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IBM FlashSystem 5000 Family Products

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This edition applies to the hardware and software described in this book only.

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Preface

This IBM® Redbooks® publication provides an introduction and overview of the latest products in the IBM FlashSystem® 5000 Family, including their hardware and software features.

Advanced topics that apply to the IBM FlashSystem and IBM Spectrum® Virtualize family can be found in other IBM Redbooks publications about FlashSystem and IBM Spectrum Virtualize (for more information, see “Related publications” on page 35).

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Thanks to the following people for their contributions to this project:

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1

Introduction

This IBM Redbooks publication provides an overview of the latest models of the IBM FlashSystem 5000 family, and describes the hardware differences and software capabilities.

All-flash and hybrid flash: This is a single family and the designation H after the machine type, for example FlashSystem 5010H, means that is the hybrid flash version.

IBM FlashSystem models are the next-generation FlashSystem control enclosures, designed to deliver a range of performance, scalability, and functional capabilities:

- IBM FlashSystem 5010, 5030, and 5100 are a virtualized, software-defined storage system designed to consolidate workloads into a single storage system for ease of management, reduced costs, highly scalable capacity, high performance, and availability.
- IBM FlashSystem 5010 and 5030 offer the performance, functionality, and cost-efficiency demanded by midrange workloads.
- The FlashSystem 5030 adds more CPU power and additional features, such as Data Reduction Pools and data-at-rest Encryption. Hosts can attach via SAS, 16 Gb FCP, or iSCSI.
- IBM FlashSystem 5100 offers NVMe-accelerated performance and proven, wide-ranging functionality in affordable storage solutions.

2

IBM FlashSystem 5000 and 5100 family hardware overview

This chapter provides hardware information about the IBM FlashSystem 5000 and 5100 models, and contains the following topics:

- Portfolio simplification
- FlashSystem 5000
- FlashSystem 5100

2.1 Portfolio simplification

IBM is simplifying its portfolio as shown in Figure 2-1.

IBM FlashSystem Family		
Previously	1Q20	
	All-flash	Hybrid flash
Storwize V5010E	FlashSystem 5010	FlashSystem 5010H
Storwize V5030E	FlashSystem 5030	FlashSystem 5030H
Storwize V5100, V5100F	FlashSystem 5100	FlashSystem 5100H
Storwize V7000 Gen3	FlashSystem 7200	FlashSystem 7200H
FlashSystem 9100 Family	FlashSystem 9200 Family	
FlashSystem 9110		
FlashSystem 9150	FlashSystem 9200	
	FlashSystem 9200R	

Figure 2-1 IBM FlashSystem family

For the FlashSystem 5000 family they have the same functional equivalency and all that has changed is the name.

Figure 2-2 shows the IBM Storwize® model and its new IBM FlashSystem model.

Machine Type	Name	Storwize Model		FlashSystem Model	FlashSystem Product Name
2072	V5010E LFF Control	212	->	2H2	IBM FlashSystem 5010 LFF Control Enclosure
	V5010E SFF Control	224	->	2H4	IBM FlashSystem 5010 SFF Control Enclosure
	V5030E LFF Control	312	->	3H2	IBM FlashSystem 5030 LFF Control Enclosure
	V5030E SFF Control	324	->	3H4	IBM FlashSystem 5030 SFF Control Enclosure
	V5000E LFF Expansion	12F	->	12G	IBM FlashSystem 5000 LFF Expansion Enclosure
	V5000E SFF Expansion	24F	->	24G	IBM FlashSystem 5000 SFF Expansion Enclosure
	V5000E HD Expansion	92F	->	92G	IBM FlashSystem 5000 High Density Expansion Enclosure
	V5010E LFF Control	S12	->	U12	IBM FlashSystem 5010 LFF Control Enclosure
	V5010E SFF Control	S24	->	U24	IBM FlashSystem 5010 SFF Control Enclosure
	V5030E LFF Control	T12	->	V12	IBM FlashSystem 5030 LFF Control Enclosure
	V5030E SFF Control	T24	->	V24	IBM FlashSystem 5030 SFF Control Enclosure
	V5000E LFF Expansion	E12	->	F12	IBM FlashSystem 5000 LFF Expansion Enclosure
	V5000E SFF Expansion	E24	->	F24	IBM FlashSystem 5000 SFF Expansion Enclosure
	V5000E HD Expansion	E92	->	F92	IBM FlashSystem 5000 High Density Expansion Enclosure
2077 / 2078	V5100 SFF Control	424	->	4H4	IBM FlashSystem 5100 NVMe Control Enclosure
	V5100 SFF Control Utility	U5B	->	UHB	IBM FlashSystem 5100 Utility NVMe Control Enclosure
	V5000 LFF Expansion	12F	->	12G	IBM FlashSystem 5100 LFF Expansion Enclosure
	V5000 SFF Expansion	24F	->	24G	IBM FlashSystem 5100 SFF Expansion Enclosure
	V5000 HD Expansion	92F	->	92G	IBM FlashSystem 5100 High Density Expansion Enclosure

Figure 2-2 IBM Storwize to IBM FlashSystem

2.2 Hardware comparison overview of the IBM FlashSystem 5000 and 5100

The IBM FlashSystem 5000 family consists of different models, and each model type provides a different set of features, as listed in Table 2-1.

Table 2-1 Model features

Platform	5010	5030	5100
Speed	2.2 GHz	1.9 GHz	1.7 GHz
Cores	2	6	8
Model	Broadwell-DE	Broadwell-DE	Skylake
Compression[a]	None	Software	40 Gbps QAT[b]
Clustering	1 I/O Group	2 I/O Groups (with other 5030)	2 I/O Groups

a. DRP compression only, RACE compression is not supported
b. Intel QuickAssist Technology

Table 2-2 shows the memory feature on the FlashSystem 5000 and 5100.

Table 2-2 Memory feature

Platform	5010	5030	5100
Option 1 per canister	1 x 8 GB (8 GB)	1 x 16 GB (16 GB)	2 x 16 GB (32 GB)
Option 2 per canister	1 x 16 GB (16 GB)	2 x 16 GB (32 GB)	6 x 16 GB (96 GB)
Option 3 per canister	2 x 16 GB (32 GB)	-	6 x 16 GB + 6 x 32 GB (288 GB)
Max Per I/O Group	64 GB	64 GB	576 GB

All of the FlashSystem 5000 control enclosures include 1 Gb Ethernet (GbE) or 10 GbE ports as standard for iSCSI connectivity. The standard connectivity can be extended with additional ports or enhanced with additional connectivity through an optional I/O adapter card feature. Table 2-3 shows which configurations are available for the FlashSystem 5000 and 5100.

Table 2-3 Available configurations

Platform	5010	5030	5100
1 GbE	► 1 x 1 GbE tech port + iSCSI[a] ► 1 x 1 GbE iSCSI only	1 x 1 GbE dedicated tech port	1 x 1 GbE dedicated tech port
10 GbE	N/A	2 x 10 GbE (iSCSI only)	4 x 10 GbE (iSCSI only)
12 Gb SAS	1 x SAS expansion	2 x SAS expansion	N/A

a. Tech port is for initial setup, then reverts to host attach

Table 2-4 shows the possible adapter card installation for the FlashSystem 5000 and 5100 (up to 1 interface card per canister[1]).

Table 2-4 Possible adapter card installations

5000	5100
4-port 16 Gb Fibre Channel only	4-port 16 Gb Fibre Channel, FC NVMeoF
4-port 10 GbE iSCSI only	2-port 25 GbE ROCE ISER, iSCSI
2-port 25 GbE iSCSI only	2-port 25 GbE iWARP ISER, iSCSI
or:	and optionally:
4-port 12 Gb SAS host attach	2-port 12 Gb SAS to allow SAS Expansions

2.3 FlashSystem 5000

The FlashSystem 5000 delivers increased performance and new levels of storage efficiency with superior ease of use. This entry storage solution enables organizations to overcome their storage challenges. Built with IBM Spectrum Virtualize software, the IBM FlashSystem family is an industry-leading solution for storage virtualization.

The solution includes technologies to complement and enhance virtual environments, delivering a simpler, more scalable, and cost-efficient IT infrastructure. The FlashSystem 5000 features two node canisters in a compact, 2U 19-inch rackmount enclosure. The models shown in Table 2-5 deliver a range of performance, scalability, and functional capabilities.

Table 2-5 Machine type and model

MTM	Full Name
2072-2H2	IBM FlashSystem 5010 LFF Control Enclosure
2072-2H4	IBM FlashSystem 5010 SFF Control Enclosure
2072-3H2	IBM FlashSystem 5030 LFF Control Enclosure
2072-3H4	IBM FlashSystem 5030 SFF Control Enclosure
2072-12G	IBM FlashSystem 5000 LFF Expansion Enclosure
2072-24G	IBM FlashSystem 5000 SFF Expansion Enclosure
2072-92G	IBM FlashSystem 5000 High Density LFF Expansion Enclosure

2.3.1 Hardware Overview for the FlashSystem 5010

The FlashSystem 5010 features two-core processors with up to 64 GB total cache, and the attachment of up to ten 2U expansion enclosures or up to four 5U expansion enclosures. This delivers support for up to 392 drives.

