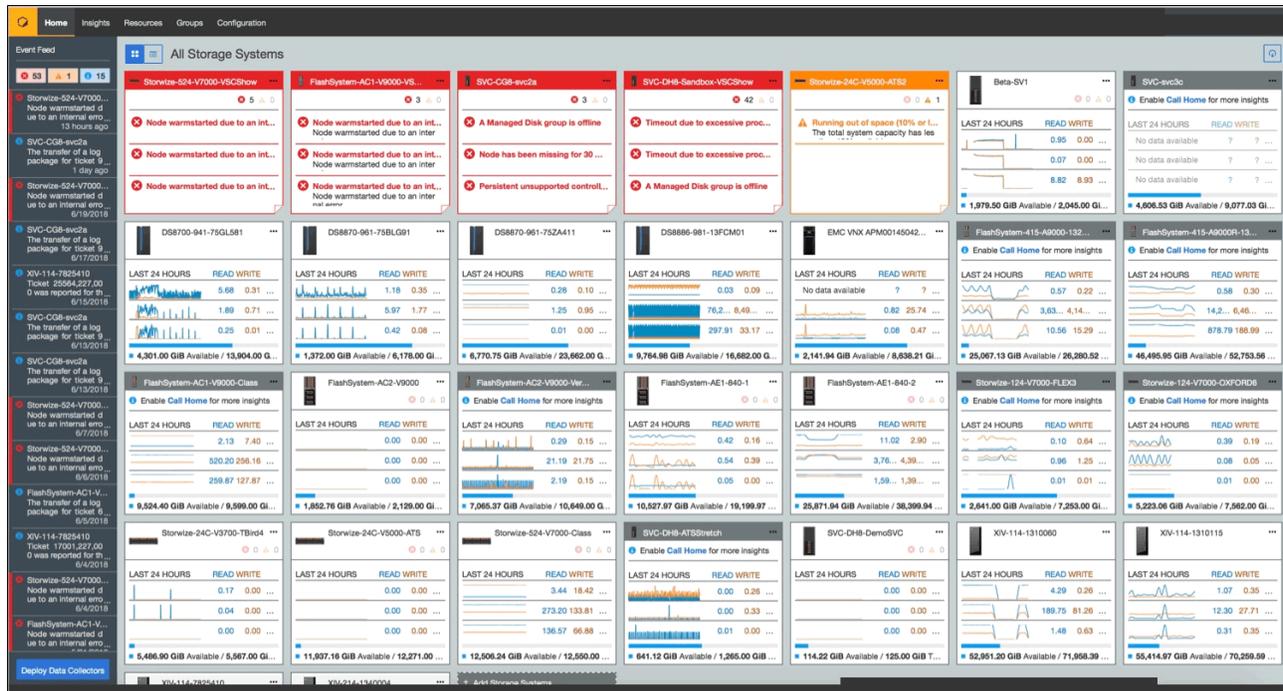

Figure 4   IBM Storage Insights dashboard

For more information about dashboard displays, see "Information and registration" on page 16.

For more information about the architecture and design overview of IBM Storage Insights, see *IBM FlashSystem 9100 Architecture, Performance, and Implementation*, SG24-8425.

Information and registration

For more information about IBM Storage Insights, see the following resources:

► *IBM Storage Insights Fact Sheet*
► Product demonstration (sign in required)
► *IBM Storage Insights Security Guide*, SC27-8774
► IBM Knowledge Center
► Product registration (used to sign up and register for this no-charge service)

IBM Spectrum Control Connect

IBM FlashSystem 7200 Software V8.4.0 supports integration of VASA and VAAI by using IBM Spectrum Control Connect V3.2.5 (formally known as IBM Spectrum Control Base) or later. This centralized server system consolidates a range of IBM storage provisioning, virtualization, cloud, automation, and monitoring solutions through a unified server platform. For more information about this feature, see IBM Knowledge Center.

IBM Spectrum Control Connect provides insight and awareness about the configuration capabilities, storage health, and events of a storage system regarding VMware and vSphere. With this capability, VMware administrators can independently and centrally manage their storage resources on IBM storage systems.

IBM Enterprise Class Support

IBM Enterprise Class Support (ECS) is available as a chargeable feature for the IBM FlashSystem 7200 with a 3-year warranty. The machine types that are listed in Table 1 qualify for this type of optional enhanced support.

Table 1   Machine types that qualify for optional Enterprise Class Support

Component	Machine type model
IBM FlashSystem 7200 Control Enclosure	2076-824 2076-U7C
IBM FlashSystem 7200 Expansion Enclosure	2076-12G 2076-24G 2076-92G

The optional, chargeable, ECS offering provides the following key enhancements to the product base 3-year warranty terms and conditions:

► IBM Technical Advisor to proactively improve problem management and communication
► Software and product installation
► Configuration support
► Onsite and remote software updates up to three times during the warranty period
► Enhanced response times for high severity problems

During the warranty period and with a current active software maintenance agreement, the client is entitled to enhanced response times for severity 1 problems. IBM also provides an IBM Service Support Representative (IBM SSR) to perform onsite product setup and installation. In addition, the IBM SSR or IBM Remote Support Center performs up to three software updates during the warranty period.

IBM Technical Advisor support is provided during the warranty period. This support enhances end-to-end support for the client's complex IT solutions. IBM Technical Advisor uses an integrated approach for coordinated, cross-team support to enable clients to maximize IT availability.

IBM Technical Advisor works with clients, sales teams, and IBM Business Partners to ensure that the Technical Delivery Assessment checklist and site planning steps are complete.

Also, with the 3-year warranty, IBM Technical Advisor proactively plans the software updates, which ensure that workstation, network access, user ID, and software download steps are complete before deploying the IBM SR or IBM Remote Support Center to perform the software update.

You can purchase IBM Enterprise Class Services (ECS) from IBM Technology Support Services (TSS). Consult your IBM Sales Representative or your IBM reseller to discuss your options, including IBM ECS as part of IBM's warranty service with the IBM FlashSystem 7200 model 2076-824 product.

For more information about this ECS offering, see the *IBM Storage Systems offer Enterprise-Class Support options* announcement letter.

IBM FlashSystem 7200 GUI

Because IBM FlashSystem 7200 Control Enclosures cluster to form a system, which is a single management interface is used for IBM FlashSystem 7200 Control Enclosures. Each IBM FlashSystem 7200 node canister is an individual server in an IBM FlashSystem 7200 clustered system on which the IBM FlashSystem 7200 software runs.

The IBM FlashSystem 7200 system includes an easy-to-use management GUI that runs on the IBM FlashSystem 7200 Control Enclosure to help you monitor, manage, and configure your system. You can access the GUI by opening any supported web browser and entering the management IP addresses. You can connect from any workstation that can communicate with the IBM FlashSystem 7200 system. The IBM FlashSystem 7200 Control Enclosure is delivered in a 2U 19-inch rack-mount enclosure.

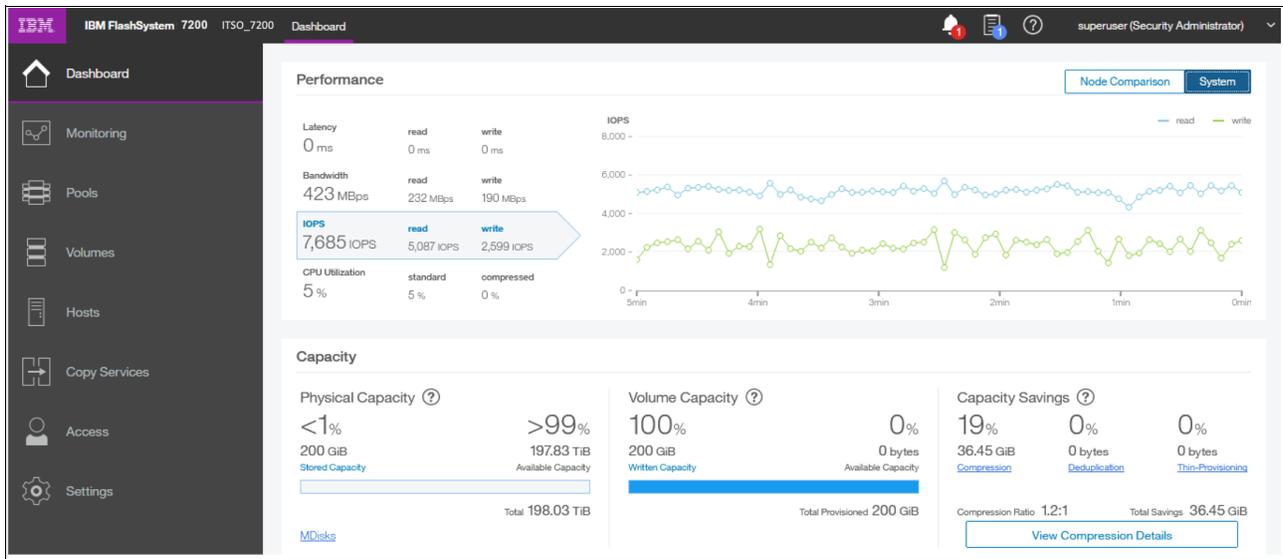Figure 5 shows the IBM FlashSystem 7200 GUI dashboard.

Figure 5   IBM FlashSystem 7200 GUI showing the dashboard

Figure 6 on page 19 shows the control enclosure window. You can open this window by selecting **Monitoring** → **System Overview** from the left side graphical menu.
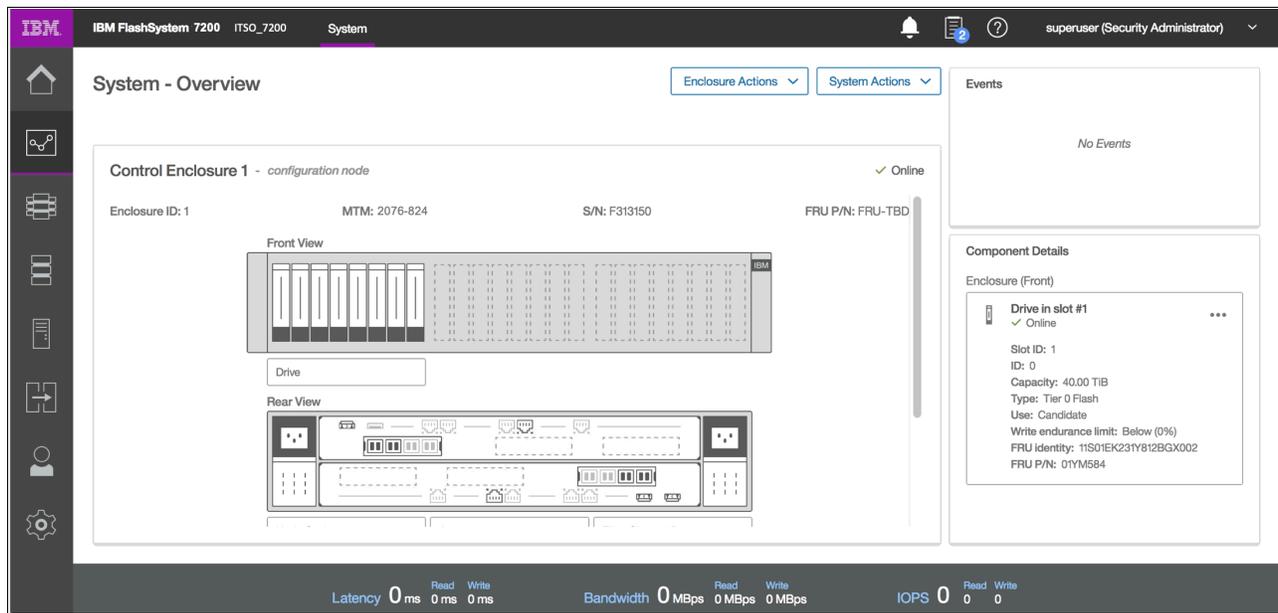
Figure 6   IBM FlashSystem 7200 system overview of the control enclosure

The IBM FlashSystem 7200 system includes a command line interface (CLI), which is useful for scripting, and an intuitive GUI for simple and familiar management of the product. The IBM FlashSystem 7200 system supports Simple Network Management Protocol (SNMP), email forwarding that uses Simple Mail Transfer Protocol (SMTP), and syslog redirection for complete enterprise management access.

With the GUI, you can quickly deploy storage and manage it efficiently. The GUI runs on the IBM FlashSystem 7200 Control Enclosure, so a separate console is not needed. Point your web browser to the system IP address, and then you can manage all of the expansion enclosures from one place.

The IBM FlashSystem 7200 Control Enclosure node canisters are configured for active-active redundancy. The node canisters run a highly customized Linux-based operating system that coordinates and monitors all significant functions in the system.

The node canisters provide a web interface, Secure Shell (SSH) access, and SNMP connectivity through external Ethernet interfaces. With the web and SSH interfaces, administrators can monitor system performance and health metrics, configure storage, and collect support data, among other features.

