SPECIFICATION

TCG Storage Interface Interactions Specification (SIIS)

V1.11
R1.18
April 30, 2023

Contact:
admin@trustedcomputinggroup.com

PUBLISHED

DISCLAIMERS, NOTICES, AND LICENSE TERMS

THIS SPECIFICATION IS PROVIDED “AS IS” WITH NO WARRANTIES WHATSOEVER, INCLUDING ANY WARRANTY OF MERCHANTABILITY, NONINFRINGEMENT, FITNESS FOR ANY PARTICULAR PURPOSE, OR ANY WARRANTY OTHERWISE ARISING OUT OF ANY PROPOSAL, SPECIFICATION OR SAMPLE.

Without limitation, TCG disclaims all liability, including liability for infringement of any proprietary rights, relating to use of information in this specification and to the implementation of this specification, and TCG disclaims all liability for cost of procurement of substitute goods or services, lost profits, loss of use, loss of data or any incidental, consequential, direct, indirect, or special damages, whether under contract, tort, warranty or otherwise, arising in any way out of use or reliance upon this specification or any information herein.

Contact the Trusted Computing Group at www.trustedcomputinggroup.org for information on specification licensing through membership agreements.

Any marks and brands contained herein are the property of their respective owners.

CHANGE HISTORY

REVISION	DATE	DESCRIPTION
V1.11/R1.01	Oct. 15, 2021	• Incorporated SIIS_section5_6_3_Update_Kioxia.docx in section 5.6.3 interactions with the Format NVM command • Added comment to mapping of NVM Subsystem Reset, pending a proposal from Western Digital • section 2.5: changed '(e.g., GenKey or Revert)' to '(see section 2.3)' • Added comments in SCSI and NVMe as placeholders for content about interaction with reservations (NetApp) • Incorporated "xxx" as a new clause 7 NVDIMM_N Interface • Added a comment to add (Assign,Deassign,Set methods) as data removal methods in section 2.3, pending further details • Added comments regarding a proposal to allow Sanitize while the Locking SP is owned • Added a comment to remap NVMe-MI resets since recent NVMe proposals clarified that there are multiple reset types. • In TPer Error mapping tables for SCSI and NVMe: added text to column headers to clarify which errors are TCG and which are for the interface
V1.11/R1.02	Jan. 13, 2022	• Updated copyright date from 2021 to 2022 • Changed TOC to 5 levels deep (from 3) • Added new defined terms to 1.5 • Removed extra blank lines where not needed • Updated document precedence (1.4.1) • Updated some of the approved references • Marked SK hynix comments about firmware update commands as 'withdrawn' • Added SCSI cmds to 7.1: REMOVE ELEMENT AND MODIFY ZONES, FORMAT WITH PRESETS • Added ATA cmds to 7.2: REMOVE ELEMENT AND MODIFY ZONES, MUTATE •
V1.11/R1.03	Feb. 9, 2022	• Added: new bit to SIIS Level 0 Discovery • Added: NVMe: interactions with reservations • Added: SD-Card interface (clause 8) • Updated: NVMe-MI resets • Replaced section 2.3 User Data Removal Method
V1.11/R1.04	Feb. 10, 2022	• Integrate the NVDIMM-N text from the correct source • Fixed cross references for NVDIMM-N
V1.11/R1.05	Mar. 15, 2022	• Section 2.5: Updated the Level 0 descriptor description of the IDENTIFIER USAGE SCOPE field to apply to both NVMe and SCSI, and to add two examples. The wording in the examples was slightly modified for word choice (see strikeouts). • Added table footnotes to tables 40 and 41 • Simplified table 44 by removing redundant text in the SECURE_CMD_STATUS column
V1.11/R1.06	May 19, 2022	• Change scope of TPer for SCSI and multiple LUs • User data removal – another modification) • Interaction with (SCSI/ATA) REMOVE ELEMENT AND MODIFY ZONES • Editorial correction in section 5.6.6.2 • Fixed misc. editorial issues in section 1.4 • Updated and sorted all cross references • Addressed all previous comments
V1.11/R1.07	May 19, 2022	• Fixed some cross references, and synchronized with our new template
V1.11/R1.08	June 23, 2022	• Removed all resolved comments • Accepted all changes and stopped change tracking
V1.11/R1.09	June 30, 2022	• In section 5.6.6.3.7, changed one instance of KeepGlobalRangeKey to KeepNamespaceGlobalRangeKey
V1.11/R1.10	June 30, 2022	• Updated Conventions, references
V1.11/R1.11	August 15, 2022	• Addressed editorial changes requested by the TC
V1.11/R1.12	August 26, 2022	• Table 25: Renamed the 2 new error ids for NVMe: Incorrect Decryption Key (and) Invalid Key
V1.11/R1.13	August 31, 2022	• Added Security Protocol 3 to Tables 23 and 24
V1.11/R1.13a	August 31, 2022	• Added that NSID field is used by Key Per IO SSC for Security Protocol 02 in Table 23. • Added that NSID field is used by Key Per IO SSC for Security Protocols 01 and 02 in Table 24. • Added references to NVMe TP4055 and TCG Key Per IO SSC drafts.
V1.11/R1.14	September 30, 2022	• Resolved TC comments spanning multiple sections
V1.11/R1.15	October 4, 2022	• Accepted all changes from R1.14. Deleted all comments.

V1.11/R1.16	November 18, 2022	• Resolved TC comments
V1.11/R1.17	March 14, 2023	• Fixed a cross reference.
V1.11/R1.18	April 30, 2023	• Prepared for final publication • Changes to document footer, title page • Updated revision history

CONTENTS

List of Tables

1 Introduction

1.1 Document Purpose

TCG Storage specifications provide a comprehensive command architecture for putting Storage Devices under policy control as determined by the trusted platform host, the capabilities of the storage device to conform with the policies of the trusted platform, and the lifecycle state of the Storage Device (SD, see section 1.6) as a trusted peripheral (TPer). This document also serves as a specification for the TPer (see section 1.6) if that is deemed appropriate.

This document provides the essential mapping between concepts and features of the TCG Storage Architecture Core Specification, and several host/device interfaces.

1.2 Scope

The scope of this document is the interaction between the TPer and interface commands and transports. This document is written from the perspective of the Storage Device, not the host. There are no host requirements (i.e., host SHALL), but there are some host recommendations (e.g., should and may).

1.3 Intended Audience

The intended audience for this document is Storage Device and peripheral device manufacturers and developers that wish to tie Storage Devices and peripherals into trusted platforms.

1.4 Conventions

1.4.1 Key Words

The key words “MUST,” “MUST NOT,” “REQUIRED,” “SHALL,” “SHALL NOT,” “SHOULD,” “SHOULD NOT,” “RECOMMENDED,” “MAY,” and “OPTIONAL” in this document normative statements are to be interpreted as described in RFC-2119 (see [1]), Key words for use in RFCs to Indicate Requirement Levels.

In addition to the above key words, the following are also used in this document to describe the requirements of particular features, including tables, methods, and usages thereof.

a) Mandatory (M): When a feature is Mandatory, the feature SHALL be implemented. A Compliance test SHALL validate that the feature is operational.
b) Optional (O): When a feature is Optional, the feature MAY be implemented. If implemented, a Compliance test SHALL validate that the feature is operational.
c) Excluded (X): When a feature is Excluded, the feature SHALL NOT be implemented. A Compliance test SHALL validate that the feature is not operational.
d) Not Required (N) When a feature is Not Required, the feature MAY be implemented. No Compliance test is required.

1.4.2 Font Conventions

Names of methods and SP tables are in Courier New font (e.g., the `Set` method, the `Locking` table). This requirement does not apply to method and table names appearing in headings or captions.

Hexadecimal numbers are in `Courier New font`.

1.4.3 Statement Type

Please note a very important distinction between different sections of text throughout this document. There are two distinctive kinds of text: informative comment and normative statements. Because most of the text in this specification will be of the kind normative statements, the authors have informally defined it as the default and, as such, have specifically called out text of the kind informative comment. They have done this by flagging the beginning and end of each informative comment and highlighting its text in gray. This means that unless text is specifically marked as of the kind informative comment, it can be considered a kind of normative statements.

> **EXAMPLE: Start of informative comment**
> This is the first paragraph of 1–n paragraphs containing text of the kind *informative comment* ...
> This is the second paragraph of text of the kind *informative comment* ...
> This is the nth paragraph of text of the kind *informative comment* ...
> To understand the TCG specification the user must read the specification. (This use of MUST does not require any action).
> **End of informative comment**

1.4.4 List Conventions

1.4.4.1 Lists overview

Lists are associated with an introductory paragraph or phrase, and are numbered relative to that paragraph or phrase (i.e., all lists begin with an a) or 1) entry).

Each item in a list is preceded by an identification with the style of the identification being determined by whether the list is intended to be an ordered list or an unordered list.

If the item in a list is not a complete sentence, the first word in the item is not capitalized. If the item in a list is a complete sentence, the first word in the item is capitalized.

Each item in a list ends with a semicolon, except the last item, which ends in a period. The next to the last entry in the list ends with a semicolon followed by an “and” or an “or” (i.e., “…; and”, or “…; or”). The “and” is used if all the items in the list are required. The “or” is used if only one or more items in the list are required.

1.4.4.2 Unordered lists

An unordered list is one in which the order of the listed items is unimportant (i.e., it does not matter where in the list an item occurs as all items have equal importance). Each list item shall start with a lowercase letter followed by a close parenthesis. If it is necessary to subdivide a list item further with an additional unordered list (i.e., have a nested unordered list), then the nested unordered list shall be indented and each item in the nested unordered list shall start with an uppercase letter followed by a close parenthesis.

The following is an example of an unordered list with a nested unordered list:

EXAMPLE - The following are the items for the assembly:
a) a box containing:
    A) a bolt;
    B) a nut; and
    C) a washer;
b) a screwdriver; and
c) a wrench.

1.4.4.3 Ordered lists

An ordered list is one in which the order of the listed items is important (i.e., item n is required before item n+1). Each listed item starts with a Western-Arabic numeral followed by a close parenthesis. If it is necessary to subdivide a list item further with an additional unordered list (i.e., have a nested unordered list), then the nested unordered list shall be indented and each item in the nested unordered list shall start with an uppercase letter followed by a close parenthesis.

The following is an example of an ordered list with a nested unordered list:

EXAMPLE - The following are the instructions for the assembly:
1) remove the contents from the box;
2) assemble the item;
   A) use a screwdriver to tighten the screws; and
   B) use a wrench to tighten the bolts;
   and
3) take a break.

1.4.5 Numbering

A binary number is represented in this standard by any sequence of digits consisting of only the Western-Arabic numerals 0 and 1 immediately followed by a lower-case b (e.g., 0101b). Underscores or spaces may be included between characters in binary number representations to increase readability or delineate field boundaries (e.g., 0 0101 1010b or 0_0101_1010b).

A hexadecimal number is represented in this standard by any sequence of digits consisting of only the Western-Arabic numerals 0 through 9 and/or the upper-case English letters A through F immediately preceded by “0x”. Underscores or spaces may be included between characters in hexadecimal number representations to increase readability or delineate field boundaries (e.g., 0xFD8C FA23 or 0x0B_FD8C_FA23). Hexadecimal numbers are in Courier New font.

A decimal number is represented in this standard by any sequence of digits consisting of only the Western-Arabic numerals 0 through 9 not immediately followed by a lower-case b or lower-case h (e.g., 25). This standard uses the following conventions for representing decimal numbers:

a) the decimal separator (i.e., separating the integer and fractional portions of the number) is a period;
b) the thousands separator (i.e., separating groups of three digits in a portion of the number) is a space; and
c) the thousands separator is used in both the integer portion and the fraction portion of a number.

A decimal number represented in this standard with an overline over one or more digits following the decimal point is a number where the overlined digits are infinitely repeating (e.g., $666.\overline{6}$ **Error! Bookmark not defined.**means 666.666 666… or 666 2/3, and $12.\overline{142857}$ means 12.142 857 142 857… or 12 1/7).

1.4.6 Bit conventions

Name (n:m), where n is greater than m, denotes a set of bits (e.g., Feature (7:0)).

1.4.7 Number range convention

p..q, where p is less than q, represents a range of numbers (e.g., words 100..103 represents words 100, 101, 102, and 103).

1.5 References to Other Documents

1.5.1 Document Precedence

If there is a conflict between this specification and any other reference, then the precedence is (where a lower number indicates higher precedence):

1. this specification;
2. references under development (see section 1.5.3); and
3. approved references (see section 1.5.2).

Each reference under development and each approved reference may specify its own document precedence.