Note: The IBM FlashSystem 5010 solution supports only one control enclosure and only one SAS expansion chain.

[1] Adapter cards must match between canisters.

The FlashSystem 5010 control enclosure models 212 and 224 have the following components:

- Two node canisters, each with a two-core processor
- 16 GB cache (8 GB per canister) with optional 32 GB cache (16 GB per canister) or 64 GB cache (32 GB per canister)
- 1 Gb iSCSI connectivity standard with optional 16 Gb FC, 12 Gb SAS, 10 Gb iSCSI (optical), or 25 Gb iSCSI (optical) connectivity
- 12 Gb SAS port for expansion enclosure attachment
- Twelve slots for 3.5-inch LFF SAS drives (Model 212) and 24 slots for 2.5-inch SFF SAS drives (Model 224)
- 2U, 19-inch rack mount enclosure with 100 - 240 V AC or -48 V DC power supplies

The LFF enclosure models support up to twelve 3.5-inch drives, and the small form factor (SFF) enclosure models support up to twenty-four 2.5-inch drives. High-performance disk drives, high-capacity nearline disk drives, and flash (solid-state drives [SSDs]) are supported. Drives of the same form factor can be intermixed within an enclosure, which provides the flexibility to address performance and capacity needs in a single enclosure. You can also intermix large form factor (LFF) and SFF expansion enclosures behind an LFF or SFF control enclosure.

Table 2-6 shows the supported 2.5-inch drives for the FlashSystem 5000.

Table 2-6 2.5-inch supported drives for the FlashSystem 5000

2.5-inch (SFF)	**Speed**	**Capacity**				
Tier 1 Flash		1.9 TB	3.84 TB	7.68 TB	15.36 TB	30.72 TB
High Performance, Enterprise Class Disk Drives	10,000 RPM	900 GB	1.2 TB	1.8 TB	2.4 TB	
High Capacity, Archival class Nearline Disk Drives	7,200 RPM	2 TB				

Table 2-7 shows the supported 3.5-inch (LFF) drives for IBM FlashSystem 5000.

Table 2-7 3.5-inch Supported drives for the FlashSystem 5000

3.5-inch (LFF)	**Speed**	**Capacity**					
High Capacity, Archival class Nearline Disk Drives	7,200 RPM	4 TB	6 TB	8 TB	10 TB	12 TB	14 TB

Figure 2-3 shows the IBM FlashSystem 5010 SFF Control Enclosure with 24 drives.

Figure 2-3 Front view of FlashSystem 5010

Figure 2-4 on page 8 shows the rear view of an IBM FlashSystem 5010 control enclosure.

Figure 2-4 Rear view of a FlashSystem 5010

Figure 2-5 shows the available connectors and LEDs on a single FlashSystem 5010 canister.

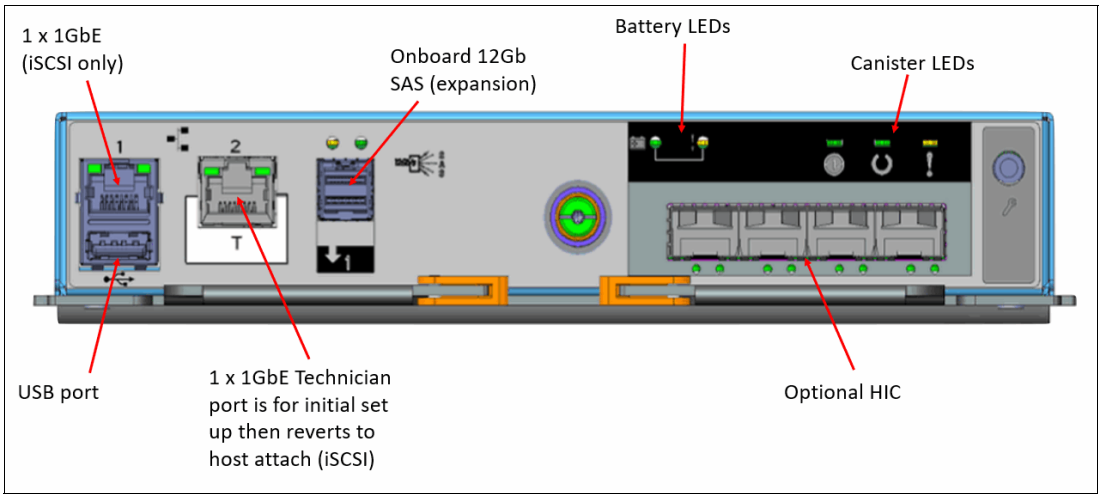

Figure 2-5 View of available connectors and LEDs on a FlashSystem 5010 single canister

2.3.2 Hardware overview for a FlashSystem 5030

The FlashSystem 5030 control enclosure models 312 and 324 have the following components:

- Two node canisters, each with a six-core processor
- 32 GB cache (16 GB per canister) with optional 64 GB cache (32 GB per canister)
- 10 Gb iSCSI (copper) connectivity standard with optional 16 Gb FC, 12 Gb SAS, 10 Gb iSCSI (optical), or 25 Gb iSCSI (optical)
- 12 Gb SAS port for expansion enclosure attachment
- Twelve slots for 3.5-inch LFF SAS drives (Model 312) and 24 slots for 2.5-inch SFF SAS drives (Model 324)
- 2U, 19-inch rack mount enclosure with 100 - 240 V AC or -48 V DC power supplies

The FlashSystem 5030 control enclosure models offer the highest level of performance, scalability, and functionality:

- Support for up to 504 drives, which allows up to 1008 drives for a two-way clustered configuration
- Data reduction pools with deduplication, compression,[2] and thin provisioning for improved storage efficiency

[2] Deduplication and compression require 64 GB of system cache

- Encryption of data at rest stored within the FlashSystem 5030 system

Figure 2-6 shows the IBM FlashSystem 5030 SFF Control Enclosure with 24 drives.

Figure 2-6 Front view of a FlashSystem 5030

Figure 2-7 shows the rear view of an IBM FlashSystem 5030 Control Enclosure.

Figure 2-7 Rear view of a FlashSystem 5030

Figure 2-8 describes the available connectors and LEDs on a single FlashSystem 5030 canister.

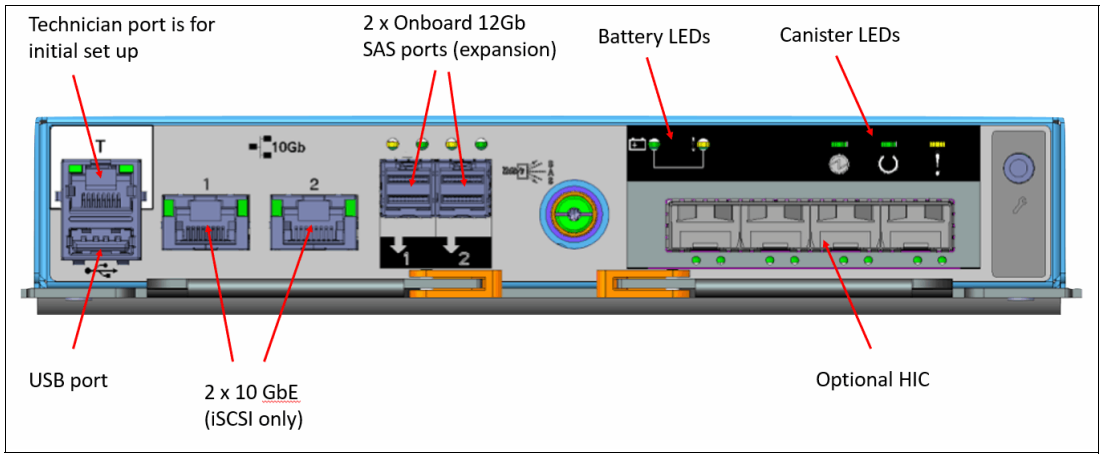

Figure 2-8 View of available connectors and LEDs on a FlashSystem 5030 single canister

2.4 FlashSystem 5100

The IBM FlashSystem 5100 is a virtualized, software-defined storage system designed to consolidate workloads into a single storage system for ease of management, reduced costs, highly scalable capacity, high performance, and availability. The FlashSystem 5100 models

4H4, and UHB deliver improved latency and performance with the implementation of NVMe technology.

The FlashSystem 5100 SFF control enclosure models 4H4, and UHB feature the following components:

- Two node canisters, each with an 8-core processor and integrated hardware-assisted compression acceleration
- 64 GB cache (32 GB per canister) standard with options 192 GB - 576 GB (per system)
- Eight 10 GbE ports standard for iSCSI connectivity
- 16 Gb or 32 Gb Fibre Channel (FC) connectivity options with FC-NVMe support
- 25 GbE connectivity options with iSCSI and iSER (RoCe V2 and iWARP) support
- Support for up to twenty-four 2.5-inch NVMe flash drives
- 2U, 19-inch rack mount enclosure

The FlashSystem 5100 model 4H4 attaches to expansion enclosure models 12G, 24G, and 92G, which support SAS Flash drives and SAS HDD Drives.

IBM 2078 Model UHB is the FlashSystem 5100 hardware component to be used in the Storage Utility Offering space. It is physically and functionally identical to the FlashSystem 5100 model 4H4 and 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, enabling allocated storage usage 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*. For thin provisioning, the data that is actually written is considered `used`. For thick provisioning, total allocated volume space is considered `used`.