The storage configuration includes defining logical units with capacities, access policies, and other parameters. No software must be installed on host computers to administer the IBM FlashSystem 7200 system beyond a web browser or a standard SSH client.

Supported platforms

The IBM FlashSystem 7200 system features extensive interoperability with support for a wide range of operating systems (including Microsoft Windows Server 2008 and 2012, Linux, and IBM AIX® and IBM i), hardware platforms (including IBM System x, IBM Power Systems, and x86 servers not from IBM), host bus adapters (HBAs), and SAN fabrics. For more information, see the IBM System Storage Interoperation Center (SSIC).

IBM FlashSystem 7200 Hardware Component Overview

The following sections provide a hardware component overview.

IBM FlashSystem 7200 Control Enclosure

The IBM FlashSystem 7200 Control Enclosure is a 2U rack-mounted NVMe flash memory enclosure that is based on IBM flash technology and provides the primary management interface (GUI) and the host interface configuration. The IBM FlashSystem 7200 Control Enclosures support FC Protocol (FCP and NVMeOF on FC) and iSCSI interfaces. For iSCSI, both RoCE and iWARP protocols are supported.

The IBM FlashSystem provides the following NVMe technologies:

► Supports unique world class IBM FlashCore Module drives with inline compression.

► Supports industry-standard NVMe drives.

► Option for Intel Optane or Samsung zSSD SCM type drives.

► NVMe-oF on FC.

► The IBM FlashSystem 7200 system is offered as two models:

– 2076 Model 824 - IBM FlashSystem 7200 SFF NVMe Control Enclosure
– 2076 Model U7C - IBM FlashSystem 7200 SFF NVMe Control Enclosure

> **Note:** The U7C utility-based model uses fixed configurations because they are Capacity on Demand (CoD) based offerings.

► Macroefficiency with up to 920 TB of raw maximum protected capacity with inline hardware data compression if you use IBM FlashCore Module NVMe types.

► Support for industry-standard NVMe drives with up to 368 TB of maximum raw capacity.

► Extreme performance with IBM MicroLatency® FlashCore Modules.

► Optional expansion enclosures provide tiering options with SSD flash drives.

The IBM FlashSystem 7200 configuration includes the following components:

► A total of 1 - 4 IBM FlashSystem 7200 Control Enclosures

► A total of 1 - 20 IBM FlashSystem 7200 Small Form Factor (SFF) or Large Form Factor (LFF) Expansion Enclosures

► A total 1 - 8 IBM FlashSystem 7200 Large Form Factor, High Density (LFF HD) Expansion Enclosures

The control enclosure includes integrated AC power supplies and battery units inside each of the node canisters. These batteries supply power to the control enclosure during a sudden power loss or failure so that the system can correctly commit all transactions to the storage medium.

The IBM FlashSystem 7200 Control Enclosure includes the following features:

► Full internal redundancy:

– Redundant and hot-swappable node canisters.
– Redundant and hot-swappable batteries within each node canister.
– Hot-swappable PCIe adapters.
– Redundant and hot-swappable power supplies, DIMMs, and fans.

► The control enclosure support up to 24 NVMe 2.5-inch drives, which can be the IBM FlashCore Module NVMe type drives or the industry-standard NVMe drives:

– The following 2.5-inch (SFF) IBM FlashCore Module NVMe types are supported in IBM FlashSystem 7200 Control Enclosures:

• 4.8 TB 2.5-inch NVMe FlashCore Module
• 9.6 TB 2.5-inch NVMe FlashCore Module
• 19.2 TB 2.5-inch NVMe FlashCore Module
• 38.4 TB 2.5-inch NVMe FlashCore Module

Distributed RAID 6 (recommended), Distributed RAID 5 (supported).

– The following 2.5-inch (SFF) NVMe industry-standard drives are supported in IBM FlashSystem 7200 Control Enclosures:

• 800 GB 2.5-inch NVMe flash drive
• 1.92 TB 2.5-inch NVMe flash drive
• 3.84 TB 2.5-inch NVMe flash drive
• 7.68 TB 2.5-inch NVMe flash drive
• 15.36 TB 2.5-inch NVMe flash drive

Traditional RAID 10 and Distributed RAID 6 (recommended), Distributed RAID 5 (supported).

– It also supports up to 12 NVMe Storage Class Memory Drives in the following capacities:

• 375 GB NVMe Storage Class Memory Drive
• 750 GB NVMe Storage Class Memory Drive
• 800 GB NVMe Storage Class Memory Drive
• 1.6 TB NVMe Storage Class Memory Drive

Distributed RAID 5, or TRAID 1 or 10 with fewer than 4 drives.

– All drives are dual-port and hot-swappable. Drives of the same form factor and connector type can be intermixed within an enclosure.

– All flash modules must be the same type and capacity within the same DRAID6 array.

Each IBM flash memory module contains IBM enhanced flash chips, FPGA chips, an IBM PowerPC® processor, and dynamic random access memory (DRAM) devices that are connected to the flash controllers and processor

► Four 8-core processors per control enclosure

► Cache options from 256 GB (128 GB per canister) to 1.5 TB (768 GB per canister)

► Eight 10 Gb Ethernet ports standard for iSCSI connectivity

► 32 Gb or 16 Gb FC, 25 Gb Ethernet, and 10 Gb Ethernet ports for FC and iSCSI connectivity

► 12 Gb SAS ports for expansion enclosure attachment

The IBM FlashSystem 7200 Control Enclosure supports FCP with point-to-point (FC-P2P), arbitrated loop (FC-AL), and switched fabric (FC-SW) topologies. FC interfaces can be configured as N_port or NL_port types.

The FC ports are configured in NPIV mode; therefore, the user must check that this configuration is preferred for their installation. If not, this configuration must be changed from the default when you set up the SAN infrastructure.

Full active-active multipathing across all interfaces is supported, although host software support for this function can vary.

Figure 7 shows the front view of the IBM FlashSystem 7200 Control Enclosure.

Figure 7   IBM FlashSystem 7200 Control Enclosure front view

The IBM FlashSystem 7200 Control Enclosure also includes the following expansion features:

► Capability for adding into clustered systems with more IBM FlashSystem 7200 Control Enclosures or IBM V7000 Gen2 or Gen 3 controllers.

► Up to 20 SAS attached expansion enclosures are supported per IBM FlashSystem 7200 controller pair, which provides up to 240 SAS HDD type drives with expansion Model 12G and up to 480 SSD/SAS type drives with expansion Model 24G.

► Up to eight LFF High Density (HD) 92G expansion controllers are supported per IBM FlashSystem 7200 Control Enclosure pair, which provides up to 736 SSD or HDD SAS flash drives of Tier 1 capacity.

Figure 8 shows the components of the IBM FlashSystem 7200 Control Enclosure from the rear. You can see the interface cards, power supply units, and the various USB and Ethernet ports. All components are concurrently maintainable, except for the passive midplane and power interposer board. All external connections are from the rear of the system.
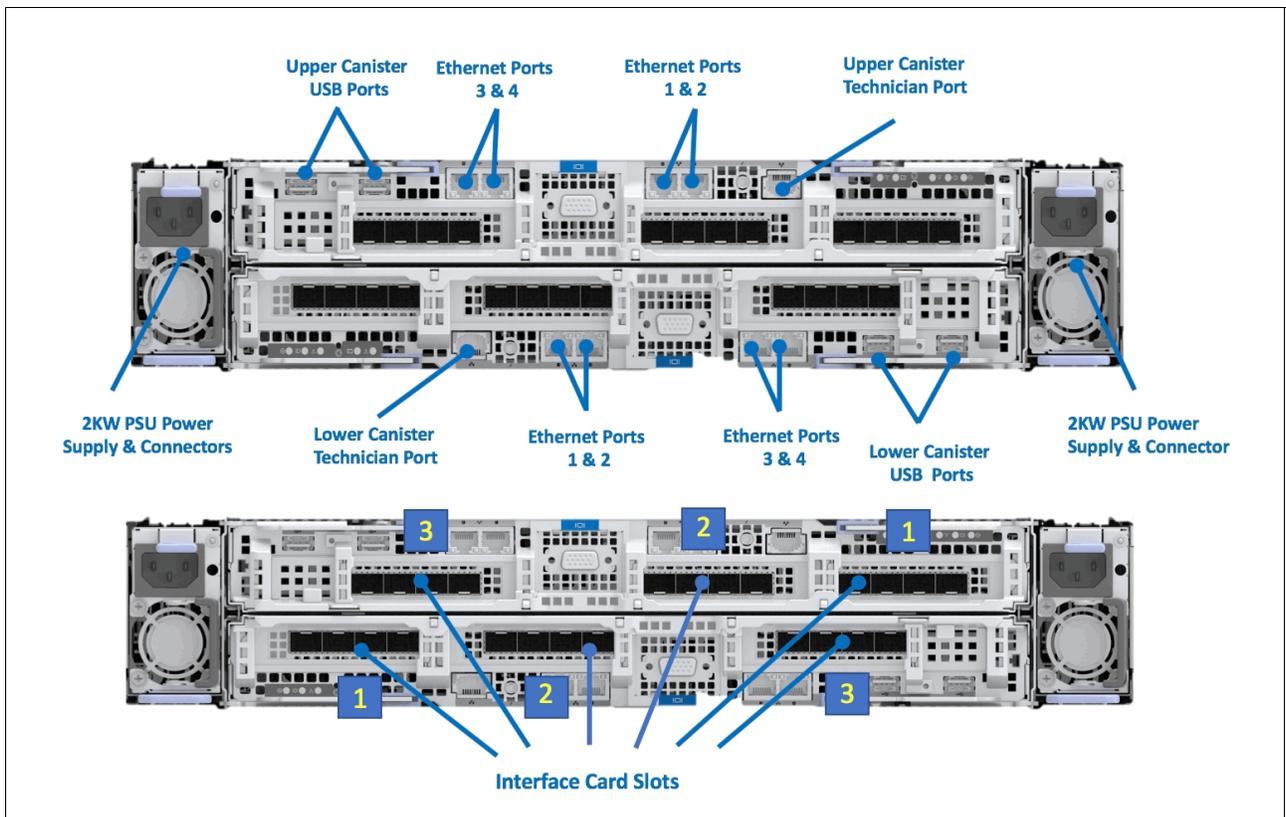

Figure 8   Rear view of IBM FlashSystem 7200 Control Enclosure

Note: The upper node canister is mounted upside down in the expansion enclosure. Therefore, the port numbering must be read right to left.

IBM FlashSystem 7200 Utility Model U7C

The IBM 2076 Model U7C is the FlashSystem 7200 hardware component that is used in the Storage Utility Offering space. It is physically and functionally identical to the FlashSystem 7200 Model 824, with the exception of target configurations and variable capacity billing.

The variable capacity billing uses IBM Spectrum Control Storage Insights to monitor the system usage, which allows allocated storage usage above a base subscription rate to be billed per TB, per month. Allocated storage is identified as storage that is allocated to a specific host (and unusable to other hosts), whether data is written or not.

For thin-provisioning, the data that is written is considered used. For thick provisioning, the total allocated volume space is considered used.

IBM FlashSystem 7200 Utility Models U7C provide a variable capacity storage offering. These models offer a fixed capacity, with a base subscription of around 35% of the total capacity.

IBM Storage Insights is used to monitor system usage, and capacity that is used. This usage is billed on a capacity-used basis. With this billing structure, you can grow or shrink usage, and pay for the configured capacity only.

IBM FlashSystem utility models are provided for customers who can benefit from a variable capacity system, where billing is based only on provisioned space. The hardware is leased through IBM Global Finance on a three-year lease, which entitles the customer to use approximately 30 - 40% of the total system capacity at no extra cost (customer individual contract dependant). If storage needs increase beyond that initial capacity, usage is billed based on the average daily provisioned capacity per terabyte per month, on a quarterly basis.

Example: A total system capacity of 115 TB

A customer has an IBM FlashSystem 7200 utility model with 4.8 TB NVMe drives for a total system capacity of 115 TB. The base subscription for such a system is 40.25 TB. During the months where the average daily usage is below 40.25 TB, no extra billing occurs.

The system monitors daily provisioned capacity and averages those daily usage rates over the month. The result is the average daily usage for the month.

If a customer uses 45 TB, 42.5 TB, and 50 TB in three consecutive months, IBM Storage Insights calculates the overage as listed in Table 2 (rounding to the nearest terabyte).

Table 2   Billing calculations based on customer usage

Average daily	Base	Overage	To be billed
45 TB	40.25 TB	4.75 TB	5 TB
42.5 TB	40.25 TB	2.25 TB	2 TB
50 TB	40.25 TB	9.75 TB	10 TB

The total capacity that is billed at the end of the quarter is 17 TB per month in this example.

Flash drive expansions can be ordered with the system in all supported configurations. Table 3 lists the feature codes that are associated with the UG8 utility model billing.