1.5.2 Approved References

[1] IETF RFC 2119, 1997, “Key words for use in RFCs to Indicate Requirement Levels”

[2] INCITS 417-2006, "Information technology - Serial Attached SCSI - 1.1 (SAS-1.1). Available from https://webstore.ansi.org/

[3] INCITS 447-2008, "Information technology - SCSI Architecture Model - 4 (SAM-4)". Available from https://webstore.ansi.org/

[4] INCITS 471-2010, Information technology - USB Attached SCSI (UAS). Available from https://webstore.ansi.org/

[5] INCITS 481-2011, "Information technology - Fibre Channel Protocol for SCSI, Fourth Version (FCP-4)". Available from https://webstore.ansi.org/

[6] INCITS 482-2012, "Information technology - ATA/ATAPI Command Set - 2 (ACS-2)". Available from https://webstore.ansi.org/

[7] INCITS 513-2015, "Information technology - SCSI Primary Commands - 4 (SPC-4)". Available from https://webstore.ansi.org/

[8] INCITS 514-2014, "Information technology - SCSI Block Commands - 3 (SBC-3)". Available from https://webstore.ansi.org/

[9] INCITS 536, "Information technology - Zoned Block Commands (ZBC-2)", Available from https://webstore.ansi.org/

[10] INCITS 549, "Information technology - Zoned Device ATA Command Set (ZAC-2)", Available from https://webstore.ansi.org/

[11] INCITS 558-2021, "Information technology - ATA/ATAPI Command Set - 5 (ACS-5)". Available from https://webstore.ansi.org/

[12] JESD220B UFS Specification version 2.0. Available from https://www.jedec.org/

[13] JESD245D Byte Addressable Energy Backed Interface. Available from https://www.jedec.org/.

[14] JESD245E Byte Addressable Energy Backed Interface. Available from https://www.jedec.org/.

[15] JESD248A DDR4 NVDIMM-N Design Specification. Available from https://www.jedec.org/.

[16] JESD84-B50 *e*•MMC Specification version 5.0. Available from https://www.jedec.org/

[17] NVM Express Management Interface Specification version 1.2b. Available from https://www.nvmexpress.org/

[18] NVM Express NVM Command Set Specification version 1.0b. Available from https://www.nvmexpress.org/

[19] NVM Express Base Specification version 2.0b. Available from https://www.nvmexpress.org/

[20] NVM Express Zoned Namespace Command Specification version 1.0b. Available from https://www.nvmexpress.org/

[21] PCI Express® Base Specification Revision 5.0. Available from https://www.pcisig.com/

[22] TCG Opal SSC Feature Set: Configurable Namespace Locking version 1.00 revision 1.00

[23] TCG Opal SSC Feature Set: Configurable NVMe Namespace and SCSI LUN Locking version 1.00 revision 1.02

[24] TCG Opal SSC Feature Set: Opal Feature Set: Single User Mode, Version 1.00

[25] TCG Storage Opal Family Feature Set: Shadow MBR for Multiple Namespaces, Version 1.00, revision 1.21

[26] Trusted Computing Group (TCG), "TCG Storage Architecture Core Specification", Version 2.01

[27] Universal Serial Bus Mass Storage Class Bulk-Only Transport (USBBOT), Revision 1.0. Available from https://www.usb.org/

[28] Universal Serial Bus Mass Storage Class USB Attached SCSI Protocol (UASP), Revision 1.0. Available from https://www.usb.org/

1.5.3 References under development

[29] *e*•MMC Security Extension version 1.0 Available from https://www.jedec.org/

[30] Extended Security Addendum version 1.0 Draft X.XX

[31] NVM Express TP4055

[32] SD Specification Part 1 Ver 9 Draft X.XX.

[33] T10/BSR INCITS 502, "Information technology - SCSI Primary Commands - 5 (SPC-5)". Available from https://t10.org/

[34] T10/BSR INCITS 506, "Information technology - SCSI Block Commands - 4 (SBC-4)". Available from https://t10.org/

[35] T13/BSR INCITS 549574, "Information technology - Zoned Device ATA Command Set -62 (ACS-6)", Available from https://www.t13.org/

[36] T13/BSR INCITS 575, "Information technology - Zoned Device ATA Command Set -3 (ZAC-3)", Available from https://www.t13.org/

[37] UFS Security Extension version 1.0 Available from https://www.jedec.org/

[38] Trusted Computing Group "TCG Storage SSC: Key Per I/O"

1.6 Definition of Terms

Term	Definition
ACMD53	ACMD53 SECURE_RECEIVE command
ACMD54	ACMD54 SECURE_SEND command
ATA	AT Attachment (see https://t13.org)
ATAPI	AT Attachment Packet Interface (see https://t13.org)
CMD23	CMD23 command (SET_BLOCK_COUNT)
e•MMC	Embedded MMC (see https://jedec.org)
Eradicate	irrevocably erase (e.g., cryptographically erase)
IF-RECV	An interface command used to retrieve security protocol data from the TPer
IF-SEND	An interface command used to transmit security protocol data to the TPer

Term	Definition
Locking SP	A security provider that incorporates the Locking Template as described in the Core Spec
Locking SP is owned	A condition in which specific modifications (see section 2.2) of an SP have been made
LUN	Logical Unit Number
MBR	Master Boot Record
Namespace	A formatted quantity of user data that may be directly accessed by a host.
NSID	Namespace Identifier
NVDIMM-N	Non-volatile DIMM type N (see https://jedec.org)
NVMe	NVM Express (see https://nvmexpress.org)
Opal family	Any of: Opal SSC, Opalite SSC, Ruby SSC, or Pyrite SSC
SAS	Serial Attached SCSI (see https://t10.org)
SATA	Serial ATA (see https://serialata.org)
SCSI	Small Computer System Interface (see https://t10.org)
SD	Storage Device
SD-interface	SecureDigital (SD) interface of a SecureDigital memory card
SSC	Security Subsystem Class. SSC specifications describe profiled sets of TCG functionality
TCG Reset	A high-level reset type defined in the Core Spec
TPer	The TCG security subsystem within a Storage Device
Trusted Peripheral	A TPer
UAS	UAS Attached SCSI (see https://t10.org)
UFS	Universal Flash Storage (see https://jedec.org)
USB	Universal Serial Bus (see https://www.usb.org)

2 Overview

2.1 Summary

This document defines for each interface:

- Mapping of interface events to TCG resets
- Mapping of IF-SEND, IF-RECV
- Handling of common TPer errors
- Discovery of security capabilities
- Miscellaneous Items

2.2 Locking SP Ownership

For the Opal family, the Locking SP is owned if:

a) an SP exists that incorporates the Locking Template; and
b) an SP that incorporates the Locking Template is not in the Manufactured-Inactive state.

For the Enterprise SSC, the Locking SP is owned if:

a) the EraseMaster C_PIN credential is not equal to MSID;
b) any BandMaster C_PIN credential is not equal to MSID; or
c) for any Locking object:
    A) the value of the WriteLockEnabled column is TRUE;
    B) the value of the ReadLockEnabled column is TRUE;
    C) the value of the RangeStart column is not equal to zero; or
    D) the value of the RangeLength column is not equal to zero.

2.3 User data removal method

A user data removal method is a method that may change the contents of user data read by the host.

For the Opal family, the following methods are user data removal methods:

a) Revert method, applied to the Admin SP or to the Locking SP;

b) RevertSP method, applied to the Locking SP;

c) Genkey method, applied to a K_AES_[128|256] table object; and

d) Erase method, applied to a locking object;

e) Deassign method, applied to locking object when KeepNamespaceGlobalRangeKey is set to FALSE or NOT specified, and

f) Assign method, applied to

    a. a Namespace Global Locking object when the Global Range Locking object is activated in Single User Mode, or

    b. a Namespace Global Range Locking object that is activated in Single User Mode, or

    c. a Namespace Non-Global Range Locking object when the Namespace Global Range Locking object associated with the namespace is activated in Single User Mode, or

    d. a Namespace Non-Global Range Locking object that is activated in Single User Mode.

Start of Informative Comment

The Set method is not considered a user data removal method. The Set method may cause implicit data loss. For example, when a locking object’s RangeStart or RangeLength column values are modified, encryption keys and locking control transition from one LBA range to another, for a subset of the logical blocks on media. If that locking object’s RangeStart and RangLength column values are then re-set to their previous configuration, original user data may still exist and be readable, but the behavior is vendor unique.

End of Informative Comment

2.4 Additional Methods Status Code

The Core Specification defines the status codes that are returned by the TPer in response to method invocations and other operations (see [17]). This specification adds a status code as described in Table 1:

Table 1 - Additional TPer Status Code

Code	Value
INCOMPATIBLE_MBR_FORMAT	0x13
WP_DATA_REMAIN	0x14

2.5 Level 0 Discovery - SIIS Feature Descriptor (M)

An SD that supports this standard SHALL return the SIIS feature descriptor described in this subclause. It is Not Required (NR) for versions of this standard prior to Version 1.10.

Table 2 - Level 0 Discovery – SIIS Feature Descriptor

Bit Byte	7	6	5	4	3	2	1	0
0	(MSB)	Feature Code						
1								(LSB)
2	Data Structure Version				Reserved			
3	Length							
4	SIIS Revision Number							
5	Reserved					Identifier Usage Scope		Key Change Zone Behavior
6..15	Reserved							

A compliant SD that returns this descriptor SHALL return the following:

- Feature Code = 0x0005
- Data Structure Version = 0x1
- Length = 0x0C
- SIIS Revision Number = As specified in Table 3
- Key Change Zone Behavior = VU
- Identifier Usage Scope = VU

Table 3 - SIIS Versions

SIIS Major Version	Standard Referenced
x00	TCG Storage Interface Interactions Specification v1.00 r1.00
x01	TCG Storage Interface Interactions Specification v1.01 r1.00
x02	TCG Storage Interface Interactions Specification v1.02 r1.00
x03	TCG Storage Interface Interactions Specification v1.03 r1.00
x04	TCG Storage Interface Interactions Specification v1.04 r1.00
x05	TCG Storage Interface Interactions Specification v1.05 r1.00
x06	TCG Storage Interface Interactions Specification v1.06 r1.00
x07	TCG Storage Interface Interactions Specification v1.07 r1.00
x08	TCG Storage Interface Interactions Specification v1.08 r1.00
x09	TCG Storage Interface Interactions Specification v1.09 r1.00
x0A	TCG Storage Interface Interactions Specification v1.10 r1.00
X0B	TCG Storage Interface Interactions Specification v1.11 r1.00
All others	Reserved

The Key Change Zone Behavior bit specifies whether or not cryptographic erase or key change methods (see section 2.3) affect the write pointer of a zoned device. For details, see section 3.6.7, section 4.6.3, and section 5.6.8.

The IDENTIFIER USAGE SCOPE field (see Table 4) indicates the scope of impact of the transport identifier value. For NVMe, the transport identifier is the NSID value. For SCSI, the transport identifier is the LUN value. This field SHALL be set to 00b for interfaces other than NVMe or SCSI.

Table 4 - IDENTIFIER USAGE SCOPE

IDENTIFIER USAGE SCOPE	Description
00b	The transport identifier field scope of impact on the TPer is not indicated.
01b	The transport identifier field (e.g., NSID or LUN) is not used to determine Persistent Reservation impact on the TPer. A Persistent Reservation on one namespace / LUN does not impact the operation of the TPer (e.g., a reservation on one namespace / LUN does not prevent TPer operation that impacts other namespaces / LUNs).
10b	The NVMe NSID field (e.g., NSID or LUN) is used to determine Persistent Reservation impact on the TPer. A persistent reservation on one namespace / LUN impacts the operation of the TPer (e.g., a reservation on one namespace / LUN may prevent TPer operation that impacts other namespaces / LUNs). For NVMe, the NSID field is required to be set to zero for operations that impact multiple namespaces, unless otherwise specified.
11b	Reserved

In the examples shown in Figure 1 and Figure 2, Host A establishes a write exclusive persistent reservation on namespace 1, namespace 2, and namespace 9. Host B establishes a write exclusive persistent reservation on namespace 5 and namespace 6. In these examples, an IF-SEND command is sent from Host A using NSID set to 2h.

If the Identifier Usage Scope field is set to 01b (see Figure 1), then the IF-SEND command is processed, regardless of the impact on any namespace in the NVM subsystem (e.g., an IF-SEND command from Host A that invokes the revert method is not blocked by the Host B write exclusive persistent reservations on namespace 5, and namespace 6).