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

The following 2.5-inch SFF NVMe FlashCore Modules are supported in the FlashSystem 5100 4H4, and UHB 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

The following 2.5-inch SFF NVMe industry-standard drives are supported in the FlashSystem 5100 4H4, and UHB control enclosures:

- 800 GB 2.5-inch 3DWPD 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

All drives are dual-port and hot-swappable. Drives can be intermixed where applicable. Expansion enclosures can be intermixed behind the SFF control enclosure.

2.4.1 Model 4H4 supported hardware

The FlashSystem 5100 model 4H4 supports the following expansions:

- Model 12G/24G 2U 12-drive or 24-drive
- Model 92G 5U 92-drive

The following 2.5-inch flash drives are supported:

- 800 GB, 1.6 TB, 1.92 TB, 3.84 TB, 7.68 TB, 15.36 TB, and 30.72 TB
- The following 2.5-inch disk drives are supported:
  - 600 GB and 900 GB 15,000 RPM SAS drives
  - 600 GB, 900 GB, 1.2 TB, 1.8 TB, and 2.4 TB 10,000 RPM SAS disks
  - 2 TB 7,200 RPM Nearline SAS disk

The following 3.5-inch disk drives are supported:

- 4 TB, 6 TB, 8 TB, 10 TB, 12 TB, and 14 TB 7,200 RPM nearline SAS disks

2.4.2 Supported fabric protocols

Table 2-8 shows the supported fabric protocols.

Table 2-8 Supported fabric protocols

Platform	Fibre Channel	iSCSI	ISER	FC-NVMeoF
5100	Yes	Yes[a]	Yes[b]	Yes

a. 10 GbE and 25 GbE (10 GbE supports only iSCSI)
b. 25 GbE only

2.4.3 Host Interface Cards

There are two PCIe Adapter slots. Table 2-9 shows the supported adapter card combinations (nodes in the same I/O group must match).

Table 2-9 Supported adapter card combinations

Supported number of cards	Ports	Protocol	Slot Position(s)	Note
0 - 1	4	16 Gb Fibre Channel	2	
0 - 1	4	32 Gb Fibre Channel	2	
0 - 1	2	25 Gb Ethernet (iWARP)	2	
0 - 1	2	25 Gb Ethernet (RoCE)	2	
0 - 1	2	12 Gb SAS Expansion	1	► Expansion only, no SAS host attach ► Four-port card, but only two are active

2.4.4 On board ports

Table 2-10 shows the onboard ports.

Table 2-10 Onboard ports

Onboard Ethernet Port	Speed	Function
1	10 GbE	Management IP, Service IP, and Host I/O (iSCSI only)
2	10 GbE	Secondary Management IP, and Host I/O (iSCSI only)
3	10 GbE	Host I/O (iSCSI only)
4	10 GbE	Host I/O (iSCSI only)
T	10 GbE	Technician Port: DHCP/DNS for direct attach service management

Figure 2-9 shows all of the connectors of a FlashSystem 5100 control bottom canister.

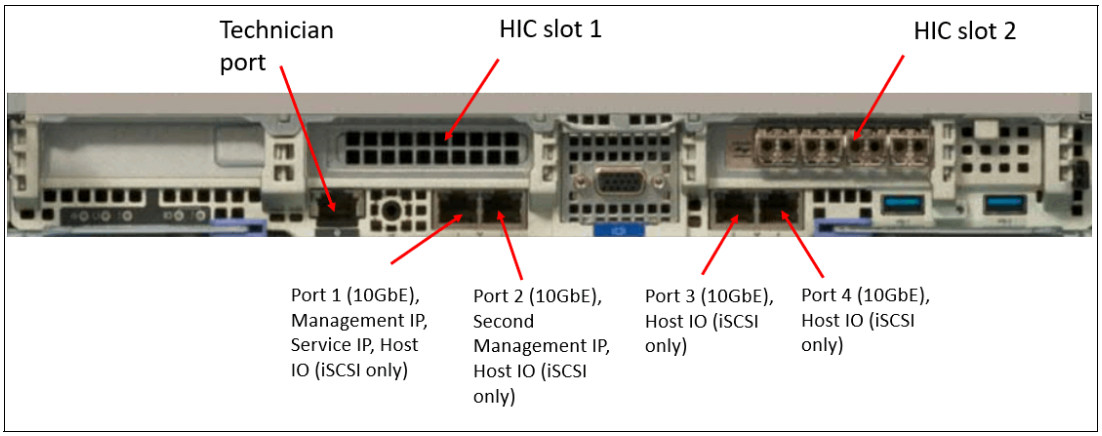

Figure 2-9 Connectors on a FlashSystem 5100 control bottom canister

3

Software features

This chapter provides an overview of the data management and protection features available on the IBM FlashSystem 5100 and FlashSystem 5000 systems.

The following aspects are covered:

- IBM Spectrum Virtualize software
- Feature set comparison
- Licensing
- Storage migration and management
- Features for storage efficiency and data reduction
- Features for enhanced data security
- Copy services and HyperSwap
- Features for application integration
- Features for manageability

3.1 IBM Spectrum Virtualize software

An IBM FlashSystem 5100 or FlashSystem 5000 control enclosure consists of two node canisters that each run IBM Spectrum Virtualize software, which is part of the IBM Spectrum Storage™ family.

IBM Spectrum Virtualize combines a variety of IBM technologies, including deduplication, compression, thin provisioning, distributed RAID arrays, SCSI Unmap, IBM HyperSwap® (high-availability solution), IBM Easy Tier® (automatic and dynamic data tiering), encryption of internal and external virtualized storage, IBM FlashCopy® (snapshot), and remote data replication. These technologies are designed to enable the FlashSystem family systems to provide a rich set of functional capabilities and deliver extraordinary levels of storage efficiency.

3.2 Feature set comparison

Even though all of the FlashSystem family systems are running the same IBM Spectrum Virtual software, the feature set available with each of the models is different. Table 3-1 compares feature sets provided by the FlashSystem 5000 and FlashSystem 5100 systems. Each of the features is described in more detail in further sections of this chapter.

Table 3-1 A comparison of the FlashSystem 5010, FlashSystem 5030, and FlashSystem 5100 systems

Feature	FlashSystem 5010	FlashSystem 5030	FlashSystem 5100
External Virtualization	Data migration only	Data migration only	Data migration and virtualization
Traditional RAID	0, 1, 10	0, 1, 10	No TRAID support on FlashCore Modules; 0, 1, 10 on industry standard NVMe drives
Distributed RAID	DRAID 5, DRAID 6	DRAID 5, DRAID 6	DRAID 5, DRAID 6
EasyTier	Yes, key-based license	Yes, key-based license	Yes, enclosure-based license
Data Reduction Pools (DRP)	Yes	Yes	Yes
Thin provisioning	Yes	Yes	Yes
Data compression	No	Yes, requires the 64GB cache feature	Yes, requires enclosure-based license
Data deduplication	No	Yes, requires the 64GB cache feature	Yes
Hardware encryption	No	Yes, key-based license	Yes, key-based license
Software encryption	No	No	Yes, for use on virtualized storage, key-based license
Volume mirroring	Yes	Yes	Yes

Feature	FlashSystem 5010	FlashSystem 5030	FlashSystem 5100
FlashCopy (snapshot)	Yes, with limitations; key-based license upgrade available	Yes, with limitations; key-based license upgrade available	Yes, enclosure-based license
Remote Mirroring	Yes, key-based license	Yes, key-based license	Yes, enclosure-based license
HyperSwap	No	Yes	Yes
VVols	Yes	Yes	Yes
Storage Insights	Yes	Yes	Yes

3.3 Licensing

All FlashSystem 5000 functional capabilities are provided through IBM Spectrum Virtualize Licensed Machine Code.

All FlashSystem 5100 functional capabilities are provided through IBM Spectrum Virtualize software.

The base license that is provided with the system includes its basic functions. However, there are also extra licenses that can be purchased to expand the capabilities of the system. Administrators are responsible for purchasing extra licenses and configuring the systems within the license agreement, which includes configuring the settings of each licensed function.

3.3.1 FlashSystem 5100 licenses (enclosure-based)

FlashSystem 5100 systems employ a license scheme which allows the use of certain licensed functions that are based on the number of enclosures that are indicated in the license. The system supports the following licensed functions:

- External Virtualization

  The system does not require a license for its own control and expansion enclosures; however, a license is required for each enclosure of any external systems that are being virtualized. Data can be migrated from existing storage systems to your system that uses the external virtualization function within 45 days of purchase of the system without purchase of a license.

  After 45 days, any ongoing use of the external virtualization function requires a license for each enclosure in each external system. The system does not require an external virtualization license for external enclosures that are only being used to provide managed disks for a quorum disk and are not providing any capacity for volumes.

- Remote Mirroring

  The Remote Mirroring (remote-copy) function enables you to set up a relationship between two volumes, so that updates that are made by an application to one volume are mirrored on the other volume. This function is licensed per enclosure. It allows the use of remote-mirroring functions on the total number of enclosures that are licensed.