Table 3   7200 U7C utility model billing feature codes

Feature code	Description
#AE00	Variable Usage 1 TB/month
#AE01	Variable Usage 10 TB/month
#AE02	Variable Usage 100 TB/month

These features are used to purchase the variable capacity that is used in the utility models. The features (#AE00, #AE01, and #AE02) provide terabytes of capacity beyond the base subscription on the system. Usage is based on the average capacity that is used per month. The total of the prior three months' usage should be totaled, and the corresponding number of #AE00, #AE01, and #AE02 features ordered quarterly.

Billing

The local project office compiles the usage information from IBM Storage Insights on a quarterly basis. This data is compared to the base system capacity subscription, and any provisioned capacity beyond that base subscription is billed per terabyte per month on a quarterly basis.

The calculated usage is based on the average use over a month. In a highly variable environment, such as managed or cloud service providers, this subscription enables the system to be use only as much as is necessary during any month. Usage can increase or decrease, and is billed accordingly.

Provisioned capacity is considered capacity that is reserved by the system. In thick-provisioned environments, this capacity is allocated to a host, whether it has data that is written or not. For thin-provisioned environments, the data that is written is used because of the different ways in which thick- and thin-provisioning use flash drive space.

Figure 9 show a summary of the IBM FlashSystem 7200 machine types and the models.

MTM	2076-U7C	2076-824
Mktg Name	FlashSystem 7200	FlashSystem 7200
Warranty	3 Year; 9x5 NBD	3 Year; 9x5 NBD
Install	Customer Set Up (CSU)	Customer Set Up (CSU)
Services	Optional priced service offerings Utility Model with fixed config Capacity purchased as required Monitored and billed via Storage Insights	ECS optional purchase includes Technical Advisor (TA), SSR install and 24/7 SBD enhanced service
Expansion Enclosures	12G, 24G, 92G,	12G, 24G, 92G,
Misc	Flash and HDD expansions	

Figure 9   IBM FlashSystem 7200 machine type and models

IBM FlashSystem 7200 Expansion Enclosures

IBM FlashSystem 7200 Expansion Enclosures are 2U or 5U rack-mounted units. The expansion enclosures are offered in the following models with several drive features:

► FlashSystem 7200 LFF Expansion Enclosure Model 12G

Supports up to 12 LFF 3.5-inch HDD drives that can be formatted as RAID 5 or DRAID6, which are high-capacity, archival-class, nearline 7,200 rpm drives in: 4 TB, 6 TB, 8 TB, 10 TB, 12 TB, and 14 TB.

► FlashSystem 7200 SFF Expansion Enclosure Model 24G:

Supports up to 24 SFF 2.5-inch drives that can be formatted as RAID 5 or DRAID6:

– High-capacity, archival-class, nearline 7,200 rpm drives in: 2 TB

– High-performance, enterprise class disk 10,000 rpm drives in: 900 GB, 1.2 TB, 1.8 TB, and 2.4 TB

– Flash drives in: 400 GB, 800 GB, 1.6 TB, 1.92 TB, 3.2 TB, 3.84 TB, 7.68 TB, 15.36 TB, and 30.72 TB

► FlashSystem 7200 HD LFF Expansion Enclosure Model 92G:

Supports up to 92 LFF 2.5-inch High-Density Drives in a 3.5 inch carrier, and can be formatted as RAID 5 or DRAID6

– High-capacity, archival-class, nearline 7,200 rpm drives in: 6 TB, 8 TB, 10 TB, 12 TB, and 14 TB

– High-performance, enterprise class disk 10,000 rpm drives in: 1.2 TB, 1.8 TB, and 2.4 TB

– Flash drives in: 1.6 TB, 1.92 TB, 3.2 TB, 3.84 TB, 7.68 TB, 15.36 TB, and 30.72 TB

Multiple expansion enclosures are supported per IBM FlashSystem 7200 controller pair, which provides up to 240 drives with expansion enclosure Model 12G, up to 480 drives with expansion enclosure Model 24G, and up to 736 drives with expansion enclosure Model 92G.

On each SAS chain, the systems can support up to a SAS chain weight of 10:

► Each 2076-12G or 2076-24G expansion enclosure adds a value of 1 to the SAS chain weight

► Each 2076-92G expansion enclosure adds a value of 2.5 to the SAS chain weight

For example, each of the following expansion enclosure configurations has a total SAS weight of 10:

► Four 2076-92G enclosures per SAS chain
► Two 2076-92G enclosures and five 2076-24G enclosures per SAS chain

Figure 10 shows the front view of the IBM FlashSystem 7200 Expansion Enclosure Model 12G.

Figure 10   Front view of the IBM FlashSystem 7200 LFF Expansion Enclosure Model 12G

The 12G model of IBM FlashSystem 7200 LFF Expansion Enclosure includes the following features:

► Two expansion canisters
► 12 Gb SAS ports for attachment to the IBM FlashSystem 7200 Control Enclosures
► 2U 19-inch rack-mount enclosure with AC power supplies

Figure 11 shows the rear view of IBM FlashSystem 7200 LFF Expansion Enclosure model 12G.

Figure 11   Rear view of IBM FlashSystem 7200 Expansion Enclosure Model 12G

Figure 12 shows the front view of the IBM FlashSystem 7200 Expansion Enclosure Model 24G.

Figure 12   Front view of the IBM FlashSystem 7200 SFF Expansion Enclosure Model 24G

The 24G model of IBM FlashSystem 7200 SFF Expansion Enclosure includes the following features:

► Two expansion canisters
► 12 Gb SAS ports for attachment to the IBM FlashSystem 7200 Control Enclosures
► 2U 19-inch rack-mount enclosure with AC power supplies

Figure 13 shows the rear view of IBM FlashSystem 7200 SFF Expansion Enclosure model 24G.

Figure 13   Rear view of IBM FlashSystem 7200 Expansion Enclosure Model 24G

IBM FlashSystem 7200 LFF HD Expansion Enclosure Model 92G delivers the following features:

► Up to 92 drives are top-loaded into drive slots of the Expansion Enclosure
► 5U 19-inch rack-mount enclosure with slide rail and cable management assembly
► Redundant 200 - 240 V AC power supplies (new PDU power cord required)

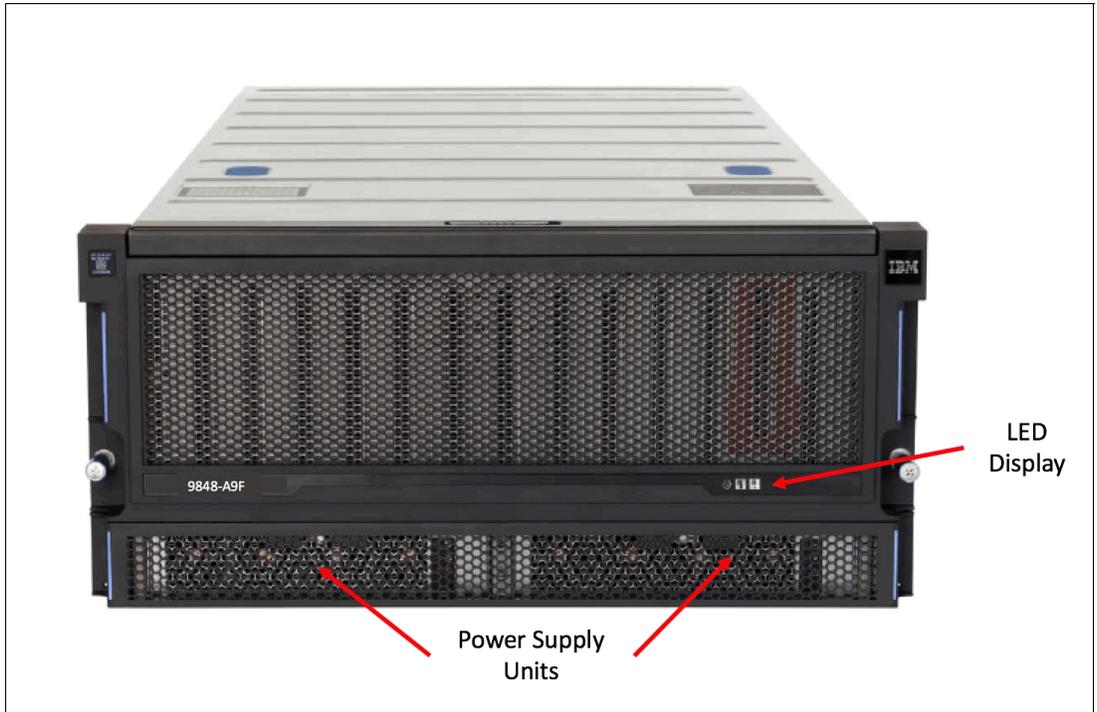Figure 14 shows the front view of IBM FlashSystem 7200 LFF HD model 92G Expansion Enclosure.

Figure 14   Front view of IBM FlashSystem 7200 LFF model 92G expansion enclosure

Figure 15 shows the rear view of IBM FlashSystem 7200 LFF model 92G Expansion Enclosure.
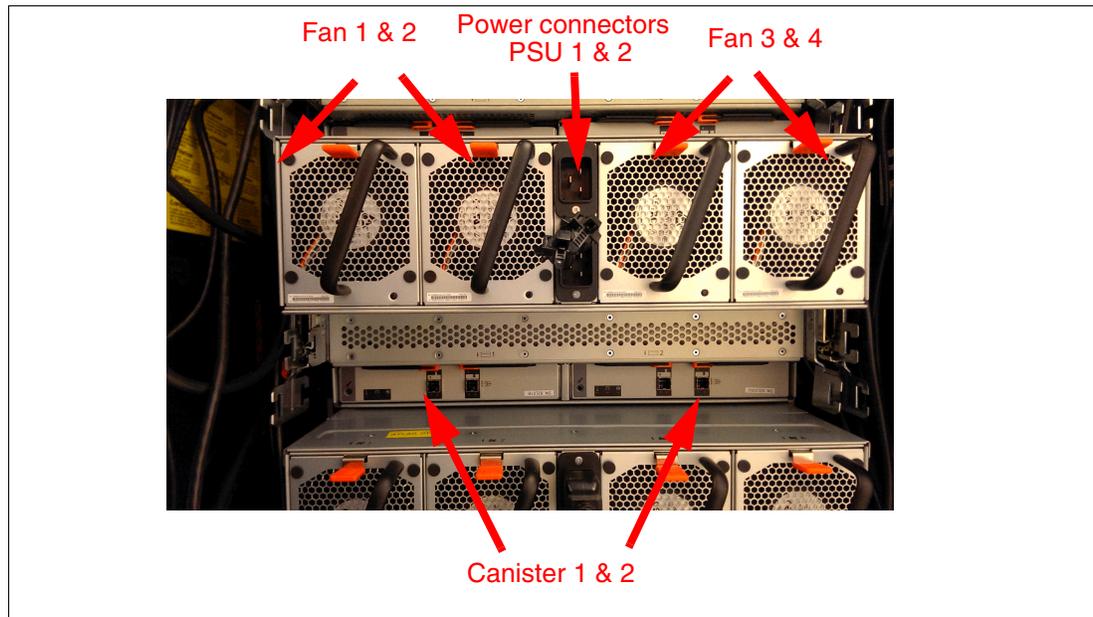

Figure 15   Rear view of IBM FlashSystem 7200 LFF model 92G expansion enclosure

Scalability and performance

The IBM FlashSystem 7200 system includes the following scalability and performance features:

► Up to 806TB usable and 1.62 PB effective flash capacity in only 2U with 2:1 compression

► Up to 3.2 PB usable and 15.8 PB maximum flash capacity in only 8U with 5:1 compression

► Extra scalability through expansion enclosures models 12G, 24G, and 92G, and increased raw capacity of up to a maximum of 32 PB

► IBM FlashSystem 7200 can deliver up to 2.3 million IOPS, with latency down to 70μs and bandwidth up to 35 GBps from a single system

► A clustered FlashSystem 7200 can scale linearly and delivers 9.2 million IOPS and 140GBps on a fully configured 4x IBM FlashSystem 7200 cluster

Advanced functions

The IBM FlashSystem 7200 system provides several advanced functions:

► HyperSwap for the IBM FlashSystem 7200 system
► NVMeoF - NVMe over Fabrics
► IP quorum base support
► Data reduction tools
► N-Port ID Virtualization support
► VMware Integration
► RAID types
► External virtualization
► Manageability and security

HyperSwap for the IBM FlashSystem 7200 system

HyperSwap is available with IBM FlashSystem 7200 Software V8.3.1 and later. You can use HyperSwap to present each volume to two I/O groups. The configuration tolerates combinations of node and site failures by using the same flexible choices of host multipathing driver interoperability as are currently available for the IBM FlashSystem 7200 system. The use of FlashCopy helps maintain a *golden image* during automatic resynchronization.