Figure 1 - Example: NSID Usage Scope (01b)

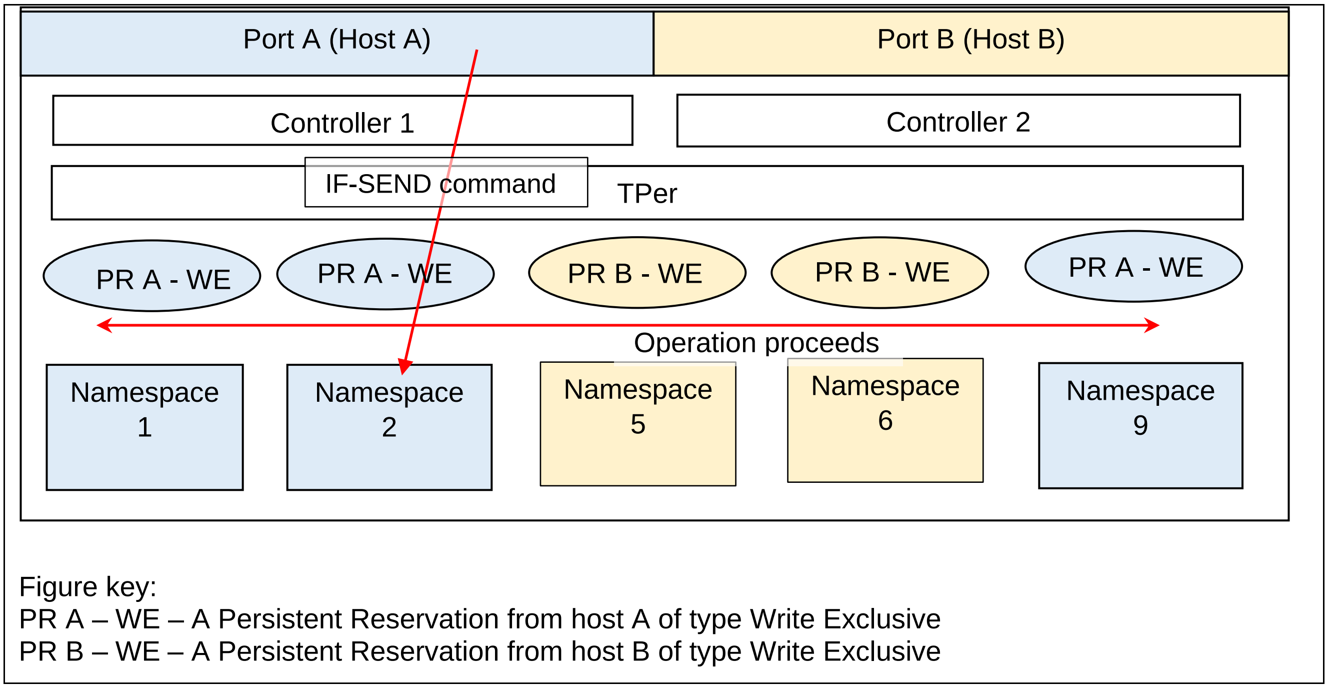


Figure key:
PR A – WE – A Persistent Reservation from host A of type Write Exclusive
PR B – WE – A Persistent Reservation from host B of type Write Exclusive

If the Identifier Usage Scope field is set to 10b (see Figure 2), then the IF-SEND command is processed only if the impact on a namespace is permitted by the persistent reservation state of all namespaces that may be impacted (e.g., an IF-SEND command from Host A that invokes the revert method is blocked by the Host B write exclusive persistent reservations on namespace 5 and namespace 6). To perform an action on all namespace irrespective of the persistent reservation state of namespaces, the IF_SEND command is required to be sent using the NSID set to 0h.

Figure 2 - Example: NSID Usage Scope (10b)

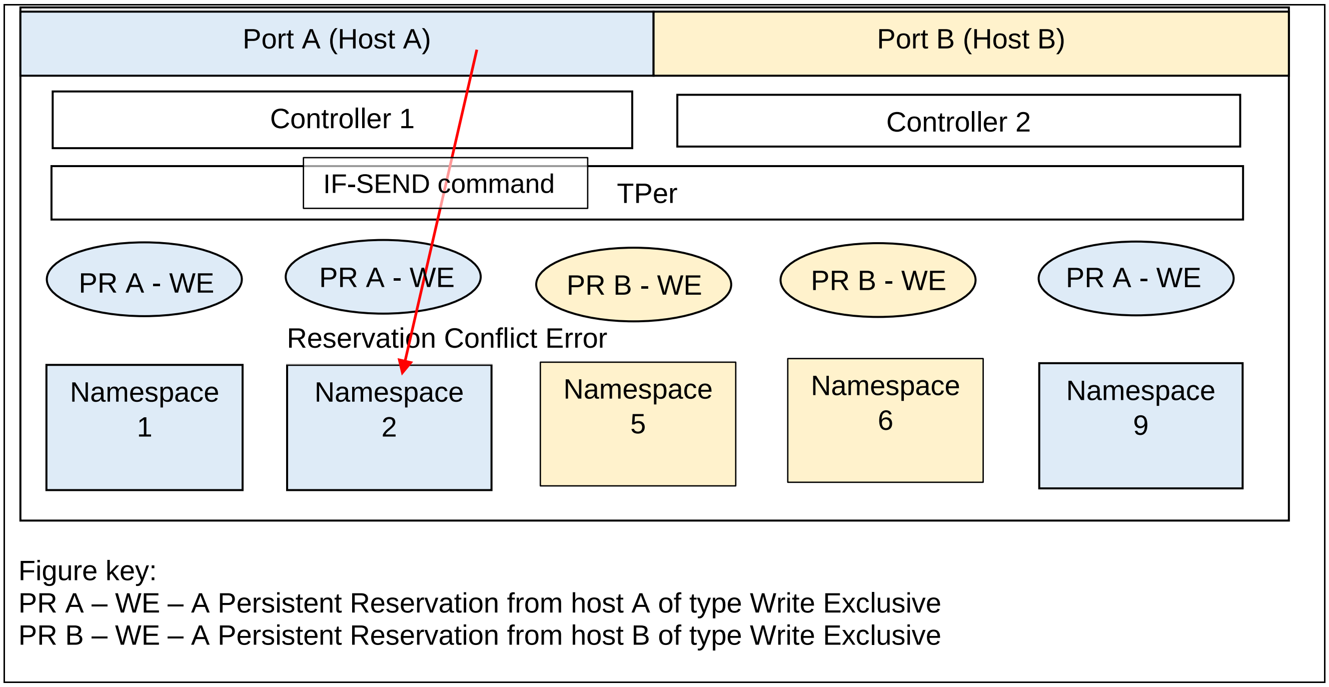


Figure key:
PR A – WE – A Persistent Reservation from host A of type Write Exclusive
PR B – WE – A Persistent Reservation from host B of type Write Exclusive

3 SCSI Interface

See [3], [29], [8], [9], [2], [29], [34], and [33] for details on SCSI architecture, commands and transports.

See [6] for details on ATAPI commands.

See [4], [27] and [28] for details on UAS and USB.

See [12] and [36] for details on UFS.

3.1 TPer scope

In the context of the SCSI interface, the scope of the TPer is a Logical Unit that provides access to user data on the target device. See section 3.6.3 for additional details.

3.2 Mapping of Resets

Mapping of interface transport reset events to TCG reset_type is specified in Table 5, Table 6, Table 7, Table 8, Table 9, Table 10, and Table 11.

Table 5 – SAS Resets Mapped to TCG reset_type (single port)

SAS Event	Maps to TCG reset_type
Power on reset	Power cycle
I_T Nexus Loss	(none)
ABORT TASK task management function	(none)
ABORT TASK SET task management function	(none)
CLEAR TASK SET task management function	(none)
CLEAR ACA task management function	(none)
I_T NEXUS RESET task management function	(none)
LOGICAL UNIT RESET task management function	Hardware Reset
Link Reset Sequence	(none)
Link reset sequence with hard reset	Hardware Reset

Table 6 – SAS Resets Mapped to TCG reset_type (dual port)

SAS Event	Maps to TCG reset_type
Power on reset	Power cycle
I_T Nexus Loss	(none)
ABORT TASK task management function	(none)
ABORT TASK SET task management function	(none)
CLEAR TASK SET task management function	(none)
CLEAR ACA task management function	(none)
I_T NEXUS RESET task management function	(none)
LOGICAL UNIT RESET task management function	Hardware Reset
Link Reset Sequence	(none)
Link reset sequence with hard reset	Hardware Reset

Table 7 – Fibre Channel Resets Mapped to TCG reset_type

FC Event	Maps to TCG reset_type	Other Comments
Power on reset	Power cycle	
I_T Nexus Loss	(none)	
ABORT TASK task management function	(none)	
ABORT TASK SET task management function	(none)	
CLEAR TASK SET task management function	(none)	
CLEAR ACA task management function	(none)	
I_T NEXUS RESET task management function	(none)	
LOGICAL UNIT RESET task management function	Hardware Reset	
LIP(AL_PD,AL_PS)	Hardware Reset	LIP directed reset
LIP(FF,AL_PS)	Hardware Reset	LIP Global reset
Port Login	(none)	
Process Login	(none)	

Table 8 – ATAPI Resets Mapped to TCG reset_type

ATAPI Event	Maps to TCG reset_type
Power on reset	Power cycle
Hardware reset	PATA: Hardware Reset SATA: If Software Settings Preservation is enabled, then COMRESET is not a TCG Hardware Reset. If Software Settings Preservation is disabled, then COMRESET is a TCG Hardware Reset.
Software reset	(none)
DEVICE RESET command	(none)

Table 9 – UAS Events Mapped to TCG reset_type

Event	Maps to TCG reset_type	Reference
Device Power Cycle	Power cycle	[27]
ABORT TASK task management function	(none)	[29]
ABORT TASK SET task management function	(none)	[29]
CLEAR TASK SET task management function	(none)	[29]
CLEAR ACA task management function	(none)	[29]
I_T NEXUS RESET task management function	(none)	[29]
LOGICAL UNIT RESET task management function	Hardware Reset	[29]
USB VBus Power Cycle	Power cycle	[27]
USB Port Reset	(none)	[27]
USB Set Configuration with wValue cleared to zero	(none)	[27]
USB Set Configuration with wValue set to non-zero value that is not equal to the current value of bConfiguration	(none)	[27]
USB Set Configuration with wValue set to non-zero value that is equal to the current value of bConfiguration	(none)	[27]
USB Bulk-Out Endpoint Reset (Also known as Clear Feature, Endpoint Halt of the first Bulk-Out pipe of the Mass Storage Interface)	(none)	[27]
USB Bulk-In Endpoint Reset (Also known as Clear Feature, Endpoint Halt of the first Bulk-In pipe of the Mass Storage Interface)	(none)	[27]
USB Suspend	Hardware Reset	[27]
USB Resume	Hardware Reset	[27]

Table 10 – USB Events Mapped to TCG reset_type

Event	Maps to TCG reset_type	Reference
Device Power Cycle	Power cycle	[27]
USB VBus Power Cycle	Power cycle	[27]
USB Port Reset	(none)	[27]
USB Set Configuration with wValue cleared to zero	(none)	[27]
USB Set Configuration with wValue set to non-zero value that is not equal to the current value of bConfiguration.	(none)	[27]
USB Set Configuration with wValue set to non-zero value that is equal to the current value of bConfiguration.	(none)	[27]
USB Bulk-Out Endpoint Reset (Also known as Clear Feature, Endpoint Halt of the first Bulk-Out pipe of the Mass Storage Interface)	(none)	[27]
USB Bulk-In Endpoint Reset (Also known as Clear Feature, Endpoint Halt of the first Bulk-In pipe of the Mass Storage Interface)	(none)	[27]
USB Interface Reset (Also known as the BBB Bulk Only Mass Storage Reset Request x 21 FF with wIndex addressing the bInterfaceNumber of the Mass Storage Interface)	(none)	[27]
USB Suspend	Hardware Reset	[27]
USB Resume	Hardware Reset	[27]

Table 11 – UFS Events Mapped to TCG reset_type

Event	Maps to TCG reset_type	Referenc e
Power-on	Power cycle	[12]
HW Pin Reset	Hardware Reset	[12]
EndPoint Reset	Hardware Reset	[12]
ABORT TASK task management function	(none)	[29]
ABORT TASK SET task management function	(none)	[29]
CLEAR TASK SET task management function	(none)	[29]
LOGICAL UNIT RESET task management function	(none)	[29]
Host System UniPro Reset	Hardware Reset	[12]

3.3 Mapping of IF-SEND and IF-RECV

3.3.1 IF-SEND

IF-SEND SHALL be implemented with the SECURITY PROTOCOL OUT [29] command, with additional requirements on the CDB as described in Table 12.

Table 12 – IF-SEND CDB field contents (SCSI)

SECURITY PROTOCOL	SECURITY PROTOCOL SPECIFIC	INC_512	TRANSFER LENGTH
0x00	Security Protocol 0x00 is not defined for IF-SEND		
0x01	a ComID	1 [a]	Non-zero [b] number of 512-byte data units.
0x02	a ComID	1 [a]	Non-zero [b] number of 512-byte data units.
0x06	a ComID	0	Number of bytes of data.

[a] If the INC_512 field in the CDB is zero, then the TPer SHALL report Other Invalid Command Parameter (see section 3.4).

[b] If the TRANSFER LENGTH field in the CDB is zero, then the TPer SHALL report Other Invalid Command Parameter (see section 3.4).

3.3.2 IF-RECV

IF-RECV SHALL be implemented with the SECURITY PROTOCOL IN [29] command, with additional requirements on the CDB as described in Table 13.