  The total number of enclosures must include the enclosures on external storage systems that are licensed for virtualization and the number of control and expansion enclosures

that are part of your local system. The remote mirroring option must be acquired for both the primary (local) and secondary (remote) systems. If FlashSystem 5000 is mirrored to a system other than FlashSystem 5000, the other system must have the appropriate and applicable license for remote mirroring.

- Compression

  The compression function require a separately orderable license that is set on a per enclosure basis. One license is required for each control or expansion enclosure and each enclosure in any external storage systems that use virtualization. With the compression function, data is compressed as it is written to disk, saving extra capacity for the system.

The FlashCopy function also requires a license to use, but it does not require any input on the system. For auditing purposes, retain the license agreement for proof of compliance.

In addition to these enclosure-based licensed functions, the system also supports encryption through a key-based license.

3.3.2 FlashSystem 5000 licenses (key-based)

The FlashSystem 5010 and FlashSystem 5030 systems use key-based licensing where an authorization code is used to activate licensed functions on the system. The authorization code is sent with the FlashSystem 5000 Licensed Function Authorization documents that you receive after purchasing the license. These documents contain the authorization codes that are required to obtain keys (also known as DFSA license keys) for each licensed function that you purchased for your system. For each license that you purchase, a separate document with an authorization code is sent to you.

Each function is licensed to a FlashSystem 5000 control enclosure. It covers the entire system (control enclosure and all attached expansion enclosures) if it consists of one IO group. If FlashSystem 5030 system consists of two IO groups, two keys are required.

The following functions need a license key before they can be activated on the system:

- Easy Tier

  Easy Tier automatically and dynamically moves frequently accessed data to flash (solid state) drives in the system, resulting in flash drive performance without manually creating and managing storage tier policies. Easy Tier makes it easy and economical to deploy flash drives in the environment. In this dynamically tiered environment, data movement is seamless to the host application regardless of the storage tier in which the data resides.

- Remote Mirroring

  The Remote Mirroring (remote-copy) function enables you to set up a relationship between two volumes, so that updates that are made by an application to one volume are mirrored on the other volume.

  The license settings only apply to the system on which you are configuring license settings. For remote-copy partnerships, a license is also required on any remote systems that are in the partnership.

- FlashCopy Upgrade

  The FlashCopy upgrade extends the base FlashCopy function that is shipped with the product. The base version of FlashCopy limits the system to 64 target volumes. With the FlashCopy upgrade license activated on the system, this limit is removed. If you reach the limit imposed by the base function before activating the upgrade license, you cannot create any more FlashCopy mappings.

To help evaluate the benefits of these new capabilities, EasyTier and Remote Copy licensed functions can be enabled at no charge for a 90-day trial period. Trials are initiated from the FlashSystem management GUI and do not require any IBM intervention. Upon expiration of the trial, the function will be automatically disabled unless a license key for that function has been installed onto the machine.

If you use a trial license, the system warns you when the trial is about to expire at regular intervals. If you do not purchase and activate the license on the system before the trial license expires, all configuration that uses the trial licenses are suspended.

3.3.3 Encryption license (key-based)

Encryption is enabled on FlashSystem 5030 and FlashSystem 5100 through the acquisition of the Encryption Enablement feature. This feature enables encryption on the entire FlashSystem Family system and externally virtualized storage subsystems.

Encryption feature uses key-based license and is activated with an authorization code. The authorization code is sent with the FlashSystem 5000 or FlashSystem 5100 Licensed Function Authorization documents that you receive after purchasing the license.

The Encryption USB Flash Drives (Four Pack) feature or IBM Security Key Manager (SKLM) are required for encryption keys management.

3.4 Storage migration and management

The IBM FlashSystem 5000 and FlashSystem 5100 systems offer a variety of technologies for managing internal storage: NVMe FlashCore modules and NVMe drives on FlashSystem 5100, and high-performance SAS disk drives, high-capacity nearline SAS disk drives, and flash (solid state) drives.

The External Virtualization feature of the FlashSystem Family systems makes the migration of data from one storage device to another easier. It also enables you to manage other IBM or third-party storage arrays in the same manner as the capacity on internal drives or modules.

3.4.1 Data migration using the External Virtualization feature

All of the FlashSystem 5000 family models can migrate data from external storage controllers, including migrating from any other IBM or third-party storage systems. The FlashSystem 5000 and FlashSystem 5100 systems use the functionality that is provided by its external virtualization capability to perform the migration. This capability places external logical units (LUs) under the control of a FlashSystem Family machine. After that, hosts continue to access them through the IBM FlashSystem 5000 system, which acts as a proxy.

The migration process typically consists of the following steps:

1. Input/output (I/O) to the LUs that exist on the external storage system must be stopped and changes must be made to the mapping of the storage system, so that the original LUs are presented directly to the FlashSystem Family machine and not to the hosts. The FlashSystem 5000 discovers the external LUs and recognizes them as *unmanaged* external storage back-end devices (MDisks).
2. The unmanaged MDisks are then imported to the FlashSystem 5000 image mode volumes and placed in a migration storage pool. This storage pool is now a logical container for the externally attached LUs. Each volume has a one-to-one mapping with an

external LU. From a data perspective, the image mode volume represents the SAN-attached LUs exactly as they were before the import operation. The image mode volumes are on the same physical drives of the storage system, and the data remains unchanged.

3. Configure your hosts for the FlashSystem 5000 attachment, configure host objects on FlashSystem 5000, and map image-mode volumes to them. After the volumes are mapped, the hosts discover their volumes and are ready to continue working with them, so I/O can be resumed.
4. Migrate image-mode volumes to the internal storage of the FlashSystem 5000 family machine by using the volume mirroring feature. Mirrored copies are created online, so a host can still access and use the volumes during the mirror synchronization process.
5. After the mirror operations are complete, the image mode volumes are removed (deleted), and external storage system can be disconnected and decomissioned or reused elsewhere.

The FlashSystem 5000 family GUI provides a storage migration wizard, which simplifies the migration task. The wizard features intuitive steps that guide users through the entire process.

3.4.2 External storage virtualization

You can use the IBM FlashSystem 5100 system to manage the capacity of other disk systems with external storage virtualization. When the FlashSystem 5100 virtualizes a storage system, its capacity is managed similarly to internal disk drives or flash modules. Capacity in external storage systems inherits all of the rich functions and ease of use of the IBM FlashSystem 5100 system.

You can use FlashSystem 5100 to preserve your existing investments in storage, centralize management, and make storage migrations easier with storage virtualization and Easy Tier. Virtualization helps insulate applications from changes that are made to the physical storage infrastructure.

To virtualize external storage with the FlashSystem 5100, map its LUs to the system and add them to a storage pool as managed disks (MDisks). After that, you are able to create and manage volumes from a capacity provisioned from external systems.

Note: The FlashSystem 5010 and FlashSystem 5030 systems do not support external virtualization for any other purpose except data migration.

To verify if your storage is supported to be virtualized with the FlashSystem 5100, see the SSIC.

3.4.3 Managing internal storage

Internal storage of the IBM FlashSystem 5000 family systems consists of SAS-attached disk drives for the FlashSystem 5000 and NVMe-attached drives, or IBM FlashCore® modules for the FlashSystem 5100. For more details about supported drive types, see Chapter 2, “IBM FlashSystem 5000 and 5100 family hardware overview” on page 3.

In order to use the internal IBM FlashSystem 5000 disks in storage pools, they need to be joined into RAID arrays to form array-type MDisks.

RAID provides two key design goals:

- Increased data reliability
- Increased input/output (I/O) performance

The IBM FlashSystem 5000 family systems support two RAID types: traditional RAID and distributed RAID.

In a traditional RAID approach, data is spread among drives in an array. However, the spare space is constituted by spare drives, which sit outside of the array. Spare drives are idling, and do not share I/O load that comes to an array. When one of the drives within the array fails, all data is read from the mirrored copy (for RAID10), or is calculated from remaining data stripes and parity (for RAID5 or RAID6), and written to a single spare drive.

In distributed RAID, spare capacity is used instead of the idle spare drives from a traditional RAID. The spare capacity is spread across the disk drives. Because no drives are idling, all drives contribute to array performance. In case of drive failure, the rebuild load is distributed across multiple drives. By this, distributed RAID addresses two main disadvantages of a traditional RAID approach: it reduces rebuild times by eliminating the bottleneck of one drive, and increases array performance by increasing the number of drives sharing the workload.

IBM FlashCore Modules installed in the FlashSystem 5100 can be aggregated into both distributed RAID 6 and distributed RAID 5 arrays, but distributed RAID 6 is recommended. IBM FlashCore Modules in the same RAID array must be of the same capacity. Traditional RAID levels 5 and 6, as well as RAID 0, 1, and 10, are not supported on NVMe FlashCore modules.

Industry-standard NVMe drives in FlashSystem 5100 and SAS drives in FlashSystem 5000 can be aggregated into distributed RAID 6 and distributed RAID 5 arrays, and also can form RAID 1 and RAID 10 arrays. Traditional RAID 5 and 6 are not supported. Industry-standard NVMe drives in the same RAID array must be of the same capacity.

RAID arrays of some levels can be created only with the system CLI, not the GUI.

Note: IBM advises using distributed RAID 6 (DRAID6) for all drive types.

Table 3-2 summarizes the supported drives, array types, and RAID levels.