> **Important:** Because remote mirroring is used to support the HyperSwap capability, remote mirroring licensing is a requirement for the use of HyperSwap. For more information, see "Software and licensing" on page 52.

IBM FlashSystem 7200 Software V8.3.1 or higher includes remote mirroring of control enclosures and expansion enclosures. IBM Spectrum Virtualize is used to provide functions for externally virtualized storage.

The HyperSwap function uses a *HyperSwap topology* to spread the nodes of the system across two sites, with storage at a third site that acts as a tie-breaking quorum device. Consider the following points:

► The HyperSwap topology locates both nodes of an I/O group in the same site. Therefore, to get a volume that is resiliently stored on both sites, at least two I/O groups are required.

► The HyperSwap topology uses extra system resources to support a fully independent cache on each site. This configuration provides full performance, even if one site is lost. In some environments, a HyperSwap topology provides better performance than a stretched topology.

► The HyperSwap function can now be configured through a new CLI that greatly simplifies the setup process to a handful of commands. The HyperSwap function also adds the ability to configure and manage local HyperSwap through the GUI for simpler configuration and operation.

► Hosts, IBM FlashSystem 7200 Control Enclosures, and IBM FlashSystem 7200 Expansion Enclosures are in one of two failure domains or sites.

► Volumes are visible as a single object across both sites (I/O groups).

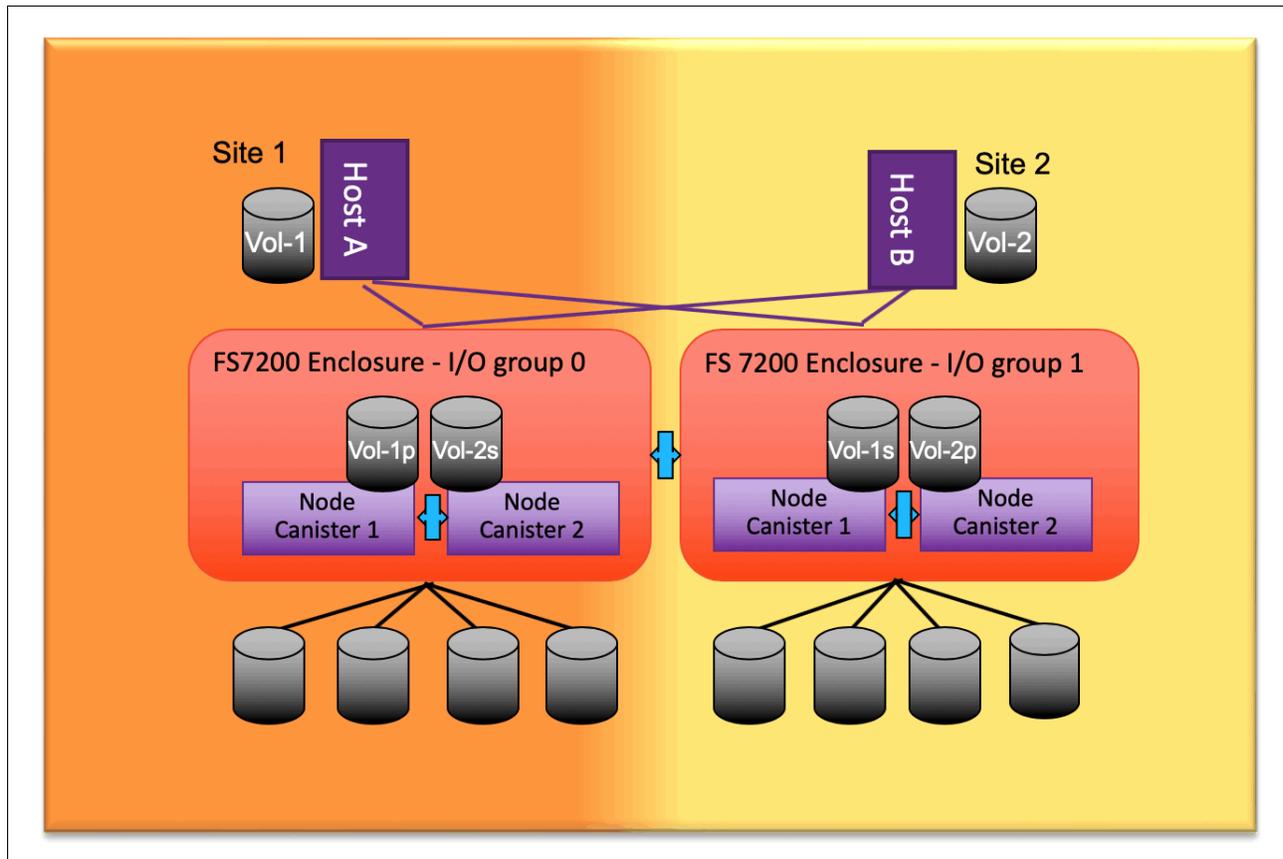Figure 16 shows how the HyperSwap function works.

Figure 16   HyperSwap function

Each primary volume (P) has a secondary volume (S) on the opposite I/O group. The secondary volumes are not mapped to the hosts. The dual-write to the secondary volumes is handled by the IBM FlashSystem 7200 HyperSwap function, and is transparent to the hosts.

HyperSwap features the following characteristics:

► The HyperSwap function is available on IBM FlashSystem 7200 Software V8.3.1 and later, and with two or more I/O groups.

► You can design a multiple-step CLI-based configuration on a single system by performing simple object creation through the GUI and CLI.

► Data is stored on two sites in parallel.

► The maximum distance between sites is 300 km (186.4 miles).

► Two independent copies of data are maintained (four if you use extra volume mirroring to two pools in each site).

► HyperSwap uses a standard host multipathing driver.

► Cache data is retained if only one site is online.

► Automatically synchronizes and resynchronizes copies.

► Automatic host-to-storage-system path optimization, based on the host site (requires Asymmetric Logical Unit Access (ALUA) and Target Port Groups Support (TPGS) support from the multipathing driver).

► Consistent state data is retained during resynchronization for DR.

- ► The maximum number of highly available volumes is 1250.
- ► Requires a remote mirroring license for volumes. Exact license requirements can vary by product.

NVMe over Fabrics

The NVMe protocol is an open collection of standards and interfaces that fully uses the benefits of non-volatile memory in all types of computing environments, from mobile to data center. It is designed to deliver high bandwidth and low latency storage access.

This section describes the NVMe protocol and interface as it relates particularly to flash-based architectures.

The NVMe protocol is an interface specification for communicating with storage devices and it is functionally the same as other protocols, such as SATA and SAS. However, the NVMe interface was designed from the ground up for fast storage media, such as flash-based solid-state drives (SSDs) and low-latency non-volatile storage technologies.

NVMe storage devices are typically directly attached to a host system over a PCI Express (PCIe) bus and the NVMe controller is contained in the storage device, which alleviates the need for another I/O controller between the CPU and the storage device. This architecture results in lower latency, throughput scalability, and simpler system designs.

This design was implemented in the FlashSystem 7200, with its dual ported PCIe-based NVMe drives.

However, the PCIe bus has a limit to the number of NVMe drives that can be attached to a host over the bus to a few tens of devices. Because the maximum length of PCIe cabling is also only a few meters, the flexibility of deploying PCIe NVMe drives outside the host server is severely limited and data center level scalability is not feasible.

NVMe over Fabrics (NVMe-oF) overcomes the limitations of the SCSI protocol and the limited number of concurrent queues by extending the benefits of low latency and high efficiency of the NVMe technology across network fabrics. This feature supports sharing of NVMe storage at a large scale (100s or 1000s of devices) and over distance.

Figure 17 on page 32 shows that the NVMe architecture supports many different network fabric technologies.
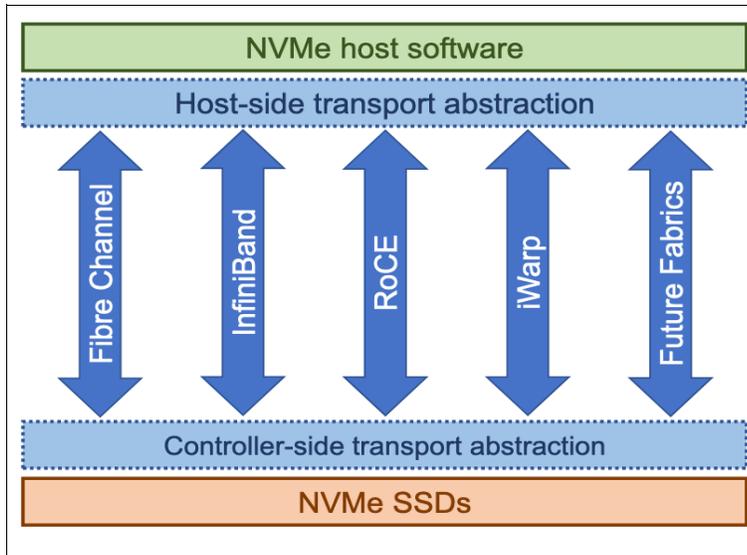
Figure 17   NVMe technology support options

The NVMe transport layer can be mapped to different network fabric technologies.

Currently, the NVMe transport layer supports the NVMe over Fabrics using Fibre Channel (referred to as FC-NVMe of NVMeFC) main fabric transport.

FC-NVMe uses Fibre Channel Protocol (FCP) as its transport mechanism, which places the data transfer in control of the target and transfers data direct from host memory, which is similar to RDMA. In addition, FC-NVMe allows for a host to send commands and data together (first burst), which eliminates the first data "read" by the target and provides better performance at distances.

The NVMe over Fabrics interface uses the same model of submission and completion queues as PCIe NVMe. As such, it maintains the same asynchronous submission and completion model and achieves similar benefits in terms of latency, efficiency, and scalability as the NVMe technology because of the shortened code paths and lockless concurrency in multi-core environments.

The IBM FlashSystem 7200 supports NVMe protocols by way of the various PCIe adapters that can be ordered and installed in the control enclosure. For more information about these options, see "Host I/O connectivity and expansion enclosure adapters" on page 46.

For more information about NVMeoF protocols and architecture, see *IBM Storage and the NVM Express Revolution*, REDP-5437.

IP quorum base support

For lower implementation and operation costs for a HA solution, you can use IP quorum base support to use lower-cost IP network-attached hosts as a quorum disk. HyperSwap implementations require FC storage on a third site to cope with tie-breaker situations if the intersite link fails, and when connectivity between sites 1 and 2 is lost. In a HyperSwap setup, a quorum disk at the third site is needed. The quorum disk on the third site must be the active quorum disk. Only the active quorum disk acts as a tie-breaker.

A quorum device is also used to store a backup copy of important system configuration data. Just over 256 MB is reserved for this purpose on each quorum device.

A system can have only one active quorum device that is used for a tie-break situation. However, the system uses up to three quorum devices to record a backup of system configuration data to be used if a disaster occurs. The system automatically selects one quorum device to be the active quorum device.

For more information about configuring quorums disks within two or three sites, see IBM Knowledge Center.

Note: Fibre Channel over IP (FCIP) connectivity is not supported between nodes when a HyperSwap system is configured without the use of inter-switch links (ISLs).

Data reduction tools

Compression and de-duplication is a key part of the IBM FlashSystem 7200 system. IBM Comprestimator and Data Reduction Estimator Tool is the key sizing tool to estimate how much capacity savings that a client can expect. IBM Comprestimator and Data Reduction Estimator Tool can recognize the patterns of the client data, and estimate the compressibility of data per volume.

IBM FlashSystem models are supported by the IBM Comprestimator (which is available as a stand-alone tool and also found in the FlashSystem 7200 GUI) and also the stand-alone Data Reduction Estimator Tool (DRET). This DRET tool is a host-based application that the user uses to estimate the amount of compression and de-duplication on the IBM FlashSystem 7200 system for specific workloads.

Choose your data reduction approach and use the tools to estimate the amount of usable storage that is required by reviewing the following tools.

Figure 18 shows how to start the Estimate Compression Saving option from the GUI.