Table 13 – IF-RECV CDB field contents (SCSI)

SECURITY PROTOCOL	SECURITY PROTOCOL SPECIFIC	INC_512	ALLOCATION LENGTH
0x00	(See [29] for details)	0 or 1	INC_512=0: Number of bytes of data. INC_512=1: Number of 512-byte data units.
0x01	a ComID	1 [a]	Non-zero [b] number of 512-byte data units.
0x02	a ComID	1 [a]	Non-zero [b] number of 512-byte data units.
0x06	a ComID	0	Number of bytes of data.

[a] If the INC_512 field in the CDB is zero, then the TPer SHALL report Other Invalid Command Parameter (see section 3.4).

[b] If the ALLOCATION LENGTH field in the CDB is zero, then the TPer SHALL report Other Invalid Command Parameter (see section 3.4), even though SPC-4 allows the ALLOCATION LENGTH field to be zero.

3.4 Handling Common TPer Errors

There are some common errors detected by the TPer. Table 14 describes how they are reported via the SCSI interface.

Table 14 – TPer Errors (SCSI)

TPer Error ID	SCSI Status	SCSI Sense Key	SCSI ASC/ASCQ	Comments
Good	GOOD	NO SENSE	NO ADDITIONAL SENSE INFORMATION	Normal command completion.
Invalid Security Protocol ID parameter	CHECK CONDITION	ILLEGAL REQUEST	INVALID FIELD IN CDB	No data SHALL be transferred.
Invalid Transfer Length parameter on IF-SEND	CHECK CONDITION	ILLEGAL REQUEST	INVALID FIELD IN CDB	No data SHALL be transferred.
Other Invalid Command Parameter	CHECK CONDITION	ILLEGAL REQUEST	INVALID FIELD IN CDB	No data SHALL be transferred.
Synchronous Protocol Violation	CHECK CONDITION	ILLEGAL REQUEST	COMMAND SEQUENCE ERROR	No data SHALL be transferred.
Data Protection Error	CHECK CONDITION	DATA PROTECT	ACCESS DENIED– NO ACCESS RIGHTS	No user data SHALL be transferred.

3.5 Discovery of Security Capabilities

3.5.1 Security Protocol 0x00

See the description of SECURITY PROTOCOL IN [29] for information on Security Protocol `0x00`.

3.6 Miscellaneous

3.6.1 Queued Commands

The TPer requires that for a given ComID the order of the IF-SEND and IF-RECV command completion be the same as the order in which the host application sent the commands.

Some transport protocols MAY NOT guarantee ordering of delivery or ordering of IF-SEND and IF-RECV command completion. Therefore, the host application communicating with the TPer should ensure that a prior IF-SEND or IF-RECV has completed prior to issuing another, or use mechanisms in the interface protocol to ensure ordering (e.g. ORDERED Task Attribute for SCSI Transport protocols).

Start of Informative Comment

The following definition of synchronous behavior does not affect the queuing behavior (if any) of the device interface. On queuing devices, synchronicity is enforced at the time IF-SEND/RECV commands are dequeued for processing by the SD. For non-queuing devices, synchronicity is enforced at the time the IF-SEND/RECV command is initially received by the device. If queuing behavior is supported, the host should use Ordered Queuing for IF-SEND/RECV commands or indeterminate behavior may result.

It is assumed that the SD can only process one IF-SEND/RECV interface command at a time.

End of Informative Comment

3.6.2 MBR Interactions

The LUN associated with the MBR is the boot LUN.

3.6.3 Logical Unit usage

If the target device does not support the TCG Storage Opal SSC Feature Set: Configurable Locking for NVMe Namespaces and SCSI LUNs (see [23]) and the target device has multiple logical units, then:

a) The target device MAY have multiple TPers (see section 3.1 and Figure 3);
b) Each TPer on the target device SHALL be associated with exactly one logical unit; and
c) Each logical unit on the target device MAY be associated with a TPer

If the target device supports the TCG Storage Opal SSC Feature Set: Configurable Locking for NVMe Namespaces and SCSI LUNs (see 3.6.3), then:

a) The target device SHALL have a single TPer (see section 3.1 and Figure 4); and
b) The scope of the TPer SHALL include all Logical units on the target device.

Figure 3 - Multiple TPers per Target Device Example

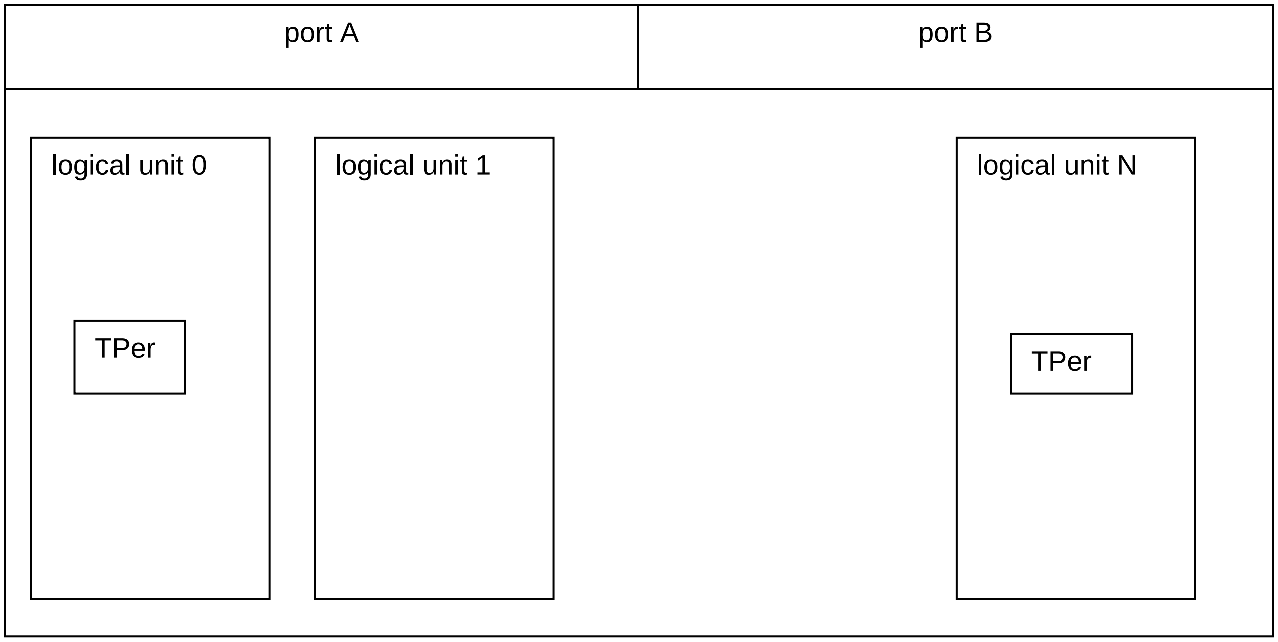
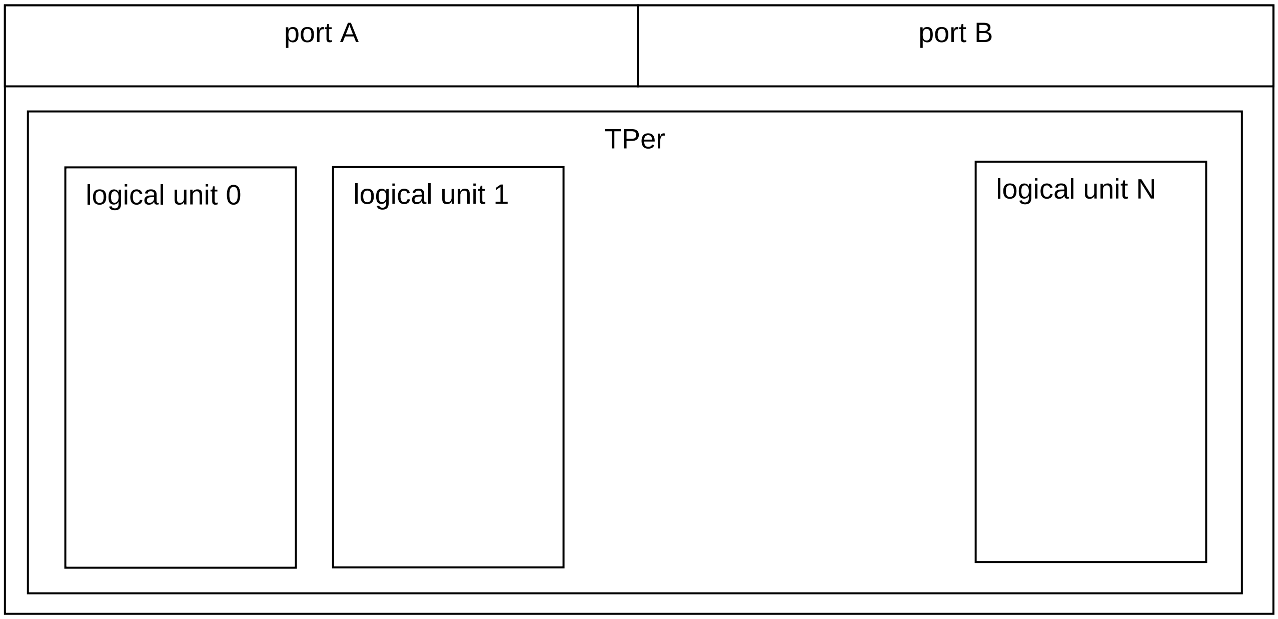


Figure 4 - Single TPer per Target Device Example



3.6.4 Interaction of the Opal family with the SANITIZE command

If the Locking SP is not owned (see section 2.2) in an Opal family TPer, then the SD MAY support SANITIZE commands.

If the Locking SP is owned (see section 2.2) in an Opal family TPer, then the SD:

a) SHALL NOT support SANITIZE commands; or
b) SHALL:
    A) report that SANITIZE commands are supported; and
    B) terminate SANITIZE commands with a Data Protection Error (see section 3.4).

3.6.5 Interaction of an Enterprise SSC with the SANITIZE command

If the Locking SP is not owned (see section 2.2) in an Enterprise SSC TPer, then the SD MAY support SANITIZE commands.

If the Locking SP is owned (see section 2.2) in an Enterprise SSC TPer, then the SD SHALL terminate a SANITIZE command with a Data Protection Error (see section 3.4).

A successful SANITIZE command SHALL eradicate all Locking SP media encryption keys and generate new media encryption keys.

3.6.6 Special Locking SP command interactions

For an SD implementing the Opal family or the Enterprise SSC, the SD SHALL terminate the:

a) READ LONG(10); and
b) READ LONG(16)

commands with CHECK CONDITION status and the sense key set to ILLEGAL REQUEST, and the additional sense code:

a) SHOULD be set to INVALID FIELD IN CDB; or
b) MAY be set to INVALID COMMAND OPERATION CODE.

For an SD implementing the Opal family or the Enterprise SSC, the SD SHALL terminate the:

a) WRITE LONG(10), (WR_UNCOR = 0); and
b) WRITE LONG(16), (WR_UNCOR = 0)

commands with CHECK CONDITION status and the sense key set to ILLEGAL REQUEST, and the additional sense code:

a) SHOULD be set to INVALID FIELD IN CDB; or
b) MAY be set to INVALID COMMAND OPERATION CODE.

3.6.7 Interactions with Zoned Block devices

If the device is not a zoned block device (see [9]), then this subclause does not apply. This subclause applies to zoned block devices only.

If the KEY CHANGE ZONE BEHAVIOR bit (see Table 2) is set to one, then cryptographic erase or key change methods (e.g., `GenKey` or `Revert`) SHALL:

a) reset the write pointer of all zones in the affected range; and
b) change the state of those Zones to Empty state (i.e. ZSE:Empty state).

If the KEY CHANGE ZONE BEHAVIOR bit is cleared to zero, then cryptographic erase or key change methods SHALL NOT:

a) change the write pointer of any zones in the affected range; and
b) change the state of those Zones.

The fields in the Geometry Reporting Feature Descriptor SHALL be set to the following values:

a) Align field = 1;
b) LogicalBlockSize = logical block size for the device;
c) AlignmentGranularity = zone size for the device; and
d) LowestAlignedLBA = 0.

3.6.8 Interactions with the FORMAT UNIT command

If the Locking SP is owned and a FORMAT UNIT command is sent to the device:

a) to change the number of logical blocks per physical block, then the SD SHALL terminate that FORMAT UNIT command with a Data Protection Error (see section 3.4); or
b) to change the size of a logical block without changing the number of logical blocks per physical block, then the SD SHALL NOT modify:
    A) the `Locking` table; or
    B) any `Datastore` tables.

3.6.9 Interactions with Verify commands

When BYTCHK is set to 1, the host provides input data and the SD verifies whether or not the data on the SD matches the input data. This allows the host to gather information about the data on the SD and should not be allowed unless the host can retrieve the data directly

3.6.10 Interactions with Extended Copy Operations

For the EXTENDED COPY command:

a) if the SD is the copy source, then the portion of the EXTENDED COPY command that operates on the SD is a read command (see [8]); and
b) if the SD is the copy destination, then the portion of the EXTENDED COPY command that operates on the SD is a write command (see [8])).