Table 3-2 Supported drives, array types, and RAID levels

Supported drives	**Non-distributed arrays (traditional RAID)**					**Distributed arrays (DRAID)**	
	RAID 0	RAID 1	RAID 5	RAID 6	RAID 10	RAID 5	RAID 6
2.5-inch and 3.5-inch SAS disk drives and solid-state drives	**Yes**	**Yes**	No	No	**Yes**	**Yes**	**Yes**
Industry-standard NVMe drives (FlashSystem 5100 only)	**Yes**	**Yes**	No	No	**Yes**	**Yes**	**Yes**
IBM FlashCore Modules (FlashSystem 5100 only)	No	No	No	No	No	**Yes**	**Yes**

3.5 Features for storage efficiency and data reduction

IBM Spectrum Virtualize software running in the IBM FlashSystem 5100 and FlashSystem 5000 systems offers several functions for storage optimization and efficiency.

3.5.1 Easy Tier

Many applications exhibit a significant skew in the distribution of I/O workload. A small fraction of the storage is responsible for a disproportionately large fraction of the total I/O workload of an environment.

Easy Tier acts to identify this skew and to automatically place data to take advantage of it. By moving the hottest data onto the fastest tier of storage, the workload on the remainder of the storage is significantly reduced. By servicing most of the application workload from the fastest storage, Easy Tier acts to accelerate application performance.

Easy Tier is a performance optimization function that automatically migrates (or moves) extents that belong to a volume between different storage tiers, based on their I/O load. Movement of the extents is online and unnoticed from the host perspective.

As a result of extent movement, the volume no longer has all its data in one tier, but rather in two or three tiers. Each tier provides optimal performance for the extent, as shown in Figure 3-1.

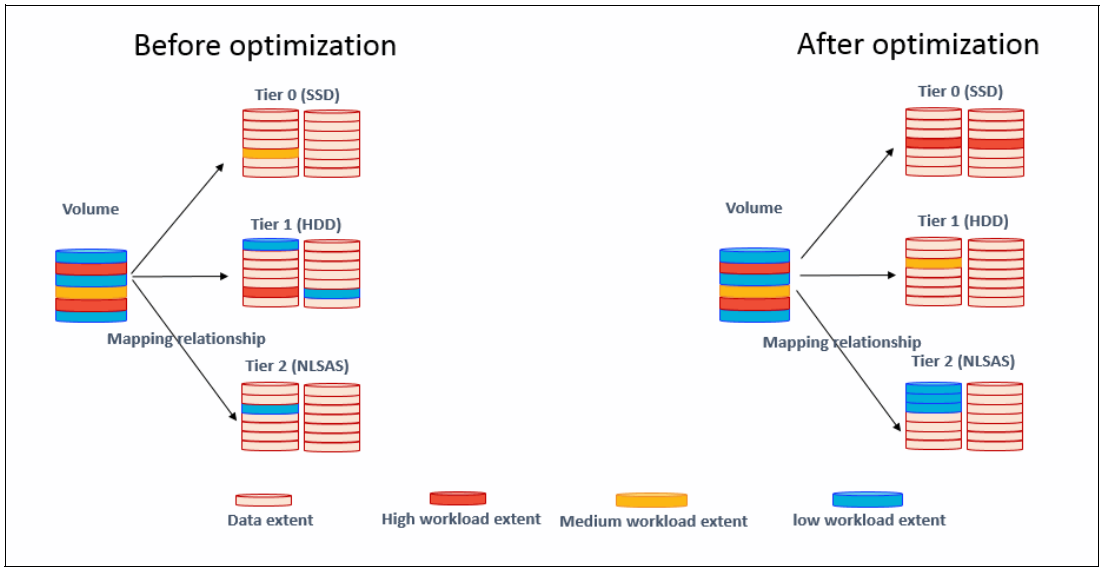

Figure 3-1 Easy Tier concept

Easy Tier monitors the I/O activity and latency of the extents on all Easy Tier enabled storage pools to create *heat maps*. Based on them, it creates an extent migration plan and promotes (moves) high activity or hot extents to a higher disk tier within the same storage pool. It also demotes extents whose activity dropped off, or cooled, by moving them from a higher disk tier MDisk back to a lower tier MDisk.

Storage pools that contain only one tier of storage can also benefit from Easy Tier if they have multiple disk arrays (or MDisks). Easy Tier has a balancing mode: it moves extents from busy disk arrays to less busy arrays of the same tier, balancing I/O load.

All arrays and MDisks belong to one of the tiers. They are classified as tier 0 flash, tier 1 flash, enterprise, or nearline tier. The system supports both tier 0 and tier 1 flash drives. Tier 0 flash drives are higher-cost flash drives that provide high performance for read and write operations. Tier 1 flash drives are lower-cost flash drives that have large capacity but lower performance and write endurance characteristics.

Easy Tier is supported on all of the FlashSystem 5100 and FlashSystem 5000 systems, but requires the appropriate license to be installed and configured.

3.5.2 Data reduction and unmap

The unmap feature is a set of SCSI primitives that enables hosts to indicate to a SCSI target (storage system) that space allocated to a range of blocks on a target storage volume is no longer required. This command enables the storage controller to take measures and optimize the system so that the space can be reused for other purposes.

The most common use case, for example, is a host application, such as VMware, freeing storage in a file system. The storage controller can then perform functions to optimize the space, such as reorganizing the data on the volume so that space is better used.

When a host allocates storage, the data is placed in a volume. To free the allocated space back to the storage pools, the SCSI Unmap feature is used. It enables host operating systems to un-provision storage on the storage controller, so that the resources can automatically be freed up in the storage pools and used for other purposes.

Data Reduction Pools (DRP) increase infrastructure capacity usage by using new efficiency functions and reducing storage costs. By using end-to-end SCSI Unmap functionality, DRP enable you to automatically de-allocate and reclaim capacity of thin-provisioned volumes that contain deleted data and enable this reclaimed capacity to be reused by other volumes.

At its core, a Data Reduction Pool uses a Log Structured Array (LSA) to allocate capacity. A Log Structured Array enables a tree-like directory to be used to define the physical placement of data blocks independent of size and logical location. Each logical block device has a range of Logical Block Addresses (LBAs), starting from 0 and ending with the block address that fills the capacity.

When written, an LSA enables you to allocate data sequentially and provide a directory that provides a lookup to match a LBA with a physical address within the array. Therefore, the volume that you create from the pool to present to a host application consists of a directory that stores the allocation of blocks within the capacity of the pool.

In Data Reduction Pools, the maintenance of the metadata results in *I/O amplification*. I/O amplification occurs when a single host-generated read or write I/O results in more than one back-end storage I/O request because of advanced functions. A read request from the host results in two I/O requests: a directory lookup and a data read. A write request from the host results in three I/O requests: a directory lookup, a directory update, and a data write. This aspect needs to be considered when sizing and planning your data-reducing solution.

Standard pools, which make up a classic solution that is also supported with the FlashSystem 5100 and FlashSystem 5000 systems, do not use LSA. A standard pool works as a container that receives its capacity from disk arrays (MDisks), splits it into extents of the same fixed size and allocates extents to volumes.

Standard pools do not cause I/O amplification and require less processing resource use compared to Data Reduction Pools. In exchange, Data Reduction Pools provide more flexibility and storage efficiency.

Table 3-3 provides an overview of volume capacity saving types that are available with Standard and Data Reduction Pools.

Table 3-3 Volume types available in pools

	Standard pool	Data Reduction Pool
Fully Allocated	Yes	Yes
Thin-provisioned	Yes	Yes
Thin-provisioned compressed	No	Yes
Thin-provisioned deduplicated	No	Yes
Thin-provisioned compressed and deduplicated	No	Yes

This book only provides an overview of DRP aspects. For more information, see *Introduction and Implementation of Data Reduction Pools and Deduplication*, SG24-8430.

3.5.3 Fully allocated and thin-provisioned volumes

Volumes can be configured as thin-provisioned or fully allocated. Both can be configured in standard pools and Data Reduction Pools.

In FlashSystem Family systems, each volume has *virtual capacity* and *real capacity* parameters. Virtual capacity is the volume storage capacity that is available to a host and is used by it to create a filesystem. Real capacity is the storage capacity that is allocated to a volume from a pool. It shows the amount of space that is used on a physical storage volume.

Fully allocated volumes are created with the same amount of real capacity and virtual capacity. This type uses no storage efficiency features.

When a fully allocated volume is created on DRP, it bypasses the LSA structure and works in the same manner as in a standard pool, requiring no processing overhead and providing no data reduction options at the pool level.

When using fully allocated volumes on the FlashSystem 5100 with FlashCore modules (FCMs), whether a Data Reduction Pool or standard pool is used, capacity savings are achieved by compressing data with hardware compression that runs on FCMs. Hardware compression on FlashCore modules is always enabled. This configuration provides maximum performance in combination with outstanding storage efficiency.

A thin-provisioned volume presents a different capacity to mapped hosts than the capacity that the volume uses in the storage pool. Therefore, real and virtual capacities might not be equal. The virtual capacity of a thin-provisioned volume is typically significantly larger than its real capacity. As more information is written by the host to the volume, more of the real capacity is used. The system identifies read operations to unwritten parts of the virtual capacity, and returns zeros to the server without using any real capacity.