From the main menu, click **Volumes** → **Volumes** and select one volume. Then, right-click the mouse to get the pop-up menu. From this menu, select **Capacity Savings** → **Estimate Compression Saving.**
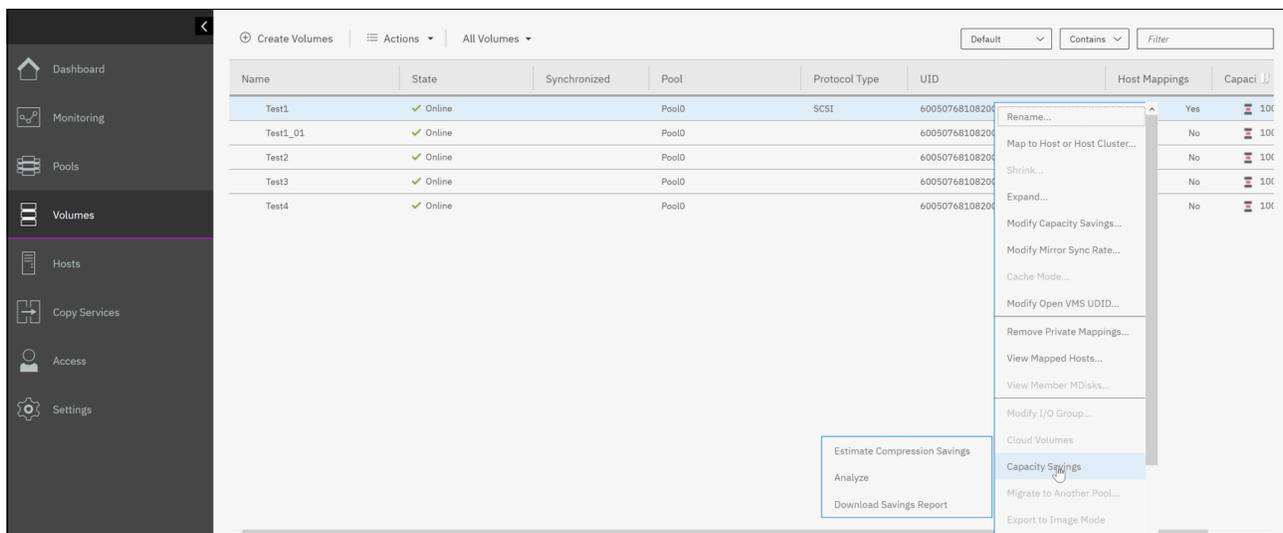

Figure 18   Estimate Compression Saving from the GUI

To estimate compression and savings on FCM and DRP approaches:

► IBM FlashCore Module - IBM FlashCore Module Compression:

– Use the FCM option

– Do not use the Estimate Compression Saving option in the GUI to calculate the IBM FlashCore Module savings

► Data Reduction Pool compression:

– Use the DRP option

– Workloads that are on any IBM Spectrum Virtualize platforms can use the Estimate Compression Saving option in the GUI

► Data Reduction Pool compression and deduplication:

– IBM Comprestimator and Data Reduction Estimator Tool shows the savings for thin-provisioning, compression, and deduplication

– IBM Comprestimator and Data Reduction Estimator Tool reads entire volumes to identify de-duplicated data, so it takes longer to run

For more information about data reduction pool compression and setup, see *Introduction and Implementation of Data Reduction Pools and Deduplication*, SG24-8430.

N-Port ID Virtualization support

Starting with V8.3.1, IBM FlashSystem 7200 Software offers NPIV support. Use NPIV to virtualize WWPNs, which increases redundancy during firmware updates and scheduled maintenance where WWPNs transparently move to the controller that is not being maintained. As a consequence, FC-attached hosts experience zero path reduction during controller outages.

> **Important:** The IBM FlashSystem 7200 system has NPIV enabled by default; therefore, if the customer does not want to use it, they must turn it off before configuring FC ports for host communications.

VMware Integration

IBM FlashSystem 7200 Software V8.3.1 and higher includes the following features, which enable tight integration with VMware:

► vCenter plug-in: Enables monitoring and self-service provisioning of the system from within VMware vCenter.

► vStorage APIs for Array Integration (VAAI) support: This function supports hardware-accelerated virtual machine (VM) copy/migration and hardware-accelerated VM initiation, and accelerates VMware Virtual Machine File System (VMFS).

► Microsoft Windows System Resource Manager (SRM) for VMware Site Recovery Manager: Supports automated storage and host failover, failover testing, and failback.

► VVOL integration for better usability: The migration of space-efficient volumes between storage containers maintains the space efficiency of volumes. Cloning a VM achieves a full independent set of VVOLs. Resiliency also is improved for VMs if volumes start running out of space.

Before the availability of VVOLs, a VM in a VMware environment was presented as a VMware disk that was called a VMware Virtual Machine Disk (VMDK). This file represented a physical disk to the VM, which can be accessed by the operating system that is installed on the VM in the same way that a physical volume on a regular server was installed.

The VMDK file was placed in a file system that is called VMFS, which is hosted by a standard volume (LUN). For example, it can be implemented on an external storage system, such as the IBM FlashSystem 7200 system. With the availability of the VVOL technology, each VM disk can now be mapped to an external storage volume (for example, an IBM FlashSystem 7200 volume).

With VVOL, the IBM FlashSystem 7200 solution is "aware" of individual VMDK files. Therefore, data operations, such as snapshot and replication, can be performed directly by the IBM FlashSystem 7200 system at the VMDK level rather than the entire VMFS data store.

> **Note:** The integration of VVOL with the IBM FlashSystem 7200 system is based on the VMware APIs for Storage Awareness (VASA). IBM support for VASA is delivered as part of IBM Spectrum Control. VASA V2 is required to use the VVOL capability.

Scaling up and scaling out

The IBM FlashSystem 7200 system has a scalable architecture that enables flash capacity to be added (scaled up) to support multiple applications, by adding expansion enclosures. Scale out expands both NVMe capacity, with the processing power to use that capacity to linearly scale IOPS and bandwidth. As a result, your organization can gain a competitive advantage through a more flexible, responsive, and efficient storage environment.

The IBM FlashSystem 7200 system has the following flexible scalability configuration options:

► Base configuration
► Scale up: Add capacity
► Scale out: Add control enclosures and capacity

Each IBM FlashSystem 7200 has two canisters (sometimes also known as *nodes* or *controllers*). Each canister contains the CPUs, cache memory, PCIe adapters, and other hardware to communicate to the NVMe drives and connected hosts systems. These canisters are housed in a chassis that is known as a *control enclosure*.

It is possible to connect up to a maximum of four control enclosures to form a cluster.

Table 4 lists the values of the CPUs, cache memory, raw NVMe drive size, and PCIe adapters for each number of control enclosures.

Table 4   Maximum values for each canisters and control enclosure n

Element	Number of CPUs	Maximum cache memory (GB)	Max NVMe 24 drive capacity raw (TB)	Inclusive onboard Ethernet ports	Max PCIe ports (FC or Ethernet)
One Canister	2	768	N/A	4	12
One Enclosure	4	1536	922	8	24
Two Enclosures	8	3072	1844	16	48
Three Enclosures	12	4608	2766	24	72

Element	Number of CPUs	Maximum cache memory (GB)	Max NVMe 24 drive capacity raw (TB)	Inclusive onboard Ethernet ports	Max PCIe ports (FC or Ethernet)
Four Enclosures	16	6144	3688	32	96

A basic configuration of an IBM FlashSystem 7200 storage platform consists of one IBM FlashSystem 7200 Control Enclosure. For a balanced increase of performance and scale, up to four IBM FlashSystem 7200 Control Enclosures can be clustered into a single storage system, multiplying performance and capacity with each addition.

The clustered IBM FlashSystem 7200 system can include dedicated internal FC switches for internal communications. However, other methods are available to configure the switches and ports to provide performance improvements.

For more information about how to restrict the FC ports for control enclosure inter-node connections and host connections, see IBM Knowledge Center.

With the scalable IBM FlashSystem 7200 configurations, you can add up to three IBM FlashSystem 7200 control enclosures to the storage system. If 379 TB usable and up to 1.6 PB maximum from four control enclosures is not enough capacity, you can increase capacity by adding SAS expansion enclosures with SSD drives.

In total, an IBM FlashSystem 7200 system can contain a maximum of four IBM FlashSystem 7200 Control Enclosures. This configuration offers a potential storage capacity of 3.2 PB usable and up to 6.4 PB effective capacity (assuming 2:1 or better hardware compression) when the IBM FCM type drives are used.

With software-based data reduction, you can scale to 16.0 PB effective, assuming 5:1 data reduction by using compression and de-duplication.

The IBM FlashSystem 7200 system is expandable to 32 PB by using SSDs and HDDs in expansion enclosures as tiered capacity.

Maximum capacity configurations

Table 5 lists the maximum raw capacity, usable capacity, and maximum effective capacity for scalable configurations that are built on the IBM FlashSystem 7200 Control Enclosures.

Table 5   IBM FlashSystem 7200 maximum usable and effective capacity.

Number of control enclosures	Maximum usable capacity by using DRAID6 with 24 drives (terabytes)	Maximum effective capacity (terabytes) with inline FCM Drive compression @ 2:1 ratio	Maximum effective capacity (terabytes) with software data reduction @ 5:1 ratio
One control enclosure	806	1612	4030
Two control enclosures	1612	3224	8060
Three control enclosures	2418	4836	12090
Four control enclosures	3224	6448	16120

Consider the following points:

► IBM FlashCore Module NVMe types drives:

 – Six drive minimum.
 – DRAID6 (recommended) and DRAID5 (supported).
 – IBM FlashCore Modules in the same RAID array must have the same capacity.

► Industry-standard NVMe drives:

 – Two drive minimum (varies by RAID type).
 – Traditional RAID 10 and DRAID6 (recommended) and DRAID5 (supported).
 – Industry-standard NVMe drives in the same RAID array must have the same capacity.

► Storage Class Memory:

 – Two drive minimum with up to 12 drives of the same type and capacity
 – Distributed RAID 5, or TRAID 1 or 10 with fewer than 4 drives

Note: IBM FlashCore Module inline compression is hardware-based and operates at line speed, having no effect on the performance.

Expansion enclosures

With IBM FlashSystem 7200 V8.3.1 and higher, the IBM FlashSystem 7200 system supports the addition of expansion enclosures.

High-density (HD) Enclosure Model 92G accepts SAS SSDs and HDDs. With these tiering options, you can have eight enclosures per control enclosure, with a maximum capacity of 1350 TB each.

Note: To support SAS-attached expansion enclosures, an ADBA - SAS Enclosure Attachment adapter must be installed in the control enclosure of the IBM FlashSystem 7200 system.

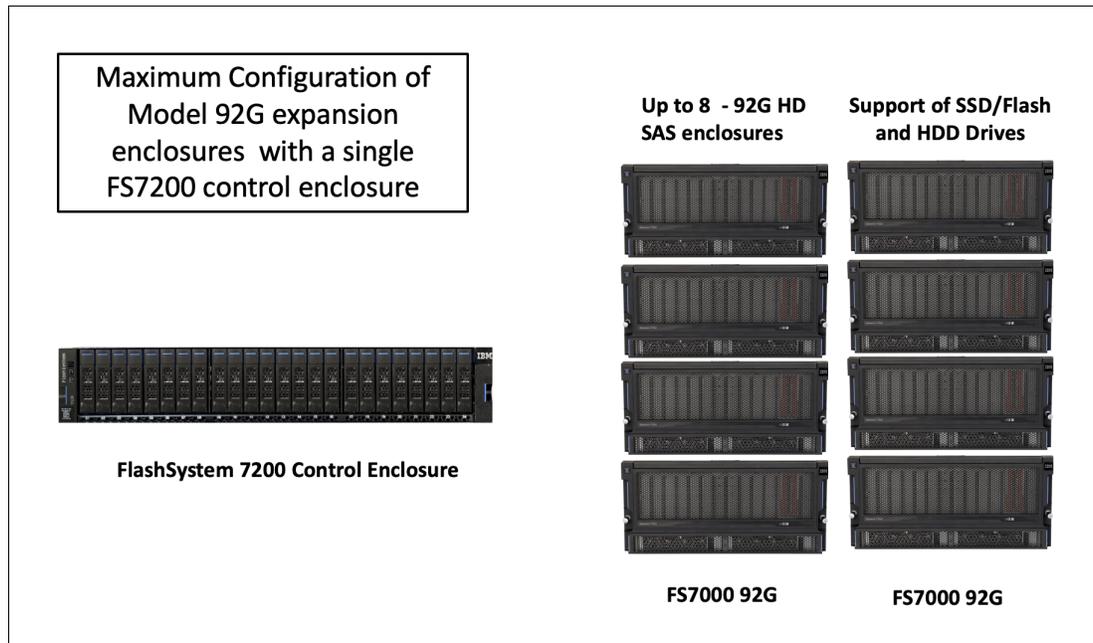Figure 19 shows the maximum enclosure configuration with 92G expansions.

Figure 19   Maximum configuration for model 92G enclosures

IBM FlashSystem 7200 LFF Expansion Enclosure Model 12G offers new tiering options with HDDs. Each LFF expansion enclosure supports up to 12 3.5-inch HDDs.

IBM FlashSystem 7200 SFF Expansion Enclosure Model 24G offers new tiering options with HDD or SSD flash drives. Each SFF expansion enclosure supports up to 24 2.5-inch flash SSD or HDDs.

Up to 20 expansion enclosures are supported per IBM FlashSystem 7200 Control Enclosure, which provides up to 480 drives with up to 1.9 PB of SAS SSD and HDD capacity.