For the POPULATE TOKEN command, if the SD is the copy source, then the POPULATE TOKEN command is a read command.

For the WRITE USING TOKEN command, if the SD is the copy destination, then the WRITE USING TOKEN command is a write command.

3.6.11 Interactions with Unmap Operations

An UNMAP command shall return a Data Protection Error (see section 3.4) if:

a) the parameter list specifies an LBA range that is included in one or more Locking objects; and
b) the values of the WriteLockEnabled column and WriteLocked column are TRUE for at least one of the Locking objects that contains at least part of any LBA range specified.

3.6.12 Interaction of the Opal family with the REMOVE ELEMENT AND TRUNCATE command

If the Locking SP is not owned (see section 2.2) in an Opal family TPer, then the SD MAY support the REMOVE ELEMENT AND TRUNCATE command.

If the Locking SP is owned (see section 2.2) in an Opal family TPer, then the SD:

a) SHALL NOT support the REMOVE ELEMENT AND TRUNCATE command; or
b) SHALL:
    A) report that the REMOVE ELEMENT AND TRUNCATE command is supported; and
    B) terminate REMOVE ELEMENT AND TRUNCATE commands with a Data Protection Error (see section 3.4).

3.6.13 Interaction of an Enterprise SSC with the REMOVE ELEMENT AND TRUNCATE command

If the Locking SP is not owned (see section 2.2) in an Enterprise SSC TPer, then the SD MAY support the REMOVE ELEMENT AND TRUNCATE command.

If the Locking SP is owned (see section 2.2) in an Enterprise SSC TPer, then the SD SHALL terminate a REMOVE ELEMENT AND TRUNCATE command with a Data Protection Error (see section 3.4).

3.6.14 Interaction of the Opal family with the REMOVE ELEMENT AND MODIFY ZONES command

If the Locking SP is owned (see section 2.2) in an Opal family TPer, then:

a) The SD MAY support the REMOVE ELEMENT AND MODIFY ZONES command; and
b) if the element to be removed is associated with a zone associated with a Locking object for which:
    A) the value of the WriteLockEnabled column is TRUE;
    B) the value of the ReadLockEnabled column is TRUE;

C) the value of the RangeStart column is not equal to zero; or
D) the value of the RangeLength column is not equal to zero,

then the TPer SHALL terminate the REMOVE ELEMENT AND TRUNCATE commands with a Data Protection Error (see section 3.4).

3.6.15 Interaction of an Enterprise SSC with the REMOVE ELEMENT AND MODIFY ZONES command

If the Locking SP is owned (see section 2.2) in an Enterprise SSC TPer, then:

a) the SD MAY support the REMOVE ELEMENT AND MODIFY ZONES command; and
b) if the element to be removed is associated with a zone associated with a Locking object for which:
   A) the value of the WriteLockEnabled column is TRUE;
   B) the value of the ReadLockEnabled column is TRUE;
   C) the value of the RangeStart column is not equal to zero; or
   D) the value of the RangeLength column is not equal to zero,

   then the TPer SHALL terminate the REMOVE ELEMENT AND TRUNCATE commands with a Data Protection Error (see section 3.4).

3.6.16 Interaction of the Opal family with the RESTORE ELEMENT AND REBUILD command

If the Locking SP is not owned (see section 2.2) in an Opal family TPer, then the SD MAY support the RESTORE ELEMENT AND REBUILD command.

If the Locking SP is owned (see section 2.2) in an Opal family TPer, then the SD:

a) SHALL NOT support the RESTORE ELEMENT AND REBUILD command; or
b) SHALL:
   A) report that the RESTORE ELEMENT AND REBUILD command is supported; and
   B) terminate RESTORE ELEMENT AND REBUILD commands with a Data Protection Error (see section 3.4).

3.6.17 Interaction of an Enterprise SSC with the RESTORE ELEMENT AND REBUILD command

If the Locking SP is not owned (see section 2.2) in an Enterprise SSC TPer, then the SD MAY support the RESTORE ELEMENT AND REBUILD command.

If the Locking SP is owned (see section 2.2) in an Enterprise SSC TPer, then the SD SHALL terminate a RESTORE ELEMENT AND REBUILD command with a Data Protection Error (see section 3.4).

3.6.18 Interface command interactions with user data removal methods

If a user data removal method (see section 2.3) is in progress on an LBA range, then the SD shall terminate all supported SCSI commands affecting that LBA range with a Synchronous Protocol Violation (see section 3.4), except for the following:

a) SECURITY PROTOCOL IN commands (see [29]);
b) SECURITY PROTOCOL OUT commands (see [29]);
c) INQUIRY commands (see [29]);
d) LOG SENSE commands that specify the Temperature log page (see [29]);
e) MODE SENSE commands that specify (see [29]):
   A. the Informational Exceptions Control mode page;
   B. the Caching mode page;
   C. the Control mode page;
   D. the Protocol Specific Port mode page; or

  E. the Protocol Specific Logical Unit mode page

f) READ CAPACITY (16) commands (see [29]);
g) REPORT LUNS commands (see [29]);
h) REPORT SUPPORTED OPERATION CODES commands (see [29]);
i) REPORT SUPPORTED TASK MANAGEMENT FUNCTIONS commands (see [29]);
j) REPORT ZONES commands (see [9]) with:
  A. the ZONE START LBA field cleared to zero;
  B. the REPORTING OPTIONS field set to 3Fh;
  C. the PARTIAL bit set to one; and
  D. the ALLOCATION LENGTH field set to a value less than or equal to 64;
k) REQUEST SENSE commands (see [29]); and
l) TEST UNIT READY command; and
m) vendor specific commands that do not affect or retrieve user data.

3.6.19 Interactions with the FORMAT WITH PRESET command

If the Locking SP is owned and a FORMAT WITH PRESET command is sent to the device:

a) to change the number of logical blocks per physical block, then the SD SHALL terminate that FORMAT WITH PRESET command with a Data Protection Error (see section 3.4); or
b) to change the size of a logical block without changing the number of logical blocks per physical block, then the SD SHALL NOT modify:
  A) the `Locking` table; or
  B) any `Datastore` tables.

3.6.20 Interactions with other SCSI commands

Table 45 specifies the interactions of SCSI commands not already described by other subclauses.

4 ATA Interface

See [6] and [10] for details on ATA architecture, commands and transports.

4.1 TPer scope

In the context of the ATA interface, the scope of the TPer is the ATA device.

4.2 Mapping of Resets

Table 15 – ATA Resets Mapped to TCG reset_type

ATA Event	**Maps to TCG** reset_type
Power on reset	Power Cycle
Hardware reset	PATA: Hardware Reset SATA: If Software Settings Preservation is enabled, then COMRESET is not a TCG Hardware Reset. If Software Settings Preservation is disabled, then COMRESET is a TCG Hardware Reset.
Software reset	(none)

4.3 Mapping of IF-SEND and IF-RECV

4.3.1 IF-SEND

IF-SEND SHALL be implemented with either the TRUSTED SEND or TRUSTED SEND DMA commands, with additional requirements on the inputs as described in Table 16:

Table 16 – IF-SEND command fields (ATA)

SECURITY PROTOCOL	SP SPECIFIC	TRANSFER LENGTH
`0x00`	Security Protocol `0x00` is not defined for IF-SEND	
`0x01`	a ComID	Non-zero [a] number of 512-byte data units.
`0x02`	a ComID	Non-zero [a] number of 512-byte data units.
`0x06`	Protocol `0x06` is not defined for ATA.	
[a] If the Transfer Length parameter is zero, then the TPer SHALL report Other Invalid Command Parameter (see section 4.4).		

4.3.2 IF-RECV

IF-RECV SHALL be implemented with either the TRUSTED RECEIVE or TRUSTED RECEIVE DMA commands, with additional requirements on the inputs as described in Table 17:

Table 17 – IF-RECV command fields (ATA)

SECURITY PROTOCOL	SP SPECIFIC	TRANSFER LENGTH
`0x00`	(See [6])	Non-zero number of 512-byte data units.
`0x01`	a ComID	Non-zero [a] number of 512-byte data units.
`0x02`	a ComID	Non-zero [a] number of 512-byte data units.
`0x06`	Protocol `0x06` is not defined for ATA.	
[a] If the Transfer Length parameter is zero, then the TPer SHALL report Other Invalid Command Parameter (see section 4.4).		

4.4 Handling Common TPer Errors

There are some common errors detected by the TPer. This section describes how they are reported via the ATA interface.

See [6] for information about the Sense Data Reporting (SDR) feature set and the SENSE DATA AVAILABLE (SDA) bit (i.e., ATA STATUS field bit 1).

Table 18 describes common TPer errors if:

a) SDR is not supported;
b) SDR is supported and SDR is disabled; or
c) SDR is supported and SDR is enabled and SENSE DATA AVAILABLE (SDA) is cleared to zero.

Table 19 describes common TPer errors if:

a) SDR is supported and SDR is enabled and SENSE DATA AVAILABLE is set to one.

Table 18 – TPer Errors (ATA) – Without Sense Data Reporting (SDA=0)

TPer Error ID	**ATA Status Field**	**ATA Error Field**	**Comments**
Good	`0x50`	`0x00`	Normal command completion.
Invalid Security Protocol ID parameter	`0x51`	`0x04`	No data SHALL be transferred.
Invalid Transfer Length parameter on IF-SEND	`0x51`	`0x04`	No data SHALL be transferred.
Other Invalid Command Parameter	`0x51`	`0x04`	No data SHALL be transferred.
Synchronous Protocol Violation	`0x51`	`0x04`	No data SHALL be transferred.
Data Protection Error	`0x51`	`0x04`	No user data SHALL be transferred.

Table 19 – TPer Errors (ATA) – With Sense Data Reporting (SDA=1)

TPer Error ID	ATA Status Field Bit 1	Sense Key	ASC/ASCQ	Comments
Good	1	NO SENSE	NO ADDITIONAL SENSE	Normal command completion.
Invalid Security Protocol ID parameter	1	ILLEGAL REQUEST	INVALID FIELD IN CDB	No data SHALL be transferred.
Invalid Transfer Length parameter on IF-SEND	1	ILLEGAL REQUEST	INVALID FIELD IN CDB	No data SHALL be transferred.
Other Invalid Command Parameter	1	ILLEGAL REQUEST	INVALID FIELD IN CDB	No data SHALL be transferred.
Synchronous Protocol Violation	1	ILLEGAL REQUEST	COMMAND SEQUENCE ERROR	No data SHALL be transferred.
Data Protection Error	1	DATA PROTECT	ACCESS DENIED–NO ACCESS RIGHTS	No user data SHALL be transferred.

4.5 Discovery of Security Capabilities

4.5.1 IDENTIFY DEVICE

The IDENTIFY DEVICE command (see [6]) indicates whether the device has support for the ATA Security feature set or the Trusted Computing feature set. See IDENTIFY DEVICE data words 48, 82, and 128 for further information.

4.5.2 Security Protocol 0x00

The TRUSTED RECEIVE command (see [6]) describes Security Protocol `0x00`.

4.6 Miscellaneous

4.6.1 Feature set interactions

4.6.1.1 Trusted Computing feature set

The Trusted Computing feature set SHALL be supported by the device.

4.6.1.2 Sense Data Reporting feature set

If the Sense Data Reporting (SDR) feature set is supported and enabled, then common TPer errors are reported as Sense Codes instead of as regular ATA errors. (See [6] and section 4.4).

4.6.1.3 Locking Template interactions with the ATA Security feature set

If the lifecycle state of the Locking SP changes from the Manufactured-Inactive state to the Manufactured state, then:

1) the TPer SHALL save the current value of:
    - A) IDENTIFY DEVICE, word 82, bit 1;
    - B) IDENTIFY DEVICE, word 85, bit 1; and
    - C) IDENTIFY DEVICE, word 128;

   and

2) the TPer SHALL change the value of IDENTIFY DEVICE, word 82, bit 1 to zero.

If the lifecycle state of the Locking SP is in the Manufactured state, then IDENTIFY DEVICE commands processed by the device SHALL indicate that the ATA Security feature set is not supported.

If the lifecycle state of the Locking SP changes from the Manufactured state to the Manufactured-Inactive state, then the TPer SHALL restore the value of the IDENTIFY DEVICE data to the values that were saved when the TPer changed the state from Manufactured-Inactive to Manufactured:

- a) IDENTIFY DEVICE, word 82, bit 1;
- b) IDENTIFY DEVICE, word 85, bit 1; and
- c) IDENTIFY DEVICE, word 128.

If there is no Locking SP or the lifecycle state of the Locking SP is in the Manufactured-Inactive state, IDENTIFY DEVICE commands processed by the device MAY indicate that the ATA Security feature set is supported.

When ATA Security is enabled (i.e., ATA security state is SEC3, SEC4, SEC5, or SEC6), the TPer SHALL prohibit issuance of an SP that incorporates the Locking Template, and SHALL prohibit a SP that incorporates the Locking Template from transitioning out of the Manufactured-Inactive state.