In a shared storage environment, thin provisioning is a method for optimizing the use of available storage. It relies on the allocation of blocks of data on demand, versus the traditional method of allocating all of the blocks up front. This method eliminates almost all white space, which helps avoid the poor usage rates that occur in the traditional storage allocation method where large pools of storage capacity are allocated to individual servers but remain unused (not written to).

If a thin-provisioned volume is created in a DRP, the system monitors it for reclaimable capacity from host unmap operations. This capacity can be reclaimed and redistributed into the pool. Space that is freed from the hosts is a process called *unmap*. A host can issue SCSI Unmap commands when the user deletes files on a filesystem, which result in the freeing of all of the capacity allocated within that unmap. Similarly, deleting a volume at the DRP level frees all of the capacity back to the pool.

A thin-provisioned volume in a standard pool can't return unused capacity back to the pool with SCSI Unmap.

A thin-provisioned volume can be converted non-disruptively to a fully allocated volume, or vice versa, by using the volume mirroring function. For example, you can add a thin-provisioned copy to a fully allocated primary volume, and then remove the fully allocated copy from the volume after they are synchronized.

Note: It is not recommended to use non-compressed thin-provisioned volumes on storage pools running on FlashCore modules. System GUI prevents the creation of such types of configurations.

3.5.4 Compression and deduplication

When using Data Reduction Pools on the FlashSystem 5100 or FlashSystem 5030, host data can be compressed or compressed and deduplicated before it is written to the disk drives.

The FlashSystem family DRP compression is based on the Lempel-Ziv lossless data compression algorithm and operates by using a real-time method. When a host sends a write request, the request is acknowledged by the write cache of the system, and then staged to the Data Reduction Pool.

As part of its staging, the write request passes through the compression engine and is then stored in compressed format. Therefore, writes are acknowledged immediately after they are received by the write cache with compression occurring as part of the staging to internal or external physical storage. This process occurs transparently to host systems making them unaware of the compression.

DRP compression is supported on the FlashSystem 5100. This system's node canisters have a compression accelerator installed that increases the throughput of I/O transfers between nodes and compressed volumes.

The FlashSystem 5030 with the 64 GB cache feature (32 GB RAM per node canister) also supports DRP compression. However this system does not have compression accelerator hardware, and is using the canister's CPU for compression and decompression. Due to this, strict performance planning and sizing is required.

The FlashSystem 5010 and FlashSystem 5030 systems with 16 GB RAM per node canister do not support data compression and deduplication.

The Comprestimator tool is available to check if your data is compressible. It estimates the space savings achieved when using compressed volumes. This utility provides a quick and easy view of showing the benefits of using compression. Comprestimator can run from the FlashSystem Family system GUI or CLI to check data that is already stored on the system. It is also available as a stand-alone, host-based utility that can analyze data on IBM or third-party storage devices. It can be found here.

Deduplication can be configured with thin-provisioned and compressed volumes in Data Reduction Pools for added capacity savings. The deduplication process identifies unique chunks of data, or byte patterns, and stores a signature of the chunk for reference when writing new data chunks.

If the new chunk's signature matches an existing signature, the new chunk is replaced with a small reference that points to the stored chunk. The matches are detected when the data is written. The same byte pattern might occur many times, resulting in the amount of data that must be stored being greatly reduced.

Deduplication is supported on volumes provisioned from DRP on the FlashSystem 5100 systems. It can also be implemented on the FlashSystem 5030 with the 64 GB cache feature. However, it might be less efficient compared to the FlashSystem 5100 because the signature database size is limited on this model. Deduplication is *not* supported on the FlashSystem 5010 and FlashSystem 5030 with 32 GB RAM per system.

To help with the profiling and analysis of existing workloads that must be migrated to a FlashSystem 5000 family system, IBM provides the Data Reduction Estimation Tool (DRET). DRET is a highly accurate, command-line, host-based utility for estimating the data reduction savings on block storage devices. The tool scans target workloads on various storage arrays (from IBM or another company), merges all scan results, and provides a data reduction estimate.

Compression and deduplication are not mutually exclusive; one or both, or neither, features can be enabled. If the volume is deduplicated and compressed, data is deduplicated first, and then compressed. Therefore, deduplication references are created on the compressed data stored on the physical domain.

3.6 Features for enhanced data security

To protect data against the potential exposure of sensitive user data and user metadata that is stored on discarded, lost, or stolen storage devices, IBM FlashSystem 5100 and FlashSystem 5030 systems support encryption of data-at-rest.

Encryption is performed by the FlashSystem 5100 or FlashSystem 5030 control enclosure for data stored within the entire FlashSystem Family system, the FlashSystem 5000 family control enclosure, all attached expansion enclosures, and for data stored in externally virtualized by the FlashSystem 5100 storage subsystems.

Encryption is the process of encoding data so that only authorized parties can read it. Data encryption is protected by the Advanced Encryption Standard (AES) algorithm that 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.

There are two types of encryption on devices running IBM Spectrum Virtualize: *hardware encryption* and *software encryption*. Which method is used for encryption is chosen automatically by the system based on the placement of the data:

- Hardware encryption: Data is encrypted by using serial-attached SCSI (SAS) hardware. It is used only for internal storage (drives).
- Software encryption: Data is encrypted by using the nodes' CPU (the encryption code uses the AES-NI CPU instruction set). It is used only for external storage, virtualized by the FlashSystem 5100.

Both methods of encryption use the same encryption algorithm, key management infrastructure, and license.

Note: Only data-at-rest is encrypted. Host to storage communication and data sent over links used for Remote Mirroring are not encrypted.

The FlashSystem 5100 also supports self-encrypting drives, where data encryption is completed in the drive itself.

Before encryption can be enabled ensure that a license was purchased and activated.

The system supports two methods of configuring encryption. You can use a centralized key server that simplifies creating and managing encryption keys on the system. This method of encryption key management is preferred for security and simplification of key management.

A key server is a centralized system that generates, stores, and sends encryption keys to the system. Some key server providers support replication of keys among multiple key servers. If multiple key servers are supported, you can specify up to four key servers that connect to the system over both a public network or a separate private network. The system supports IBM Security Key Lifecycle Manager or Gemalto SafeNet KeySecure key servers to handle key management.

In addition, the system supports storing encryption keys on USB flash drives. USB flash drive-based encryption requires physical access to the systems and is effective in environments with a minimal number of systems. For organizations that require strict security policies regarding USB flash drives, the system supports disabling a canister's USB ports to prevent unauthorized transfer of system data to portable media devices. If you have such security requirements, use key servers to manage encryption keys.

3.7 Copy services and HyperSwap

The system provides copy services functions that can be used for migration, to improve availability and support disaster recovery.

3.7.1 Volume mirroring

By using volume mirroring, a volume can have two physical copies in one FlashSystem 5000 family system. Each volume copy can belong to a different pool, and use a different set of capacity saving features.

When a host writes to a mirrored volume, the system writes the data to both copies. When a host reads a mirrored volume, the system picks one of the copies to read. If one of the mirrored volume copies is temporarily unavailable, the volume remains accessible to servers. The system remembers which areas of the volume are written, and re-synchronizes these areas when both copies are available.

You can create a volume with one or two copies, and you can convert a non-mirrored volume into a mirrored volume by adding a copy. When a copy is added in this way, the system synchronizes the new copy so that it is the same as the existing volume. Servers can access the volume during this synchronization process.

Volume mirroring can be used to migrate data to or from a FlashSystem Family system. For example, you can start with a non-mirrored image-mode volume in the migration pool, and

then add a copy to that volume in the destination pool on internal storage. After the volume is synchronized, you can delete the original copy that is in the source pool. During the synchronization process, the volume remains available.

Volume mirroring is also used to convert fully allocated volumes to use data reduction technologies, such as thin-provisioning, compression, or deduplication, or to migrate volumes between storage pools. Volume mirroring is available on the FlashSystem 5100 and FlashSystem 5000 systems without additional licenses.

3.7.2 FlashCopy

The FlashCopy, or snapshot, function creates a point-in-time copy of data that is stored on a source volume to a target volume. FlashCopy is sometimes described as an instance of a time-zero copy (T0). Although the copy operation takes some time to complete, the resulting data on the target volume is presented so that the copy appears to have occurred immediately, and all data is available immediately. Advanced functions of FlashCopy allow operations to occur on multiple source and target volumes.

Management operations are coordinated to provide a common, single point-in-time for copying target volumes from their respective source volumes. This creates a consistent copy of data that spans multiple volumes.

The function also supports multiple target volumes to be copied from each source volume. This can be used to create images from different points in time for each source volume.

FlashCopy is used to create consistent backups of dynamic data and test applications, and to create copies for auditing purposes and for data mining. It can be used to capture the data at a particular time to create consistent backups of dynamic data. The resulting image of the data can be backed up, for example, to a tape device. When the copied data is on tape, the data on the FlashCopy target disks becomes redundant and can be discarded.

Another possible FlashCopy application is creating test environments. It can be used to test an application with real business data before the existing production version of the application is updated or replaced. With FlashCopy, a fully functional and space-efficient clone of a volume containing real data can be created. It enables read and write access for the test environment while keeping the real production environment data both safe and untouched. After testing is complete, the clone volume can be discarded or retained for future use.