Figure 20 shows the maximum configuration of 20 expansion enclosures in the 12G or 24G models.
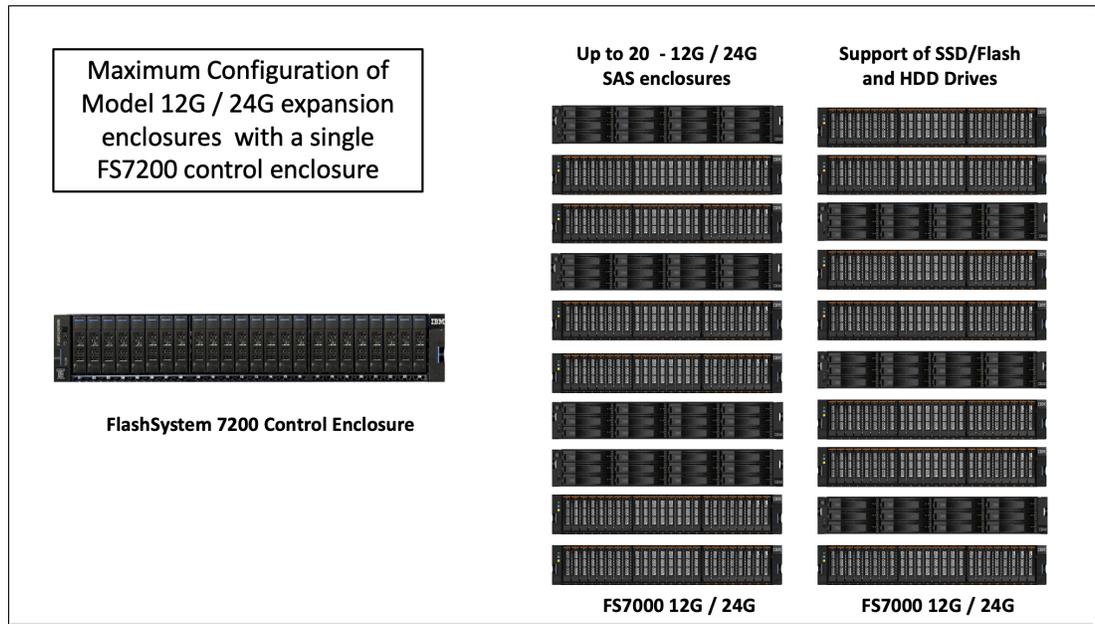

Figure 20   Maximum configuration for model 12G / 24G enclosures

Expansion enclosure drive offerings

The LFF expansion enclosure Model 12G, SFF expansion enclosure Model 24G, and LFF HD expansion enclosure Model 92G all deliver increased storage density and capacity for the IBM FlashSystem 7200 system, with cost-efficiency while maintaining its highly flexible and intuitive characteristics.

The models of the expansion enclosure support a complete range of 3.5- inch SAS HDDs and 2.5- inch SAS SSD and HDDs (in 3.5-inch carriers on Model 92G) to easily increase storage capacity and density in a flexible and affordable manner.

These HDD and SSD flash drive options are available for the IBM FlashSystem 7200 solution with a maximum of 32 PB combined NVMe flash and SAS capacity that is configured on four IBM FlashSystem 7200 control enclosures.

> **Note:** The IBM Spectrum Virtualize maximum storage limit is 32 PB.

RAID types

The IBM FlashSystem 7200 system supports the following main DRAID types and optional traditional RAID types:

► IBM FlashCore Modules:

  – Six drive minimum
  – Distributed DRAID6 (recommended) and DRAID5 (supported)
  – IBM FlashCore Modules in the same RAID array must be of the same capacity

► Industry-standard NVMe drives:

  – Two drive minimum (varies by RAID type)
  – Traditional TRAID 10 and DRAID6 (recommended) and DRAID5 (supported)

- – Industry-standard NVMe drives in the same RAID array must be of the same capacity
► SCM NVMe drives:
  - – Two drive minimum with up to 12 drives of the same type and capacity
  - – Distributed DRAID5, or traditional TRAID 1 or 10 with fewer than four drives
  - – Can occupy any slots in the control enclosure
  - – SCM NVMe drives in the same RAID array must be of the same capacity
► IBM FlashSystem 7200 Expansion Enclosure

  SAS SSD flash drives: RAID 0, 1, and 10 and DRAID6 (recommended), and DRAID5 (supported)

The extra SAS attached expansion enclosures can be configured with various RAID options. DRAID (DRAID5 and DRAID6) offers improved RAID rebuild times and improved performance. DRAID6 is preferred for expansion enclosures because of the drive sizes in use.

Supported array types and RAID levels

IBM FlashSystem 7200 systems support IBM FlashCore Module NVMe drives, industry-standard NVMe drives, and SAS drives that are within expansion enclosures. The type and level of arrays varies, depending on the type of drives in the I/O group.

Table 6 lists the supported drives, array types, and RAID levels. For all types of drives, DRAID6 is recommended (except for SCM drives).

The IBM FlashSystem 7200 system does *not* support mixing SAS drives in an array with NVMe drives or mixing IBM FlashCore Modules in an array with industry-standard NVMe drives.

Table 6   Summary of supported drives, array types, and RAID levels

Supported drives	TRAID					DRAID		
	RAID 0	RAID 1	RAID 5	RAID 6	RAID 10	RAID 1	RAID 5	RAID 6
Industry-standard NVMe drives	X	X			X	X	X	X
IBM FlashCore Module NVMe drives					X[a]	X	X	X
SCM NVMe drives		X			X	X	X	X
SAS SSDs (Expansion Enclosure)	X	X			X	X	X	X

a. except for 38.4 TB FCM Drives

For more information about the types of supported RAID configurations, see IBM Knowledge Center.

Note: DRAID6 is recommended for all types of drives (except for SCM drives). Some of the RAID type arrays can be created only by using the CLI, not the GUI.

External virtualization

The IBM FlashSystem 7200 system offers external virtualization technology that helps you manage other IBM or third-party storage arrays with thin- provisioning, space-efficient copies, and DR tools, such as data replication. External virtualization also makes the migration of data from one storage device to another easier.

You can use the IBM FlashSystem 7200 system to manage the capacity of other disk systems with external storage virtualization. When the IBM FlashSystem 7200 system virtualizes a storage system, its capacity becomes part of the IBM FlashSystem 7200 system and is managed in the same manner as the capacity on internal flash modules within the IBM FlashSystem 7200 system. Capacity in external storage systems inherits all the rich functions and ease of use of the IBM FlashSystem 7200 system.

You can use IBM FlashSystem 7200 to preserve your investments in storage, centralize management, and make storage migrations easier with storage virtualization and Easy Tier. The IBM FlashSystem 7200 system provides nondisruptive operations because of storage virtualization. Virtualization helps insulate applications from changes that are made to the physical storage infrastructure. When you add storage capacity or a new tier of storage, for example, the changes are transparent to applications, so you have minimal downtime.

Any externally virtualized storage needs extra licenses to be purchased and are charged on a capacity basis of the storage added.

Manageability and security

The IBM FlashSystem 7200 system offers the following manageability and security features:

► Advanced security for data at rest with hardware-accelerated AES-XTS 256 encryption.

► IBM obtained FIPS 140-2 Level 1 certification for IBM FlashCore Modules in the IBM FlashSystem 9100.

   At the time of this writing, the newer IBM FlashCore Modules in the IBM FlashSystem 7200 are going through FIPS validation.

► A GUI to manage the IBM FlashSystem 7200 Control Enclosures and the IBM FlashSystem 7200 Expansion Enclosures. The GUI is available in any supported browser. Included in the GUI is the IBM FlashSystem 7200 command-line interface (CLI), which support a collection of commands that you can use to manage the IBM FlashSystem 7200 system.

► The IBM FlashSystem 7200 running Spectrum Virtualize 8.4.0 software supports the Representational State Transfer (REST) model application programming interface (API). The REST-API consists of command targets that are used to retrieve system information and to create, modify, and delete system resources

► RSA provides secure connection for IBM Remote Support, which can be used for remote troubleshooting, remote code load, and obtain diagnostic logs.

► Email and SNMP alerts.

► Syslog redirect to send system log messages to another host.

Reliability, availability, and serviceability

IBM FlashSystem 7200 delivers the following enterprise-class reliability features:

► Concurrent code load enables customer applications to remain online during firmware upgrades to all components, including the flash drives.

► Redundant hot-swappable components. The IBM FlashSystem 7200 Control Enclosure has two clustered, hot-swappable node canisters that contain hot-swappable fan modules, memory DIMMs, batteries, trusted platform module (TPM), and PCIe adapters. The enclosure also houses two AC power supplies that are N+1 redundant and hot-swappable.

 If an IBM FlashCore Module failure occurs, critical customer applications can remain online while the defective module is replaced because a spare module is available. IBM Variable Stripe RAID is a patented IBM technology that provides an intra-module RAID stripe within each flash module. Variable Stripe RAID technology helps reduce downtime, and maintains performance and capacity during partial or full flash chip failures.

► IBM enhanced technology in the SCM drives for higher storage density and improved performance.

► IBM FlashSystem 7200 Control Enclosures support concurrent code load. Both onsite and remote code upgrades are supported.

Encryption

IBM FlashSystem 7200 data encryption is based on the AES algorithm, which uses a 256-bit symmetric encryption key in XTS mode, as defined in the IEEE 1619-2007 standard and NIST Special Publication 800-38E as XTS-AES-256. The data encryption key is protected by a 256-bit AES key wrap of a key that is derived from the access key that is stored on the USB flash drive. The wrapped key is stored in the system in non-volatile form.

Encryption on the IBM FlashSystem 7200 system requires the following feature codes:

► Encryption Enablement (#ACE1)

 This feature enables the encryption function. A single instance of this feature enables the function on the entire IBM FlashSystem 7200 system (IBM FlashSystem 7200 Control Enclosure and all attached IBM FlashSystem 7200 Expansion Enclosures) and on externally virtualized storage subsystems.

 USB flash drives (#ACEA) or IBM SKLM are required for encryption key management.

► Encryption USB Flash Drives (Four Pack) Optional (#ACEA)

 This feature provides four USB flash drives for storing the encryption master access key.

 Unless IBM SKLM is used for encryption keys management, a total of three USB flash drives are required per IBM FlashSystem 7200 cluster when encryption is enabled in the cluster, regardless of the number of systems in the cluster. If encryption is used in a cluster, this feature should be ordered on one IBM FlashSystem 7200 system, which results in a shipment of four USB flash drives.

Encryption can be applied to virtualized storage arrays, even if the virtualized array does not include encryption capabilities. In this scenario, the encryption is done by using the Spectrum Virtualize software and is not as fast as the built-in hardware type encryption.

Encrypted volumes are transparent to applications, which eases implementation and operation. In addition, the IBM FlashSystem 7200 system includes the following functions:

► Encryption Activation

    Adding an encryption license to a system is *not* concurrent and must be done at array initialization time.

► Encryption Deactivation

    Removing encryption is also non-concurrent and destroys any data on the array.

► Encryption Rekey

    Changing the encryption key on a previously initialized system is concurrent and can be done while array is in use.

Both operations require that you purchase Encryption Enablement Pack (#ACE1).

Self-encrypting drives

The IBM FlashCore Modules and NVMe FCM type drives, including the SCMs, in the IBM FlashSystem 7200 Control Enclosure are self-encrypting drives (SEDS). With SEDs, you can encrypt the data on the drive within the hardware.

These types of flash drives include the following features:

► Encryption of data is done in the electrical circuit of the drive, so it is not affected by performance issues from software encryption.

► Data Encryption Keys never leave the confines of the SED, and are never loaded into CPU or memory.

► You can perform a fast cryptographic erasure of a SED by using a single CLI command to replace the DEK or revert the entire device to factory settings.

► Support a security feature that is called *auto-lock*, which protects against someone plugging your drive into another system and accessing your data.

► Drives automatically lock themselves on power loss and require an access key at start time to unlock and allow I/O operations.

► If a SED drive is taken from a system with encryption and placed in another system, the drive data is not readable. The systems post an error message that indicates it is locked. The only way to use the drive if to format it. This formatting also performs a cryptographic erase by removing any encryption keys so that all of the data on the drive is destroyed.

Combining system encryption with self-encrypting drives

For control enclosures that support NVMe architecture, NVMe-attached drives are self-encrypting and self-compressing. With self-encrypting drives that use NVMe architecture, data encryption is completed in the drive. Data encryption keys remain on the drive without being stored in system memory.

In addition, the system supports automatic locks of encrypted drives when the system or drive is powered down. When the drive or system restarts, a master key is required to unlock the drive and continue I/O operations.

Because the encryption of data is done in the electrical circuit of the drive, it is not affected by any performance issues from software encryption.

SEDs encrypt the data and you can use SEDs without enabling encryption on the system. However, SEDs are unlocked by default at power-up time, unless configured with extra protection.