4.6.1.4 Interaction of the Opal family with the ATA Sanitize Device feature set

If the Locking SP is not owned in an Opal family TPer (see section 2.2), then the SD MAY support (i.e., IDENTIFY DEVICE, word 59, bit 12 = 1) the ATA Sanitize Device feature set.

If the Locking SP is owned in an Opal family TPer, the SD SHALL:

- a) report that the ATA Sanitize Device feature set is not supported (i.e., IDENTIFY DEVICE, word 59, bit 12 = 0); or
- b) perform the following operations:
    - A) report that the ATA Sanitize Device feature set is supported (i.e., IDENTIFY DEVICE word 59, bit 12 = 1); and
    - B) terminate the following commands with a Data Protection Error (see section 4.4):
        - a) CRYPTO SCRAMBLE EXT command;
        - b) OVERWRITE EXT command;
        - c) BLOCK ERASE EXT command;
        - d) SANITIZE ANTIFREEZE LOCK EXT command; and
        - e) SANITIZE FREEZE LOCK EXT command.

4.6.1.5 Interaction of an Enterprise SSC with the ATA Sanitize Device feature set

If the Locking SP is owned (see section 2.2) in an Enterprise SSC TPer, then the SD SHALL terminate the following commands with a Data Protection Error (see section 4.4):

a) CRYPTO SCRAMBLE EXT command;
b) OVERWRITE EXT command;
c) BLOCK ERASE EXT command;
d) SANITIZE ANTIFREEZE LOCK EXT command; and
e) SANITIZE FREEZE LOCK EXT command,

A successful SANITIZE command SHALL eradicate all Locking SP media encryption keys and generate new media encryption keys.

4.6.1.6 Interaction of the Opal family Activate method with the ATA Security feature set

An Activate Error condition occurs when the `Activate` method is not successful.

If the `Activate` method is invoked on the Locking SP while ATA Security is enabled (i.e., ATA security state is SEC3, SEC4, SEC5, or SEC6), then the method invocation SHALL fail with a status of FAIL.

4.6.2 Special Locking SP command interactions

If:

a) an SD implements the Opal family or the Enterprise SSC; and
b) the Sense Data Reporting feature is supported and is enabled,

then the SD SHALL terminate the following ATA commands with the Sense Key set to ILLEGAL REQUEST and the additional sense set to INVALID COMMAND OPERATION CODE:

a) READ LONG;
b) WRITE LONG;
c) SCT READ LONG; and
d) SCT WRITE LONG.

If:

a) an SD implements the Opal family or the Enterprise SSC; and
b) the Sense Data Reporting feature is not supported or is not enabled,

then the SD SHALL return command aborted for the following ATA commands:

a) READ LONG;
b) WRITE LONG;
c) SCT READ LONG; and
d) SCT WRITE LONG.

4.6.3 Interactions with Zoned Block devices

If the device is not a zoned block device (see [10]), then this subclause does not apply. This subclause applies to zoned block devices only.

If the KEY CHANGE ZONE BEHAVIOR bit is set to one, then cryptographic erase or key change methods (e.g., `GenKey` or `Revert`) SHALL:

a) reset the write pointer of all zones in the affected range; and
b) change the state of those Zones to Empty state (i.e. ZSE:Empty state).

If the KEY CHANGE ZONE BEHAVIOR bit (see Table 2) is cleared to zero, then cryptographic erase or key change methods SHALL NOT:

a) change the write pointer of any zones in the affected range; and
b) change the state of those Zones.

The fields in the Geometry Reporting Feature Descriptor SHALL be set to the following values:

a) Align field = 1;
b) LogicalBlockSize = logical block size for the device;
c) AlignmentGranularity = zone size for the device; and
d) LowestAlignedLBA = 0.

4.6.4 Interactions with SET SECTOR CONFIGURATION EXT

If the Locking SP is owned and a SET SECTOR CONFIGURATION EXT command is sent to the device:

a) to change the number of logical blocks per physical block, then the SD SHALL terminate that SET SECTOR CONFIGURATION EXT command with a Data Protection Error (see section 3.4); or
b) to change the size of a logical block without changing the number of logical blocks per physical block, then the SD SHALL NOT modify:
    A) the `Locking` table; or
    B) any `Datastore` tables.

4.6.5 Interactions with DATA SET MANAGEMENT commands

If the device processes:

a) a DATA SET MANAGEMENT EXT command with the TRIM bit set to one;
b) a DATA SET MANAGEMENT XL command with the TRIM bit set to one; or
c) a SEND FPDMA QUEUED command with the SUBCOMMAND field set to DATA SET MANAGEMENT and the TRIM bit set to one,

then the device SHALL return a Data Protection Error (see section 4.4) for that command if:

a) the DATA SET MANAGEMENT Request Data specifies an LBA range that is included in one or more Locking objects; and
b) the values of the WriteLockEnabled column and WriteLocked column are TRUE for at least one of the Locking objects that contains at least part of any LBA range specified.

4.6.6 Interaction of the Opal family with the REMOVE ELEMENT AND TRUNCATE command

If the Locking SP is not owned (see section 2.2) in an Opal family TPer, then the SD MAY support the REMOVE ELEMENT AND TRUNCATE command.

If the Locking SP is owned (see section 2.2) in an Opal family TPer, then the SD:

a) SHALL NOT support the REMOVE ELEMENT AND TRUNCATE command; or
b) SHALL:
    A) report that the REMOVE ELEMENT AND TRUNCATE command is supported; and
    B) terminate REMOVE ELEMENT AND TRUNCATE commands with a Data Protection Error (see section 4.4).

4.6.7 Interaction of an Enterprise SSC with the REMOVE ELEMENT AND TRUNCATE command

If the Locking SP is not owned (see section 2.2) in an Enterprise SSC TPer, then the SD MAY support the REMOVE ELEMENT AND TRUNCATE command.

If the Locking SP is owned (see section 2.2) in an Enterprise SSC TPer, then the SD SHALL terminate a REMOVE ELEMENT AND TRUNCATE command with a Data Protection Error (see section 4.4).

4.6.8 Interaction of the Opal family with the REMOVE ELEMENT AND MODIFY ZONES command

If the Locking SP is owned (see section 2.2) in an Opal family TPer, then:

a) the SD MAY support the REMOVE ELEMENT AND MODIFY ZONES command; and
b) if the element to be removed is associated with a zone associated with a Locking object for which:
    A) the value of the WriteLockEnabled column is TRUE;
    B) the value of the ReadLockEnabled column is TRUE;
    C) the value of the RangeStart column is not equal to zero; or
    D) the value of the RangeLength column is not equal to zero,

    then the TPer SHALL terminate the REMOVE ELEMENT AND TRUNCATE commands with a Data Protection Error (see section 3.4).

4.6.9 Interaction of an Enterprise SSC with the REMOVE ELEMENT AND MODIFY ZONES command

If the Locking SP is owned (see section 2.2) in an Enterprise SSC TPer, then:

a) the SD MAY support the REMOVE ELEMENT AND MODIFY ZONES command; and
b) if the element to be removed is associated with a zone associated with a Locking object for which:
    A) the value of the WriteLockEnabled column is TRUE;
    B) the value of the ReadLockEnabled column is TRUE;
    C) the value of the RangeStart column is not equal to zero; or
    D) the value of the RangeLength column is not equal to zero,

    then the TPer SHALL terminate the REMOVE ELEMENT AND MODIFY ZONES commands with a Data Protection Error (see section 3.4).

4.6.10 Interaction of the Opal family with the RESTORE ELEMENT AND REBUILD command

If the Locking SP is not owned (see section 2.2) in an Opal family TPer, then the SD MAY support the RESTORE ELEMENT AND REBUILD command.

If the Locking SP is owned (see section 2.2) in an Opal family TPer, then the SD:

a) SHALL NOT support the RESTORE ELEMENT AND REBUILD command; or
b) SHALL:
    A) report that the RESTORE ELEMENT AND REBUILD command is supported; and

B) terminate RESTORE ELEMENT AND REBUILD commands with a Data Protection Error (see section 4.4).

4.6.11 Interaction of an Enterprise SSC with the RESTORE ELEMENT AND REBUILD command

If the Locking SP is not owned (see section 2.2) in an Enterprise SSC TPer, then the SD MAY support the RESTORE ELEMENT AND REBUILD command.

If the Locking SP is owned (see section 2.2) in an Enterprise SSC TPer, then the SD SHALL terminate a RESTORE ELEMENT AND REBUILD command with a Data Protection Error (see section 4.4).

4.6.12 Interface command interactions with user data removal methods

If a user data removal method (see section 2.3) is in progress on an LBA range, then the device SHALL terminate all supported ATA commands affecting that LBA range with a Synchronous Protocol Violation (see section 4.4), except for the following:

a) TRUSTED RECEIVE command (see [11]);
b) TRUSTED RECEIVE DMA command (see [11]);
c) TRUSTED SEND command (see [11]);
d) TRUSTED SEND DMA command (see [11]);
e) TRUSTED NON-DATA command (see [11]);
f) CHECK POWER MODE command (see [11]);
g) IDENTIFY DEVICE command (see [11]);
h) IDLE IMMEDIATE command with UNLOAD (see [11]);
i) READ LOG EXT command (see [11]) or READ LOG DMA EXT command (see [11]) if one of the following log addresses is requested:
    A) 10h (i.e., NCQ Command Error log);
    B) 30h (i.e., IDENTIFY DEVICE data log); or
    C) E0h (i.e., SCT Command/Status log);
j) REPORT ZONES EXT command (see [10]) with:
    A) the ZONE LOCATOR field cleared to zero;
    B) the REPORTING OPTIONS field set to 3Fh (i.e., conventional zones);
    C) the RETURN PAGE COUNT field set to 0001h; and
    D) the PARTIAL bit set to one;
k) REQUEST SENSE DATA EXT command (see [11]);
l) SANITIZE STATUS EXT command (see [11]);
m) SET FEATURES PUIS feature set device spin-up sub command (see [11]);
n) SMART READ LOG command (see [11]) if one of the following log addresses is requested:
    A) 30h (i.e., IDENTIFY DEVICE data log); or
    B) E0h (i.e., SCT Command/Status log);
o) SMART RETURN STATUS command (see [11]); and
p) vendor specific commands that do not affect or retrieve user data.

4.6.13 Interactions with the MUTATE EXT commands

If the Locking SP is owned and a MUTATE EXT command is sent to the device:

a) to change the number of logical blocks per physical block, then the SD SHALL terminate that MUTATE EXT command with a Data Protection Error (see section 3.4); or
b) to change the size of a logical block without changing the number of logical blocks per physical block, then the SD SHALL NOT modify:
    A) the `Locking` table; or
    B) any `Datastore` tables.

4.6.14 Interactions with other ATA commands

Table 46 specifies the interactions of ATA commands not already described by other subclauses.

5 NVM Express Interface

See [19] for details on NVM Express architecture, commands and transports.

5.1 TPer scope

In the context of the NVMe interface, the scope of the TPer is the NVM subsystem, except for namespaces that are permanently write protected (see the Namespace Write Protection feature in [19] and section 5.6.1).

5.2 Mapping of Resets

For PCIe reset events, where bit 0 of the CMIC field in the Identify Controller data structure is:

a) cleared to zero (i.e., the NVM subsystem contains only one NVM subsystem port), then the mapping of PCIe resets to TCG resets SHALL be as defined in Table 20; or
b) set to one (i.e., the NVM subsystem may contain more than one NVM subsystem port), then the mapping of PCIe resets to TCG resets SHALL be as defined in Table 21.

The mapping of NVMe-MI resets to TCG reset events SHALL be as defined in Table 22.

Table 20 – NVM Express over PCIe Resets Mapped to TCG reset_type (single port)

NVM Express Event	**Maps to TCG** reset_type	**Reference**
Main Power loss / PCIe cold reset	Power Cycle	[21]
PCIe hot reset	None	[21]
PCIe warm reset	Hardware Reset	[21]
PCIe transaction layer Data Link Down status	None	[21]
NVMe subsystem reset	Hardware Reset	[19]
NVMe Controller reset (CC.EN transitions from 1 to 0)	None	[19]
NVMe Function level (PCI) reset	None	[19]
NVMe Queue level reset	None	[19]

Table 21 – NVM Express over PCIe Resets Mapped to TCG reset_type (multiple ports)

NVM Express Event	**Maps to TCG** reset_type	**Reference**
Main Power loss / PCIe cold reset	Power Cycle	[21]
PCIe hot reset	None	[21]
PCIe warm reset	None	[21]

PCIe transaction layer Data Link Down status	None	[21]
NVMe subsystem reset	Hardware Reset	[19]
NVMe Controller reset (CC.EN transitions from 1 to 0)	None	[19]
NVMe Function level (PCI) reset	None	[19]
NVMe Queue level reset	None	[19]

Table 22 – NVM Express MI Resets Mapped to TCG reset_type (multiple ports)

NVM Express MI Event	**Maps to TCG** reset_type	**Reference**
Management Endpoint Reset	Hardware Reset	[19]
NVMe-MI Reset Command with Reset Type = Reset NVM Subsystem	Hardware Reset	[19]
SMBus Reset	None	[19]

5.3 Mapping of IF-SEND and IF-RECV

5.3.1 IF-SEND

IF-SEND SHALL be implemented with the Security Send command, with additional requirements on the inputs as described in Table 23:

Table 23 – IF-SEND command parameters (NVM Express)

Security Protocol	**SP Specific** [b]	**Transfer Length**	**Namespace Identifier**
`0x00`	Security Protocol `0x00` is not defined for IF-SEND		Is not used [a]

`0x01`	SPSP0 = ComID (7:0)
	SPSP1= ComID (15:8)
		Number of bytes to transfer.	Is not used [a]

`0x02`	SPSP0 = ComID (7:0)
	SPSP1= ComID (15:8)
		Number of bytes to transfer.	Is not used [a]

`0x03`	SPSP0= ComID (7:0)
	SPSP1= ComID (15:8)
		Number of bytes to transfer.	Is not used [a], except as specified in the Key Per IO SSC Specification (see [38]).