FlashCopy can perform a restore from any existing FlashCopy mapping. Therefore, you can restore (or copy) from the target to the source of your regular FlashCopy relationships. When restoring data from FlashCopy, this method can be qualified as reversing the direction of the FlashCopy mappings. This approach can be used for various applications, such as recovering production database application after an errant batch process that caused extensive damage.

The FlashSystem 5100 system requires a license to use the FlashCopy function. The license is not policed by the system and does not require any input. For auditing purposes, retain the license agreement for proof of compliance.

All FlashSystem 5000 systems include a license to use not more than 64 FlashCopy mappings in the base package. If more than 64 FlashCopy targets are required, a *FlashCopy upgrade* license is available that removes this limit.

3.7.3 Remote mirroring

You can use remote mirroring, or remote copy functions, to set up a relationship between two volumes, where updates made to one volume are mirrored on the other volume. The volumes can be on two different systems (intersystem). In addition, the FlashSystem Family systems support volumes that reside on the same system (intrasystem).

Although data is only written to a single volume, the system maintains two copies of the data. If the copies are separated by a significant distance, the remote copy can be used as a backup for disaster recovery.

For a remote copy relationship, one volume is designated as the primary and the other volume is designated as the secondary. Host applications write data to the primary volume, and updates to the primary volume are copied to the secondary volume. Normally, host applications do not run I/O operations to the secondary volume.

The following types of remote mirroring are available:

- Metro Mirror

  Provides a consistent copy of a source volume on a target volume. Data is written to the target volume synchronously after it is written to the source volume so that the copy is continuously updated.

  With synchronous copies, host applications write to the primary volume but do not receive confirmation that the write operation has completed until the data is written to the secondary volume.

  This ensures that both the volumes have identical data when the copy operation completes. After the initial copy operation completes, the Metro Mirror function maintains a fully synchronized copy of the source data at the target site at all times. The Metro Mirror function supports copy operations between volumes that are separated by distances up to 300 km.

  For disaster recovery purposes, Metro Mirror provides the simplest way to maintain an identical copy on both the primary and secondary volumes. However, as with all synchronous copies over remote distances, there can be a performance impact to host applications. This performance impact is related to the distance between primary and secondary volumes and, depending on application requirements, its use might be limited based on the distance between sites.

- Global Mirror

  Provides a consistent copy of a source volume on a target volume. The data is written to the target volume asynchronously and the copy is continuously updated. When a host writes to the primary volume, confirmation of I/O completion is received before the write operation completes for the copy on the secondary volume. Due to this, the copy might not contain the most recent updates when a disaster recovery operation is completed.

  If a failover operation is initiated, the application must recover and apply any updates that were not committed to the secondary volume. If I/O operations on the primary volume are paused for a small length of time, the secondary volume can become an exact match of the primary volume. This function is comparable to a continuous backup process in which the last few updates are always missing. When you use Global Mirror for disaster recovery, you must consider how you want to handle these missing updates.

  The secondary volume is generally less than 1 second behind the primary volume, which minimizes the amount of data that must be recovered if a failover occurs. However, a high-bandwidth link must be provisioned between the two sites.

- Global Mirror with change volumes (GMCV)

Enables support for Global Mirror with higher recovery point objective (RPO) by the use of change volumes. This function is for use in environments where the available bandwidth between the sites is smaller than the update rate of the replicated workload.

With Global Mirror with change volumes, or Global Mirror with cycling, change volumes must be configured for both the primary and secondary volumes in each relationship. A copy is taken of the primary volume in the relationship to the change volume. The background copy process reads data from the stable and consistent change volume, copying the data to the secondary volume in the relationship.

Copy-on-write technology is used to maintain the consistent image of the primary volume for the background copy process to read. The changes that took place while the background copy process was active are also tracked. The change volume for the secondary volume can also be used to maintain a consistent image of the secondary volume while the background copy process is active.

GMCV provides less requirements to inter-site link bandwidth than other remote copy types, it is mostly used when link parameters are not sufficient to maintain remote copy relationship without impacting host performance.

Intersystem replication is possible over Fibre Channel or Internet Protocol (IP) link. The native IP replication feature enables replication between any SVC/FlashSystem family systems, using the built-in networking ports of the system nodes.

Note: All three types of remote copy are supported to work over IP link, however recommended type is Global Mirror with change volumes.

A license is required for the FlashSystem 5100 or FlashSystem 5000 to participate in a remote copy relationship of any type. For the FlashSystem 5030 systems that contain two I/O groups, two licenses are needed.

3.7.4 HyperSwap

The IBM HyperSwap function is a high availability feature that provides dual-site, active-active access to a volume. HyperSwap functions are available on systems that can support more than one I/O group, such as the FlashSystem 5100 and FlashSystem 5030.

With HyperSwap, a fully independent copy of the data is maintained at each site. When data is written by hosts at either site, both copies are synchronously updated before the write operation is completed. The HyperSwap function automatically optimizes itself to minimize data that is transmitted between two sites, and to minimize host read and write latency.

If the nodes go offline or the storage at either site goes offline, leaving an online and accessible up-to-date copy, the HyperSwap function can automatically fail over access to the online copy. The HyperSwap function also automatically re-synchronizes the two copies when possible.

The HyperSwap solution requires one FlashSystem 5100 or FlashSystem 5030 control enclosure at each site, and it requires a third site that acts as a tie-breaking quorum device. The third site can be implemented as FC-attached storage or IP-linked quorum application.

To construct HyperSwap volumes, active-active replication relationships are made between the copies at each site. These relationships automatically run and switch direction according to which copy or copies are online and up to date. The relationships provide access to whichever copy is up to date through a single volume, which has a unique ID. This volume is visible as a single object across both sites (I/O groups), and is mounted to a host system.

The HyperSwap function works with the standard multipathing drivers that are available on a wide variety of host types, with no additional host support required to access the highly available volume. Where multipathing drivers support Asymmetric Logical Unit Access (ALUA), the storage system tells the multipathing driver which nodes are closest to it, and should be used to minimize I/O latency. You just need to tell the storage system which site a host is connected to, and it configures host pathing optimally.

Because remote mirroring is used to support the HyperSwap capability, remote mirroring licensing is a requirement for this feature on the FlashSystem 5100 and FlashSystem 5030. Depending on the number of HyperSwap volumes, a FlashCopy upgrade license might also be required on the FlashSystem 5030.

3.8 Features for application integration

The IBM FlashSystem 5100 and FlashSystem 5000 include 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, and resiliency is improved for VMs if volumes start running out of space.

3.8.1 Virtual Volumes

The system supports VMware vSphere Virtual Volumes, sometimes referred to as VVols, which allow VMware vCenter to automate the management of system objects like volumes and pools. Virtual Volumes (VVols) is an integration and management framework that virtualizes the FlashSystem family systems, enabling a more efficient operational model that is optimized for virtualized environments and centered on the application instead of the infrastructure.

Virtual Volumes simplify operations through policy-driven automation that enables more agile storage consumption for virtual machines and dynamic adjustments in real time, when they are needed. It simplifies the delivery of storage service levels to individual applications by providing finer control of hardware resources and native array-based data services that can be instantiated with virtual machine granularity.

With Virtual Volumes (VVols), VMware offers a paradigm in which an individual virtual machine and its disks, rather than a LUN, becomes a unit of storage management for a storage system. Virtual volumes encapsulate virtual disks and other virtual machine files, and natively store the files on the storage system.

By using a special set of APIs called vSphere APIs for Storage Awareness (VASA), the storage system becomes aware of the virtual volumes and their associations with the relevant virtual machines. Through VASA, vSphere and the underlying storage system establish a two-way out-of-band communication to perform data services and offload certain virtual

machine operations to the storage system. For example, some operations, such as snapshots and clones can be offloaded.

For further information on VVols and actions required to implement this feature on the host side, see the VMware website.

IBM support for VASA is provided by IBM Spectrum Connect (before version 3.4.0, IBM Spectrum Control Base Edition, SCB). The FlashSystem family system administrator can assign ownership of Virtual Volumes to IBM Spectrum Connect by creating a user with the VASA Provider security role. IBM Spectrum Connect provides communication between the VMware vSphere infrastructure and the FlashSystem Family system.

Although the system administrator can complete certain actions on volumes and pools that are owned by the VASA Provider security role, IBM Spectrum Connect retains management responsibility for Virtual Volumes. For more information about IBM Spectrum Connect, see the IBM Spectrum Connect documentation.

Note: At the time of writing, VVols are not supported on Data Reduction Pools, because they use child pool functionality, which is available with standard pools only.

3.9 Features for manageability

The IBM FlashSystem 5100 and FlashSystem 5000 systems offer the following manageability and serviceability features:

- An intuitive GUI
- IBM Callhome
- IBM Storage Insights

3.9.1 The FlashSystem family system GUI

The IBM FlashSystem 5000 family systems include an easy-to-use management GUI that runs on one of the node canisters in the 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.

The IBM FlashSystem 5100 and FlashSystem 5000 systems use a GUI with the same look and feel as other IBM FlashSystem family solutions for a consistent management experience across all platforms. The GUI has an improved overview dashboard that provides all information in an easy-to-understand format, and enables visualization of effective capacity. With the GUI, you can quickly deploy storage and manage it efficiently.