System-level encryption in Spectrum Virtualize allows you to use USB flash drives or IBM SKLM to manage access to encrypted objects on the system. This process ensures that when a system is powered on, this extra encryption key is required to read the data on the drives.

Consider the following points:

► SEDs always encrypt, and you cannot stop them from doing so.

► You can use SEDs without enabling encryption on the system, but SEDs are unlocked by default (unless configured with extra protection).

► With system encryption in IBM Spectrum Virtualize, you can use USB flash drives or IBM SKLM to manage access to encrypted objects on the system.

► Software in the operating system is required to manage an access key that can be used to lock and unlock the SEDs and bring them online for I/O.

Therefore, the best solution is to use the SEDs with the Encryption Enablement Pack, and the USB or IBM SKLM type encryption, or a mixture of both. This configuration ensures the maximum level of encrypting for your data that is on the IBM FlashSystem 7200.

Transparent cloud tiering and encryption

Transparent cloud tiering is a licensed function that enables volume data to be copied and transferred to cloud storage. The system supports creating connections to cloud service providers to store copies of volume data in private or public cloud storage.

With transparent cloud tiering, administrators can move older data to cloud storage to free up capacity on the system. Point-in-time snapshots of data can be created on the system and then copied and stored on the cloud storage.

An external cloud service provider manages the cloud storage, which reduces storage costs for the system. At the time of this writing, IBM supports the OpenStack Swift and Amazon S3 cloud service providers.

The following considerations apply to transparent cloud tiering and encryption:

► When a cloud account is created, it must continue to use the same encryption type throughout the life of the data in that cloud account. Even if the cloud account object is removed and remade on the system, the encryption type for that cloud account cannot be changed while back up data for that system exists in the cloud provider.

► When performing rekeying operations on a system that has an encryption-enabled cloud account, perform the commit operation immediately after the prepare operation. Retain the previous system master key (on a USB or in the keyserver) because this key might be needed to retrieve your cloud backup data when performing a T4 recovery or an import.

► The `restore_uid` option should not be used when the backup is imported to a new cluster.

► Importing transparent cloud tiering data is supported only from systems whose backup data was created at V7.8.0.1 or later.

► Transparent cloud tiering uses Sig V2 when connecting to Amazon regions. It does not currently support regions that require Sig V4.

For more information, search for 7200 transparent cloud tiering at IBM Knowledge Center.

Secure drive erasure process

The FlashSystem 7200 running Spectrum Virtualize V8.3.1 or higher provides methods to securely erase data from a drive, or from a boot drive, when a control enclosure is decommissioned or before a drive is removed from the system during a repair activity.

Secure data deletion effectively erases or overwrites all traces of data from a data storage device. The original data on that device becomes inaccessible and cannot be reconstructed. You can securely delete data on individual drives and on a boot drive of a control enclosure. The methods and commands that are used to securely delete data enable the system to be used in compliance with European Regulation EU2019/424.

The following types of drive can be used for this process:

► Expansion enclosure SAS solid-state drive (SSD) and hard disk (HDD) drives
► NVMe drives (FCM and industry standard)
► Control enclosure node canister SSD boot drives

The methods that the system uses to securely delete data from the drives varies according to the CLI commands that each type of drive can support. The completion time for the erase procedure also varies, depending on the amount of data and the method that is used to delete the data. In each case, the result is that the data on the drive effectively becomes impossible to access when the operation completes.

Table 7 lists the types of erasure, the methods used, and the time taken.

Table 7   Methods to securely delete data from drives

Priority	Deletion type	Method	Completion time
1	Cryptographic erase	Changes the encryption key and makes the data inaccessible	Instant
2	Block erase	Quickly raises and lowers the voltage level of the storage element. Physical blocks are altered with a vendor-specific value	Fast
3	Data Overwrite	Replaces the existing data with random data	Slow

The methods that are used to securely delete data vary according to manufacture, drive type, and drive firmware. For more information, see the documentation that is provided by the drive manufacturer.

If a drive supports more than one data deletion method, the system uses the highest-priority method.

For more information about the CLI commands to use to run this secure erase function, see IBM Knowledge Center.

Options and feature codes

This section describes the options and feature codes of the IBM FlashSystem 7200 Control Enclosure.

Memory options

Table 8 lists the various memory options by feature code.

Table 8   IBM FlashSystem 7200 memory options per control enclosure

Base Memory (GB)	#ACGJ Plant or Field Upgrade (GB)	#ACGB Plant or Field Upgrade (GB)	Total Memory (GB)
256	N/A	N/A	256
256	512	N/A	768
256	512	768	1536

The following feature codes are available:

► (#ACGJ) - 512 GB Cache upgrade

This feature indicates that the base machine is configured with 512 GB (256 GB for each node canister). Selecting this feature determines the cache upgrade paths of the machine.

► (#ACGB) - 768 GB Cache upgrade

This feature provides another 768 GB of cache (384 GB for each node canister) to increase the total system cache by 768 GB.

> **Note:** A quantity of one ACGJ must be ordered with this feature if not already fitted.

Host I/O connectivity and expansion enclosure adapters

Six PCIe slots are available for port expansions in the IBM FlashSystem 7200 Control Enclosure. Each canister has three PCIe adapter slots and both canisters must have the same configuration. The PCIe adapter feature codes offers a pair of adapters to ensure that they are supplied symmetrically in each canister.

The IBM FlashSystem 7200 control enclosure can be configured with three I/O adapter features to provide up to 24 16 Gb FC ports or up to 12 25 Gb Ethernet (iSCSI or iSCSI Extensions for RDMA (iSER) capable) ports. The control enclosure also includes eight 10 Gb Ethernet ports as standard for iSCSI connectivity and two 1 Gb Ethernet ports for system management. A feature code also is available to include the SAS Expansion adapter if the user wants to implement the optional expansion enclosures.

For more information about the limits and rules for adapter placement to ensure correct best practices, see *IBM Spectrum Virtualize FAQ: IBM Spectrum Virtualize with the IBM FlashSystemfamily and IBM SAN Volume Controller.*

Table 9 lists the maximum host port count per building block configuration (1, 2, 3, or 4 control enclosures.

Table 9   Maximum host port count per control enclosure

Number of control enclosures	16 Gb/32 Gb FC	Onboard iSCSi	25 Gb iSCSI (RoCE)	25 Gb iSCSI (iWARP)
One	24	8	12	12
Two	48	16	24	24
Three	72	24	36	36
Four	96	32	48	48

Note: All connectivity ports are NVMe-oF hardware-ready.

Table 10 lists the current features for host connectivity for the IBM FlashSystem 7200 Control Enclosure 2076-824 and 2076-U7C machine types.

Table 10   Supported expansion enclosure and interface components MTMs 2076-824 and 2076-U7C

Item	Feature code	Description	Ports
16 Gb FC 4 Port Adapter Pair	#ADB3	This feature provides two I/O adapters. It is used to add 16 Gb FC connectivity.	Each adapter has four 16 Gb FC ports and shortwave SFP transceivers.
32 Gb FC 4 Port Adapter Pair	#ADB4	This feature provides two I/O adapters. It is used to add 32 Gb FC connectivity.	Each adapter has four 32 Gb FC ports and shortwave SFP transceivers.
25 GbE (RoCE) Adapter Pair	#ADB6	This feature provides two I/O adapters. It is used to add 25 Gb Ethernet connectivity. Supports RoCE V2.	Each adapter has two 25 Gb Ethernet ports and SFP28 transceivers.
25 GbE (iWARP) Adapter Pair	#ADB7	This feature provides two I/O adapters. It is used to add 25 Gb Ethernet connectivity. Supports RDMA with iWARP.	Each adapter has two 25 Gb Ethernet ports and SFP28 transceivers.
SAS Expansion Enclosure Attach Card (Pair)	#ADBA	This feature provides two 4-port 12 Gb SAS expansion enclosure attachment adapters. This feature is used to attach up to 20 expansion enclosures.	Each adapter has two active SAS ports.
16 Gb FC LW SFP Transceivers (Pair)	#ACHU	This feature provides two 16 Gb longwave SFP transceivers for use with 16 Gb FC I/O ports.	#AHB3 is a prerequisite. The maximum allowed is four for each instance of #AHB3.
32 Gb FC LW SFP Transceivers (Pair)	#ACHV	This feature provides two 32 Gb longwave SFP transceivers for use with 32 Gb FC I/O ports.	#AHB4 is a prerequisite. The maximum allowed is four for each instance of #AHB4.

Cables

The following cables are available:

- ► (#ACSQ): 1 m OM3 Fiber Cable (LC)
- ► (#ACSR): 5 m OM3 Fiber Cable (LC)
- ► (#ACSS): 10 m OM3 Fiber Cable (LC)
- ► (#ACST): 25 m OM3 Fiber Cable (LC)
- ► (#ACUA): 0.6 m 12 Gb SAS Cable (mSAS HD)
- ► (#ACUB): 1.5 m 12 Gb SAS Cable (mSAS HD)
- ► (#ACUC): 3 m 12 Gb SAS Cable (mSAS HD)
- ► (#ACUD): 6 m 12 Gb SAS Cable (mSAS HD)

IBM FlashCore Modules and industry-standard NVMe drive options

The IBM FlashSystem 7200 system supports IBM FlashCore Modules, industry-standard flash drives, and an intermix of both.

IBM FlashCore Modules combine IBM MicroLatency technology, advanced flash management, and reliability into a 2.5-inch SFF NVMe with built-in, performance-neutral hardware compression and encryption.

For improved flexibility, IBM FlashSystem 7200 systems also support various industry-standard self-encrypting NVMe flash drives.

The available NVMe flash drive use the following feature codes:

- ► (#ADS5): 4.8 TB NVMe FlashCore Module
- ► (#ADS6): 9.6 TB NVMe FlashCore Module
- ► (#ADS7): 19.2 TB NVMe FlashCore Module
- ► (#ADS8): 38.4 TB NVMe FlashCore Module
- ► (#ADT1): 800 GB NVMe Flash Drive
- ► (#ADT2): 1.92 TB NVMe Flash Drive
- ► (#ADT3): 3.84 TB NVMe Flash Drive
- ► (#ADT4): 7.68 TB NVMe Flash Drive
- ► (#ADT5): 15.36 TB NVMe Flash Drive
- ► (#ADTA): 375 GB NVMe Storage Class Memory Drive
- ► (#ADTB): 750 GB NVMe Storage Class Memory Drive
- ► (#ADTE): 800 GB NVMe Storage Class Memory Drive
- ► (#ADTF): 1.6 TB NVMe Storage Class Memory Drive

Consider the following limitations and points regarding drives:

- ► IBM FlashCore Modules:

    - – Six drive minimum
    - – DRAID6 (recommended) or DRAID5 (supported)
    - – IBM FlashCore Modules in the same RAID array must be of the same capacity

- ► Industry-standard NVMe drives:

    - – Two drive minimum (varies by RAID type)
    - – RAID 10 and DRAID6 (recommended) and DRAID5 (supported)
    - – Industry-standard NVMe drives in the same RAID array must be of the same capacity.