Security Protocol	SP Specific [b]	Transfer Length	Namespace Identifier
`0x06`	Security Protocol `0x06` is not defined for NVMe.		

[a] See [19] for behavior when the Namespace Identifier (NSID) field is not used. Also see Table 4 for NSID Usage Scope.

[b] Starting with NVMe Revision 1.2a, the SP Specific (SPSP) field was split into two fields (SPSP0 and SPSP1).

5.3.2 IF-RECV

IF-RECV SHALL be implemented with the Security Receive command, with additional requirements on the inputs as described in Table 24:

Table 24 – IF-RECV command parameters (NVM Express)

Security Protocol	SP Specific [b]	Allocation Length	Namespace Identifier
`0x00`	See [19]	Number of bytes to transfer.	Is not used [a]

`0x01`	SPSP0= ComID (7:0)
	SPSP1= ComID (15:8)
		Number of bytes to transfer.	Is not used [a], except as specified in the Configurable Namespace Locking Feature set (see [23]) and in the Key Per IO SSC Specification (see [38]) for Namespace Level 0 Discovery.

`0x02`	SPSP0= ComID (7:0)
	SPSP1= ComID (15:8)
		Number of bytes to transfer.	Is not used [a], except as specified in the Key Per IO SSC Specification (see [37]).

`0x03`	SPSP0= ComID (7:0)
	SPSP1= ComID (15:8)
		Number of bytes to transfer.	Is not used [a]

`0x06`	Security Protocol `0x06` is not defined for NVMe.		

[a] See [19] for behavior when the Namespace Identifier (NSID) field is not used. Also see Table 4 for NSID Usage Scope.

[b] Starting with NVMe Revision 1.2a, the SP Specific (SPSP) field was split into two fields (SPSP0 and SPSP1).

5.4 Handling Common TPer Errors

There are some common errors detected by the TPer. This section describes how they are reported via the NVM Express interface.

Common TPer errors are reported in the NVM Express Admin Completion Queue, Status Field (see [19]). The Status Code Type (SCT) field, the Status Code (SC) field, and the Do Not Retry bit SHALL indicate and map the TPer error as in Table 25.

Table 25 – TPer Errors (NVM Express)

TPer Error ID	NVMe Status Code Type	NVMe Status Code	NVMe Do Not Retry bit	Comments
Good	Generic Command Status	Successful Completion	0	Normal command completion.
Invalid Security Protocol ID parameter	Generic Command Status	Invalid Field in Command	1	No data SHALL be transferred.
Invalid Transfer Length parameter on IF-SEND	Generic Command Status	Invalid Field in Command	1	No data SHALL be transferred.
Other Invalid Command Parameter	Generic Command Status	Invalid Field in Command	1	No data SHALL be transferred.
Synchronous Protocol Violation	Generic Command Status	Command Sequence Error	1	No data SHALL be transferred.
Data Protection Error	Media and Data Integrity Errors	Access Denied	1	No user data SHALL be transferred.
Invalid Security State	Command Specific Status	Invalid Format	1	No data SHALL be transferred.
Operation Denied	Generic Command Status	Operation Denied	1	No data SHALL be transferred.
Incorrect Decryption Key	Generic Command Status	Incorrect Key	1	Data not associated with an incorrect key may be transferred, but data associated with an incorrect key SHALL NOT be transferred.
Invalid Key	Generic Command Status	Invalid Key Tag	1	No data SHALL be transferred.

5.5 Discovery of Security Capabilities

5.5.1 Identify Controller Data Structure

The Optional Admin Command Support (OACS) of the Identify Controller Data Structure (see [19]) indicates whether the device has support for the Security Send and Security Receive commands.

5.5.2 Security Protocol 0x00

The Security Receive command (see [19]) describes Security Protocol `0x00`.

5.6 Miscellaneous

5.6.1 Namespaces

5.6.1.1 Overview

An NVM subsystem SHALL have no more than one TPer. The TPer is associated with the NVM subsystem except for namespaces that are permanently write protected (see section 5.1). The TPer is not associated with controllers in the NVM subsystem).

The following requirements apply regardless of the number of existing namespaces:

a) The NVM subsystem SHALL NOT change a namespace ID reported by the NVM Express Identify command and associated with any namespace managed by the TPer as a result of a power cycle or any NVM Express event.

b) When a namespace is created, it SHALL become associated with the Global Range.

Some namespace and TCG interactions vary depending on the number of existing namespaces (see [19]) in the TPer (see Table 26).

Table 26 – Namespace Management

Number of Existing Namespaces	Reference
0	5.6.1.2
1	5.6.1.3
Greater than 1	5.6.1.4

5.6.1.2 No Existing Namespace

5.6.1.2.1 Global Range Locking object Interactions

Start of Informative Comment

The Global Range Locking object may be configured even if no namespace exists in the TPer.

End of Informative Comment

5.6.1.2.2 Non-Global Range Locking object Interactions

If no namespace exists, then attempts to modify non-Global Range Locking objects SHALL fail with a status of INVALID_PARAMETER. Other operations on non-Global Range Locking objects (e.g., Get, Next) SHALL operate as indicated in the applicable SSC specification.

5.6.1.2.3 Namespace Management

If no namespace exists in the TPer, and:

a) the value of the ReadLockEnabled column of the Global Range Locking object is TRUE and the value of the ReadLocked column of the Global Range Locking object is TRUE; or
b) the value of the WriteLockEnabled column of the Global Range Locking object is TRUE and the value of the WriteLocked column of the Global Range Locking object is TRUE,

then execution of the Namespace Management command with the Select (SEL) field set to Create SHALL fail with a status of Operation Denied.

5.6.1.3 Single Namespace

5.6.1.3.1 Global Range Locking object Interactions

If only one namespace exists in the TPer, then the column values of the Global Range Locking object (e.g., ReadLocked and WriteLocked) apply to all LBAs within that namespace that are not associated with any non-Global Range Locking objects.

Successful execution of any method that results in the cryptographic erasure of the Global Range Locking object SHALL result in the cryptographic erasure of all LBAs within that namespace that are not associated with any non-Global Range Locking objects.

5.6.1.3.2 Non-Global Range Locking Object Interactions

If only one namespace exists in the TPer, then the TPer MAY support configuration of non-Global Range Locking objects.

5.6.1.3.3 Namespace Management

If only one namespace exists in the TPer, and:

a) the value of the ReadLockEnabled column of the Global Range Locking object is TRUE and the value of the ReadLocked column of the Global Range Locking object is TRUE;
b) the value of the WriteLockEnabled column of the Global Range Locking object is TRUE and the value of the WriteLocked column of the Global Range Locking object is TRUE;
c) the value of the RangeStart column of any non-Global Range Locking object is not equal to zero; or
d) the value of the RangeLength column of any non-Global Range Locking object is not equal to zero,

then execution of the Namespace Management command SHALL fail with a status of Operation Denied.

5.6.1.3.4 MBR Shadowing for Single Namespace

If the `Set` method is invoked on the `MBRControlObj` in the `MBRControl` Table, and:

a) the provided Enabled column value is TRUE; and
b) the LBA Format of the `MBR` table is incompatible with the LBA format of the Namespace,

then the `Set` method MAY fail with a Status Code of INCOMPATIBLE_MBR_FORMAT.

5.6.1.4 Multiple Namespaces

5.6.1.4.1 Global Range Locking object Interactions

If more than one namespace exists in the TPer, then the column values of the Global Range Locking object (e.g., ReadLocked and WriteLocked) apply to all existing namespaces in the TPer.

If:

a) the value of the ReadLockEnabled column of the Global Range Locking object is TRUE; and
b) the value of the ReadLocked column of the Global Range Locking object is TRUE,

then all namespaces are read locked, and any command that reads user data or metadata (e.g., Read commands) SHALL fail with a status of Data Protection Error (see section 5.3).

If:

a) the value of the WriteLockEnabled column of the Global Range Locking object is TRUE; and
b) the value of the WriteLocked column of the Global Range Locking object is TRUE,

then all namespaces are write locked and any command that modifies user data or metadata (e.g., Write, Write Zeroes, Write Uncorrectable, or Data Management - Deallocate commands) SHALL fail with a status of Data Protection Error.

A TPer with more than one namespace MAY support a separate media encryption key for each namespace. In this case, the K_AES_* object referenced by the ActiveKey column value of the Global Range Locking object SHALL represent all media encryption keys in use for individual namespace encryption. Successful execution of any method that results in the cryptographic erasure of the Global Range Locking object SHALL result in the cryptographic erasure of all existing namespaces in the TPer.

5.6.1.4.2 Non-Global Range Locking object Interactions

If more than one namespace exists in the TPer, the Global Range Locking object is the only Locking object that is configurable. Attempts to modify other Locking objects SHALL fail with a status of INVALID_PARAMETER. Other operations on non-Global Range Locking objects (e.g., Get, Next) SHALL operate as indicated in the applicable SSC specification.

5.6.1.4.3 Namespace Management

If more than one namespace exists in the TPer, and:

a) the value of the ReadLockEnabled column of the Global Range Locking object is TRUE and the value of the ReadLocked column of the Global Range Locking object is TRUE; or
b) the value of the WriteLockEnabled column of the Global Range Locking object is TRUE and the value of the WriteLocked column of the Global Range Locking object is TRUE,

then execution of the Namespace Management command SHALL fail with a status of Operation Denied.

5.6.1.4.4 Geometry Feature Descriptor with Multiple Namespaces

The host should ignore the Geometry Feature Descriptor.

5.6.1.4.5 LockingInfoTable with Multiple Namespaces

The host should ignore the AlignmentRequired, LogicalBlockSize, Alignment Granularity, and LowestAlignedLBA columns in the `LockingInfo` table. The MaxRanges column of the `LockingInfo` table SHALL operate as indicated in the applicable SSC specification.

5.6.1.4.6 MBR Shadowing for Multiple Namespaces

If MBR shadowing (see [26]) is supported by the TPer, the `MBR` and `MBRControl` tables in the Locking SP are shared by all namespaces and controllers within the TPer.

If the `Set` method is invoked on the `MBRControlObj` in the `MBRControl` table, and:

a) the provided Enabled column value is TRUE; and
b) the LBA Format is incompatible between the content of MBR table and any existing Namespace,

then the `Set` method MAY fail with a Status Code of INCOMPATIBLE_MBR_FORMAT.

The MBR shadow size in logical blocks depends on the specific namespace logical block size.

If MBR shadowing is active, the TPer SHALL respond to LBA requests for any namespace from LBA 0 up to the LBA that maps to the end of the `MBR` table with values from the `MBR` table.

Read commands to the MBR shadow region when MBR shadowing is active SHALL return data from the `MBR` table formatted according to the logical block size of the specified namespace.

Once the Done column of the `MBRControl` table is set to TRUE, MBR shadowing SHALL be disabled for all namespaces.

It is the responsibility of the host to manage `MBR` table content between namespaces within the TPer. LBA format compatibility is not a TPer responsibility.

5.6.2 Locking Template interactions with the Namespace Management command

If:

a) the Locking SP is owned;
b) a controller processes a Namespace Management command;
c) the Enabled column value of the `MBRControl` table is TRUE; and
d) the Namespace Management command specifies the creation of a namespace with an LBA Format (see [12]) that is different from any of the existing Namespaces,

then the Namespace Management command SHALL fail with a status of Operation Denied.

5.6.3 Locking Template interactions with the Format NVM command

The Format NVM command MAY be supported on a TPer that contains an SP that incorporates the Locking Template.

If the Format NVM command is received by the storage device and all logical blocks in every targeted Namespace are associated with a Locking object that is in a Write Unlocked state, then Format NVM command SHALL be processed as specified in [19] and SHALL NOT alter the Locking SP configuration, including PIN values, access control setting, etc.

If the Format NVM command is received by the storage device and any logical block in any targeted Namespace is associated with a Locking object that is in a Write Locked state, then the Format NVM command SHALL fail with a status of Invalid Security State.