Figure 3-2 shows the IBM FlashSystem 5030 dashboard view. This is the default view that is displayed after the user logs on to the system.

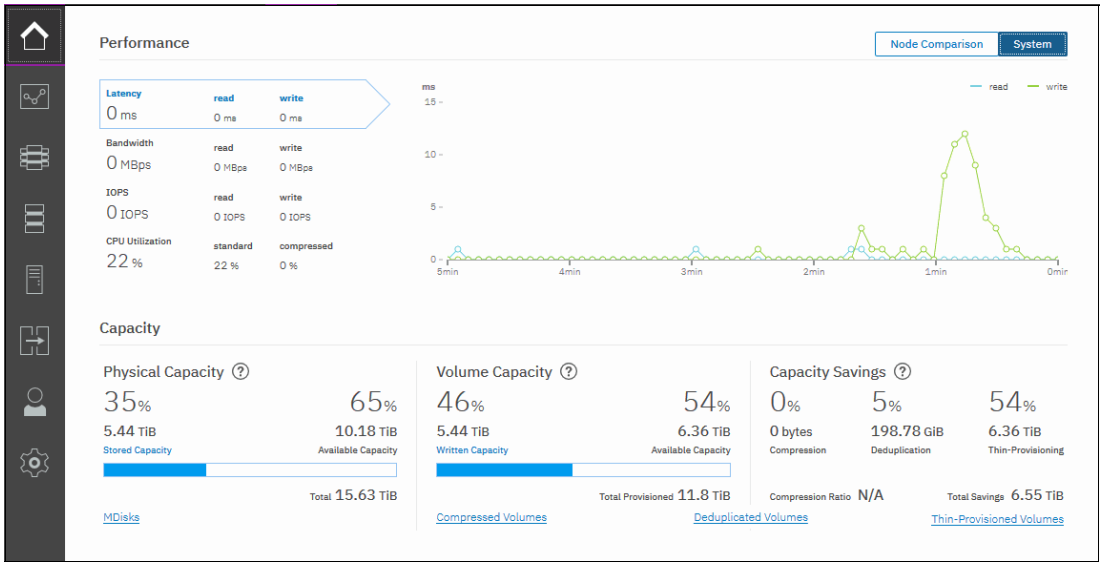

Figure 3-2 FlashSystem 5030 GUI dashboard

The IBM FlashSystem family systems also provides a CLI, which is useful for advanced configuration and scripting.

The FlashSystem family systems support Simple Network Management Protocol (SNMP), email notifications that uses Simple Mail Transfer Protocol (SMTP), and syslog redirection for complete enterprise management access.

3.9.2 IBM Call home

Call home connects the system to IBM Service Personnel who can monitor and respond to system events to ensure that your system remains up and running. The call home function opens a service alert if a serious error occurs in the system, automatically sending details of the error and contact information to IBM Service Personnel.

If the system is entitled for support, a Problem Management Record (PMR) is automatically created and assigned to the appropriate IBM support team. The information provided to IBM in this case would be an excerpt from the Event Log containing the details of the error, and client contact information from the system. This enables IBM Service Personnel to contact the client and arrange service on the system, which can greatly improve the speed of resolution by removing the need for the client to detect the error and raise a Support call themselves.

The system supports two methods to transmit notifications to the support center:

- Call home with cloud services

  Call home with cloud services sends notifications directly to a centralized file repository that contains troubleshooting information that is gathered from customers. Support personnel can access this repository and automatically be assigned issues as problem reports.

  This method of transmitting notifications from the system to support removes the need for customers to create problem reports manually. Call home with cloud services also eliminates email filters dropping notifications to and from support which can delay resolution of problems on the system.

  This method only sends notifications to the predefined support center.

- Call home with email notifications

  Call home with email notification sends notifications through a local email server to support and local users or services that monitor activity on the system. With email notifications, you can send notifications to support and designate internal distribution of notifications as well, which alerts internal personnel of potential problems. Call home with email notifications requires configuration of at least one email server and local users.

  However, external notifications to the support center can be dropped if filters on the email server are active. To eliminate this problem, call home with email notifications is not recommended because the only method to transmit notifications to the support center. Call home with email notifications can be configured together with cloud services.

IBM highly encourages all clients to take advantage of the Call home feature to enable you and IBM to partner for your success.

3.9.3 IBM Storage Insights

IBM Storage Insights is an IBM Cloud™ software as a service offering that can help you monitor and optimize the storage resources in the system and across your data center. IBM Storage Insights monitors your storage environment and provides status about multiple systems in a single dashboard. You can view data from the perspectives of the servers, applications, and file systems. Two versions of IBM Storage Insights are available: IBM Storage Insights and IBM Storage Insights Pro.

When you order the FlashSystem 5100 or FlashSystem 5000 system, IBM Storage Insights is available for free. With this version, you can monitor the basic health, status, and performance of various storage resources.

IBM Storage Insights Pro is a subscription-based product that provides a more comprehensive view of the performance, capacity, and health of your storage resources. In addition to the features offered by IBM Storage Insights, IBM Storage Insights Pro provides tools for intelligent capacity planning, storage reclamation, storage tiering, and performance troubleshooting services. Together, these features can help you reduce storage costs and optimize your data center.

IBM Storage Insights is a part of the monitoring and helps to ensure continued availability of the IBM FlashSystem 5100 and FlashSystem 5000 systems.

Cloud-based IBM Storage Insights provides a single dashboard that gives you a clear view of all of 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. 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.

The following features are some of those available with IBM Storage Insights:

- 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 following information:
  - 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 auto log collection capability to collect the logs and send them to IBM before IBM Support looks in to the problem. This capability can save as much as 50% of the time to resolve the case.

Figure 3-3 shows a view of the IBM Storage Insights dashboard.

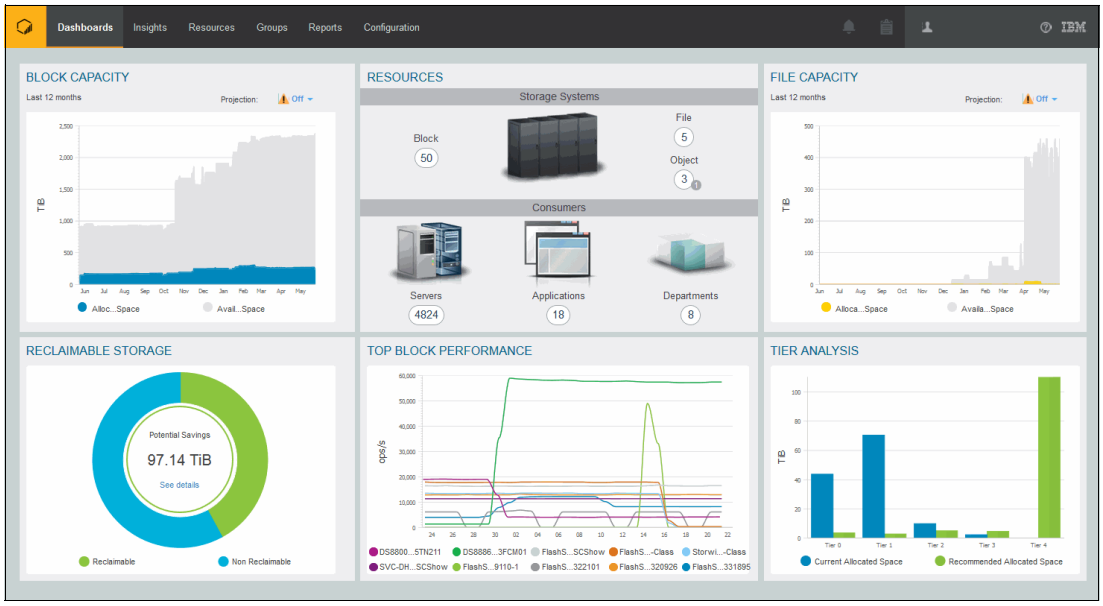

Figure 3-3 Storage Insights dashboard

In order for IBM Storage Insights to operate, a lightweight data collector is installed in your data center to stream performance, capacity, asset, and configuration metadata to your IBM Cloud instance. The metadata flows in one direction: from your data center to IBM Cloud over HTTPS. Only metadata is collected. The actual application data that is stored on the storage systems can't be accessed by the data collector. In the IBM Cloud, your metadata is AES256-encrypted and protected by physical, organizational, access, and security controls.

IBM Storage Insights is ISO/IEC 27001 Information Security Management certified.

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

- Storage Insights Fact Sheet
- Functional demonstration environment
- Storage Insights security information
- Storage Insights registration

Related publications

The publications listed in this section are considered particularly suitable for a more detailed discussion of the topics covered in this book.

IBM Redbooks

You can search for, view, download, or order documents and other Redbooks publications, Redpaper publications, web docs, drafts, and other materials, at the following website:

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IBM FlashSystem 5000 publications and support

IBM FlashSystem 5000 publications and support are available at the IBM Knowledge Center:

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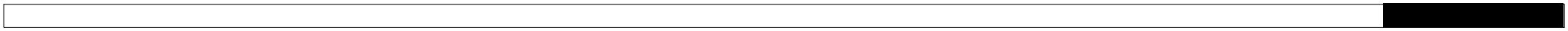

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