- ► SCM NVMe drives:

    - – Two drive minimum (varies by RAID type), 12 drives maximum
    - – DRAID5 supported
    - – SCM NVMe drives in the same RAID array must be of the same capacity

IBM FlashSystem 7200 Expansion Enclosure options (models 12G, 24G, and 92G)

The following SAS flash SSD and HDD drive feature codes are available:

- ► Supported on Model 12G only (maximum of 12):

  - (#AHD3): 4 TB 7.2K 3.5 Inch NL HDD
  - (#AHD4): 6 TB 7.2K 3.5 Inch HDD
  - (#AHD5): 8 TB 7.2K 3.5 Inch NL HDD
  - (#AHD6): 10 TB 7.2K 3.5 Inch NL HDD
  - (#AHD7): 12 TB 7.2K 3.5 Inch NL HDD
  - (#AHD8): 14 TB 7,200 rpm 12 Gb SAS NL 3.5 Inch HDD

- ► Supported on Model 24G only (maximum of 24):

  - (#AHF2): 900 GB 10K 2.5 Inch HDD
  - (#AHF3): 1.2 TB 10K 2.5 Inch HDD
  - (#AHF4): 1.8 TB 10K 2.5 Inch HDD
  - (#AHF5): 2.4 TB 10K 2.5 Inch HDD
  - (#AHG2): 2 TB 7.2K 2.5 Inch NL HDD
  - (#AHH2): 400 GB 2.5 Inch Flash Drive
  - (#AHH3): 800 GB 2.5 Inch Flash Drive
  - (#AHH4): 1.6 TB 2.5 Inch Flash Drive
  - (#AHH5): 3.2 TB 2.5 Inch Flash Drive
  - (#AHH9): 800 GB 3DWPD 12 Gb SAS 2.5 Inch Flash Drive
  - (#AHHG): 1.92 TB 12 Gb SAS 2.5 Inch Flash Drive
  - (#AHHH): 3.84 TB 12 Gb SAS 2.5 Inch Flash Drive
  - (#AHHJ): 7.68 TB 12 Gb SAS 2.5 Inch Flash Drive #
  - (#AHHK): 15.36 TB 12 Gb SAS 2.5 Inch Flash Drive
  - (#AHHL): 30.72 TB 12 Gb SAS 2.5 Inch Flash Drive
  - (#AH2A): 1.92 TB 12 Gb SAS 2.5-inch Flash Drive
  - (#AH2B): 3.84 TB 12 Gb SAS 2.5-inch Flash Drive
  - (#AH2C): 7.68 TB 12 Gb SAS 2.5-inch Flash Drive
  - (#AH2D): 15.36 TB 12 Gb SAS 2.5-inch Flash Drive

- ► Supported on Model 92G only. Maximum of 92

  - (#AH73): 1.2 TB 10K 3.5 Inch HDD
  - (#AH74): 1.8 TB 10K 3.5 Inch HDD
  - (#AH75): 2.4 TB 10K 3.5 Inch HDD
  - (#AH77): 6 TB 7.2K 3.5 Inch NL HDD
  - (#AH78): 8 TB 7.2K 3.5 NL HDD
  - (#AH79): 10 TB 7.2K 3.5 NL HDD
  - (#AH7A): 12 TB 7.2K 3.5 Inch NL HDD
  - (#AH7B): 14 TB 7,200 rpm 12 Gb SAS NL 3.5 Inch HDD
  - (#AH7D): 1.6 TB 3.5 Inch Flash Drive
  - (#AH7E): 3.2 TB 3.5 Inch Flash Drive
  - (#AH7J): 1.92 TB 12 Gb SAS 3.5 Inch Flash Drive
  - (#AH7K - #AH7B) - 3.84TB 12 Gb SAS 3.5 Inch Flash Drive
  - (#AH7L): 7.68 TB 12 Gb SAS 3.5 Inch Flash Drive
  - (#AH7M): 15.36 TB 12 Gb SAS 3.5 Inch Flash Drive
  - (#AH7N): 30.72 TB 12 Gb SAS 3.5 Inch Flash Drive

Physical and electrical specifications

Specifications for the control and expansion enclosures are listed in the following sections.

IBM FlashSystem 7200 Control Enclosure (2076 824 and 2076 U7C)

The IBM FlashSystem 7200 Control Enclosure has the following specifications:

► Physical specifications:
  – Height: 8.8 cm (3.5 in.)
  – Width: 48.3 cm (19.0 in.)
  – Depth: 85.0 cm (33.5 in.)
  – Approximate weight:
    • Empty: 38.5 kg (84.7 lb.)
    • Fully configured: 46.6 kg (102.5 lb.)

► Air temperature: °
  – Operating: 5 - 35° C (41 - 95° F) 0 - 3048 m (0 - 10,000 ft.). Above 900 m, de-rate maximum air temperature 1° per 300 m
  – Nonoperating: 1 - 50° C (34 - 122° F)

► Relative humidity:
  – Operating: 8 - 80% noncondensing
  – Non-operating: 8 - 80% noncondensing

► Electrical power:
  – Voltage range: 200 - 240 V AC
  – Frequency: 50 - 60 Hz
  – Power: 2000 W
  – Heat dissipation (BTU per hour): 6825
  – Acoustical noise emission: 8.1 bels (idling), 8.1 bels (operating)

IBM FlashSystem 7200 LFF and SFF Expansion Enclosure (2076 Model 12G and 2076 Model 24G)

The IBM FlashSystem 7200 Expansion Enclosure 12G / 24G has the following specifications:

► Physical specifications:
  – Height: 8.7 cm (3.4 in.)
  – Width: 48.3 cm (19.0 in.)
  – Depth: 55.6 cm (21.9 in.)
  – Approximate weight:
    • Empty: 16.7 kg (36.8 lb)
    • Fully configured: 25.0 kg (55.1 lb)

► Air temperature:
  – Operating: 5 - 35° C (41 - 95° F) 0 - 3048 m (0 - 10,000 ft). Above 900 m, de-rate maximum air temperature 1° per 175 m
  – Nonoperating: 1 - 50° C (34 - 122° F)

- ► Relative humidity:
    - – Operating: 8 - 80% noncondensing
    - – Nonoperating: 8 - 80% noncondensing

- ► Electrical power:
    - – Voltage range: 100 - 240 V AC
    - – Frequency: 50 - 60 Hz
    - – Power: 800 W
    - – Heat dissipation (BTU per hour): 1,037
    - – Acoustical noise emission: 6.2 bels (idling), 6.2 bels (operating)

IBM FlashSystem 7200 LFF Expansion Enclosure (2076 Model 92G)

The IBM FlashSystem 7200 Expansion Enclosure 92G has the following specifications:

- ► Physical specifications:
    - – Height: 22.2 cm (8.75 in.)
    - – Width: 48.3 cm (19.0 in.)
    - – Depth: 96.8 cm (38.1 in.)
    - – Approximate weight:
        - • Empty: 67.0 kg (147.7 lb)
        - • Fully configured: 135.0 kg (297.0 lb)

- ► Air temperature:
    - – Operating: 5 - 35° C (41 - 95° F) 0 - 3048 m (0 - 10,000 ft). Above 900 m, de-rate maximum air temperature 1° per 300 m
    - – Nonoperating: 1 - 50° C (34 - 122 degrees F)

- ► Relative humidity:
    - – Operating: 8 - 80% noncondensing
    - – Nonoperating: 8 - 80% noncondensing

- ► Electrical power:
    - – Voltage range: 180 - 264 V AC
    - – Frequency: 47 - 63 Hz
    - – Power: 2400 W
    - – Heat dissipation (BTU per hour): 8,189
    - – Acoustical noise emission: 8.5 bels (idling), 8.5 bels (operating)

Note: All noise emission levels that are stated are the declared (upper limit) sound power level in bels, for a random sample of machines. All measurements are made in accordance with ISO 7779 and reported in conformance with ISO 9296.

Software and licensing

All IBM FlashSystem 7200 systems feature IBM FlashSystem 7200 Software V8.3.1 or later pre installed. The product numbers are used for the base licenses for each model of the IBM FlashSystem 7200 system:

► IBM Spectrum Virtualize Software for IBM FlashSystem 7200 Controller V8.4.0 (5639-DB8)

  IBM Spectrum Virtualize Software for IBM FlashSystem 7200 Controller (5639-DB8) requires at least one IBM FlashSystem 7200 control enclosure 2076-824 for installation

► IBM Spectrum Virtualize Software for IBM FlashSystem 7200 Expansions V8.4.0 (5639-XD8):

  – IBM Spectrum Virtualize Software for IBM FlashSystem 7200 Expansions (5639-XD8) requires at least one IBM FlashSystem 7200 Expansion Enclosure (2076-12G, 2076-24G, or 2076-92G) for installation

  – The high-density enclosures (2076-92G) require four of the base software charge codes to support the number of drive slots in the system

All features are inclusive except for encryption, which is a feature code that is enabled for those countries that allow it, and external virtualization. Any connected storage that is not an IBM FlashSystem 7200 Control Enclosure requires the External Virtualization license per storage capacity unit (SCU) based on the tier of storage that is available on the external storage system. In addition, if you are using FlashCopy and Remote Mirroring on an external storage system, you must purchase a per-tebibyte license to use these functions.

Consider the following points:

► IBM FlashSystem 7200 control enclosures support external storage virtualization. Use of the external virtualization capability is entitled through the acquisition of IBM Spectrum Virtualize Software for SAN Volume Controller (SW PID 5641-VC8 in AAS and SW PID 5725-M19 in IBM Passport Advantage®).

► With the IBM FlashSystem 7200 system, a license also is needed for the hardware assisted encryption if it is purchased (Encryption Enablement Pack [#ACE1]). This feature code is needed if you want to use USB-Key encryption, SKLM-based encryption, or both on the control enclosure.

► The 5641-VC8 (External Virtualization, FlashCopy, and Remote Mirroring Features) and 5641-CP8 (Compression) licenses are licensed per enterprise within one country. These licenses are the same as for IBM SAN Volume Controller. Therefore, existing SAN Volume Controller licenses can be used for the IBM FlashSystem 7200 system for these features.

► A storage system that is used only as a quorum device does not need a software license.

To set these licenses, use the Licensed Function page in the System Setup wizard. If you are adding these licenses to a system, select **Settings → System → Licensed Function** in the management GUI. You can also use the `chlicense` CLI command to update current license settings on the system.

For more information about IBM Spectrum Virtualize licensing, see this web page and IBM Knowledge Center.

IBM Spectrum Virtualize External Licensing

The IBM FlashSystem 7200 supports differential, capacity, and key-based licensing. For example, with external virtualization, differential licensing charges different rates for different types of storage, which provides cost effective management of capacity across multiple tiers of storage. Licensing for these functions are based on the number of storage capacity units (SCUs) purchased.

With other functions, such as remote mirroring and FlashCopy, the license grants a specific number of terabytes of capacity for that function.

Key-based licenses, such as encryption, require an authorization code and key to be downloaded to the system before the function can be used.

> **Note:** SCUs are needed only for virtualized storage that does not have the 5639-DB8 or XD8 base license.

The SCU is defined in terms of the category of the storage capacity, as listed in Table 11.

Table 11   SCU category definitions

License	Drive class	SCU ratio
SCM	Storage Class Memory (SCM) devices	SCU equates to 1.00 TB usable of Category 1 storage
Flash	All flash devices, other than SCM drives	SCU equates to 1.00 TB usable of Category 1 storage
Enterprise	10K or 15K RPM drives	SCU equates to 1.18 TB usable of Category 2 storage
Nearline	Nearline Serial ATA (SATA) drives	SCU equates to 4.00 TB usable of Category 3 storage

Table 12 shows an example of calculating SCUs. The example is a customer who virtualizes external disk arrays with 30 TB SSD flash drives, 200 TB Enterprise drives, and 2400 TB Nearline capacity.

Table 12   Example of calculating SCUs

Category	Type	Capacity	Rule	# of SCUs
Category 1	SSD	30	/ 1	30
Category 2	Enterprise	200	/ 1.18	170
Category 3	Nearline	2400	/ 4	600
Total				**800**

As shown in Table 12, 800 SCUs are required for the example. When you calculate the number of SCUs per category, fractions must be rounded up to the next higher integer number.

For more information about IBM Spectrum Virtualize Differential Licensing, search for 7X00 licensed functions at IBM Knowledge Center.

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Offerings (for small, medium, and large enterprise customer segments), rates, terms, and availability can vary by country. For more information, contact your local IBM Global Financing organization or see the IBM Global Financing website.

Ordering information

For more information about ordering IBM FlashSystem 7200 expansions, see "Scaling up and scaling out" on page 35.

For more information about ordering hardware features, see "Options and feature codes" on page 46.

For more information about ordering software licenses, see "Software and licensing" on page 52.

Related information

For more information, see the following documents:

► *Introduction and Implementation of Data Reduction Pools and Deduplication*, SG24-8430:

  http://www.redbooks.ibm.com/abstracts/sg248430.html

► IBM Knowledge Center - IBM FlashSystem:

  https://www.ibm.com/support/knowledgecenter/en/search/flashsystem

► IBM FlashSystem 7200 product page:

  https://www.ibm.com/us-en/marketplace/flashsystem-7200

► IBM Offering Information page (announcement letters and sales manuals):

  http://www.ibm.com/common/ssi/index.wss?request_locale=en

► IBM Spectrum Virtualize FAQ

  Details about the IBM Spectrum Virtualize products, covering IBM FlashSystem family and SAN Volume Controller:

  https://www.ibm.com/downloads/cas/2DWAMWRB

► IBM FlashSystem Family Overview FAQ

  Overview of the IBM FlashSystem family with guidance on how to select the product that is right for you:

  https://www.ibm.com/downloads/cas/90GKVW2R

► IBM FlashWatch FAQ

Guidance about the IBM FlashWatch programs:

https://www.ibm.com/downloads/cas/YVMYPED

Author

Jon Herd is an IBM Storage Technical Advisor working for the ESCC, Germany. He covers the United Kingdom, Ireland, and Sweden, advising customers on a portfolio of IBM storage products, including IBM FlashSystem products. Jon has been with IBM for more than 45 years, and has held various technical roles, including Europe, Middle East, and Africa (EMEA) level support on mainframe servers and technical education development. He has written many IBM Redbooks publications about IBM FlashSystem products and is an IBM Redbooks Platinum level author. He holds IBM certifications in Supporting IT Solutions at an expert level, and Technical IT Specialist at an experienced level. He is also a certified Chartered Member of the British Computer Society (MBCS - CITP), a Certified Member of the Institution of Engineering and Technology (MIET) and a Certified Technical Specialist of the Open Group.

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