For more details on LBA and logical block association to Locking objects if the TPer supports the Configurable Namespace Locking Feature Set, see [22].

Start of Informative Comment

The Format NVM command may fail with a status of Data Protection Error if it attempts to change a LBA format and the AlignmentGranularity column of LockingInfo Table (e.g, the value of RangeStart or RangeLength column of any Locking object does not correspond to the AlignmentGranularity after changing LBA format).

End of Informative Comment

If the TPer supports the Shadow MBR for Multiple Namespaces Feature Set (see [25]), and:

a) the Locking SP is owned;
b) a controller processes a Format NVM command;
c) the Enabled column value of the `MBRControl` table (see [25]) is TRUE; and
d) the Format NVM command specifies changes to an LBA Format of the Namespace corresponding to the value of NamespaceID column of `MBRControl` table (see [25]) from the original LBA Format (see [12])

then the Format NVM command SHALL fail with a status of Invalid Security State.

5.6.4 Interaction of the Opal Family with the Sanitize command

If the Locking SP is not owned (see section 2.2), then the SD MAY support (i.e., the SANICAP field is non-zero) the Sanitize command.

If the Locking SP is owned, then the SD SHALL:

a) report that the Sanitize command is not supported (i.e., the SANICAP field is zero); or
b) perform the following:
    A) report that the Sanitize command is supported (i.e., the SANICAP field is non-zero); and
    B) terminate the Sanitize command with a Data Protection Error (see section 5.4).

5.6.5 Locking Template interactions with Dataset Management, Attribute – Deallocate

The TPer that contains an SP that incorporates the Locking Template MAY support the Dataset Management command with attribute, Deallocate.

The Dataset Management command with Attribute – Deallocate SHALL fail and report Data Protection Error (see section 5.4) if:

a) the command provides an LBA range that is included in one or more Locking objects; and
b) the values of the WriteLockEnabled column and WriteLocked column are TRUE for at least one of the Locking objects that contains at least part of the LBA range specified.

5.6.6 Interactions of the Opal Family with Namespace Write Protection

5.6.6.1 Overview

The NVM subsystem that contains an SP that incorporates the Locking Template MAY support Namespace Write Protection (see [12]). This section describes the interaction of the Opal Family with Namespace Write Protection.

If any namespace with the Permanent Write Protect state exists in the NVM subsystem and the Locking SP is not owned in an Opal family TPer, then the namespace SHALL not be included in the scope of the TPer (see section 5.1) upon successful invocation of the `Activate` method.

Start of Informative Comment

No TCG method affects the configuration of Namespace Write Protection.

Since a namespace with the Permanent Write Protect state is excluded from the scope of the TPer (see section 5.1), the successful invocation of any TCG method has no effect on the namespace. For example, user data in the namespace is not altered by the successful invocation of the `Revert` method. Similarly, the Shadow MBR is not applicable to a Permanent Write Protected Namespace even if the Shadow MBR is enabled.

End of Informative Comment

If any namespace with the Write Protect Until Power Cycle or Write Protect state exists in the TPer and the Locking SP is owned in an Opal family TPer, then the write-locking feature SHALL be applied to the namespace as described in Table 27:

Table 27 - Write Access Restriction

Namespace Write Protection state	Write lock state	Request to write user data
No Write Protect	Write locked	Not allowed
	Write unlocked	Allowed
Write Protect / Write Protect Until Power Cycle	Write locked	Not allowed
	Write unlocked	

5.6.6.2 Interactions of the NVMe Set Features command with NS Write Protection Config

If:

a) the Locking SP is owned; and
b) the value of the ReadLockEnabled column of the Global Range Locking object is TRUE or the value of the WriteLockEnabled column of the Global Range Locking object is TRUE,

then the Set Features command with the Feature Identifier set to 0x84 (i.e., Namespace Write Protection Config), and the Write Protection State field set to Permanent Write Protect SHALL fail with a status of Feature Not Changeable.

If the TPer supports the Configurable Namespace Locking Feature Set (see [23]) and:

a) the Locking SP is owned (see section 2.2);
b) the value of the NamespaceID column in a Locking object contains the value of the Namespace ID field in a Set Features command with the Feature Identifier set to 0x84 (i.e., Namespace Write Protection Config); and
c) the associated Namespace Global Range Locking object is assigned to that namespace,

then the Set Features command with the Feature Identifier set to 0x84 (i.e., Namespace Write Protection Config), and the Write Protection State field set to Permanent Write Protect SHALL fail with a status of Feature Not Changeable.

If the TPer supports the Shadow MBR for Multiple Namespaces Feature Set (see[25]) and:

a) the Locking SP is owned;
b) a controller processes a Set Features command with the Feature Identifier set to 0x84 (i.e., Namespace Write Protection Config), and the Write Protection State field set to Permanent Write Protect; and
c) the value of the Enabled column of the `MBRControl` table is TRUE and the value of the NamespaceID column of the `MBRControl` table is equal to the Namespace Identifier (NSID) field of the Set Features command,

then the Set Features command SHALL fail with a status of Feature Not Changeable.

Any namespace with the Permanent Write Protect state SHALL NOT be included in the scope of the TPer (see section 5.1) upon the successful invocation of the Set Features command.

Start of Informative Comment

The host may invoke the Set Features command with the Write Protection State field set to Write Protect or Write Protect Until Power Cycle on a namespace even if Global Range Locking object is Write Locked or Read Locked.

If the Tper supports the Configurable Namespace Locking Feature Set, then the host may invoke the Set Features command with the Feature Identifier set to 0x84 (i.e., Namespace Write Protection Config), and the Write Protection

State field set to Write Protect or Write Protect Until Power Cycle on a namespace even if the Namespace Global Range Locking object is assigned to the namespace and the Namespace Global Range Locking object is Write Locked or Read Locked.

End of Informative Comment

5.6.6.3 Interactions with Opal Family TCG Methods

The following sections describes the interactions between the NVMe protocol and the Opal Family TCG methods.

5.6.6.3.1 Interactions with the Set Method

If the TPer supports the Shadow MBR for Multiple Namespaces Feature Set (see [25]) and:

a) the Locking SP is owned; and
b) the `Set` method is invoked on the NamespaceID column of the `MBRControl` table and the value of the NamespaceID column is equal to the Namespace Identifier of a namespace with the Permanent Write Protect state,

then the `Set` Method SHALL fail with a status of INVALID_PARAMETER.

5.6.6.3.2 Interactions with the GenKey Method

If:

a) the Locking SP is owned;
b) a namespace with the Write Protect Until Power Cycle or Write Protect state exists in the TPer; and
c) the `GenKey` method is invoked on the Global Range Locking object or non-Global Range Locking object,

then the `GenKey` Method:

a) SHALL be applied to namespace(s) with the No Write Protect status;
b) SHALL NOT be applied to namespace(s) with Write Protect Until Power Cycle or Write Protect state; and
c) SHALL fail with a status of WP_DATA_REMAIN.

If the TPer supports the Configurable Namespace Locking Feature Set (see [27]); and:

a) the Locking SP is owned;
b) a Namespace Global Range Locking object is assigned to a namespace;
c) a namespace with the Write Protect Until Power Cycle or Write Protect state exists in the TPer; and
d) the `GenKey` method is invoked on the Namespace Global Range Locking object,

then the `GenKey` Method SHALL fail with a status of WP_DATA_REMAIN.

5.6.6.3.3 Interactions with the Revert Method

If:

a) the Locking SP is owned; and
b) any namespace with the Write Protect Until Power Cycle or Write Protect state exists in the TPer,

then the `Revert` Method SHALL fail with a status of WP_DATA_REMAIN.

5.6.6.3.4 Interactions with the RevertSP Method

If:

a) the Locking SP is owned; and
b) any namespace with the Write Protect Until Power Cycle or Write Protect state exists in the TPer,

then the `RevertSP` Method SHALL fail with a status of WP_DATA_REMAIN.

5.6.6.3.5 Interactions with the Erase Method

If the TPer supports the Single User Mode Feature Set (see [24]) and:

a) Locking SP is owned;
b) any namespace with the Write Protect Until Power Cycle or Write Protect state exists in the TPer; and
c) the `Erase` method is invoked on the Global Range Locking object or non-Global Range Locking object,

then the `Erase` Method:

a) SHALL be applied to namespace(s) with the No Write Protect status;
b) SHALL NOT be applied to namespace(s) with Write Protect Until Power Cycle or Write Protect state, and
c) SHALL fail with a status of WP_DATA_REMAIN.

If the TPer supports the Single User Mode Feature Set (see [24]) and:

a) the Locking SP is owned;
b) the TPer supports the Configurable Namespace Locking Feature Set (see [28]);
c) a Namespace Global Range Locking object is assigned to a namespace;
d) a namespace with the Write Protect Until Power Cycle or Write Protect state exists in the TPer; and
e) the `Erase` method is invoked on the Namespace Global Range Locking object,

then the `Erase` Method SHALL fail with a status of WP_DATA_REMAIN.

5.6.6.3.6 Interactions with the Assign Method

If the TPer supports the Configurable Namespace Locking Feature Set (see [23]) and:

a) the Locking SP is owned;
b) a namespace with the Write Protect Until Power Cycle or Write Protect state exists in the TPer; and
c) a Namespace Global Range Locking object is assigned to a namespace;
d) the `Assign` method is invoked to assign a Locking object to the namespace with the Write Protect Until Power Cycle or Write Protect state,

then the `Assign` Method SHALL fail with a status of INVALID_PARAMETER.

Start of Informative Comment

If the TPer supports TCG Opal SSC Feature Set: Configurable Namespace Locking, then it is allowed to assign the Namespace Global Range on a namespace with the No Write Protect, Write Protect Until Power Cycle, or Write Protect state. It is permitted to assign the Namespace non-global Range for a namespace with the No Write Protect state.

End of Informative Comment

5.6.6.3.7 Interactions with the Deassign Method

If the TPer supports the Configurable Namespace Locking Feature Set (see [23]) and:

a) the Locking SP is owned;
b) a namespace with the Write Protect Until Power Cycle or Write Protect state exists in the TPer;
c) the `Deassign` method is invoked without the KeepNamespaceGlobalRangeKey parameter set to TRUE to deassign a Locking object from the namespace with the Write Protect Until Power Cycle or Write Protect state,

then the `Deassign` Method SHALL fail with a status of INVALID_PARAMETER.

5.6.7 Interface command interactions with user data removal methods

If a user data removal method (see section 2.3) is in progress on an LBA range, then the controller shall terminate all supported NVMe commands affecting that LBA range with a Synchronous Protocol Violation (see section 5.4), except for the following:

a) Security Send command (see [19]);
b) Security Receive command (see [19]);
c) Abort command (see [19]);
d) Asynchronous Event Request command (see [19]);
e) Create I/O Completion Queue command (see [19]);
f) Create I/O Submission Queue command (see [19]);
g) Delete I/O Completion Queue command (see [19]);
h) Delete I/O Submission Queue command (see [19]);
i) Get Features command (see [19]);
j) Get Log Page command (see [19]) for these log pages:
    A) Error Information;
    B) SMART / Health Information;
    C) Changed Namespace List;
    D) Reservation Notification; and
    E) Sanitize Status;
k) Identify command (see [19]);
l) Keep Alive command (see [19]);
m) Set Features command (see [19]);
n) Zone Management Receive (see [19]);
o) Opcode 7Fh for these Fabric commands (see [19]):
    A) Property Set;
    B) Connect;
    C) Property Get;
    D) Authentication Send;
    E) Authentication Receive; and
    F) vendor specific fabric commands that do not affect or retrieve user data;

and

p) vendor specific commands that do not affect or retrieve user data.

5.6.8 Interactions with Zoned Namespaces

If a namespace is not a zoned namespace (see [19]), then this subclause does not apply. This subclause applies to all zoned namespaces.

If the KEY CHANGE ZONE BEHAVIOR bit (see Table 2) is set to one, then cryptographic erase or key change methods (e.g., `GenKey` or `Revert`) SHALL:

a) reset the write pointer of all zones in the affected range; and
b) change the state of those Zones to Empty state (i.e. ZSE:Empty state).

If the KEY CHANGE ZONE BEHAVIOR bit is cleared to zero: then cryptographic erase or key change methods SHALL NOT:

a) change the write pointer of any zones in the affected range; and
b) change the state of those Zones.

The Geometry Reporting Feature for Multiple Namespaces Descriptor and the fields in the Geometry Reporting Feature Descriptor SHALL be set to the following values:

a) Align field = 1;
b) LogicalBlockSize = LogicalBlockSize;
c) AlignmentGranularity = Zone Size (ZSZE); and
d) LowestAlignedLBA = 0.

5.6.9 Interactions with the Verify command

The Verify command MAY be supported on an NVM subsystem that contains an SP that incorporates the Locking Template.

If the Locking SP is owned, then for any Verify command that targets an LBA Range associated with a Locking Object for which:

a) the value of the ReadLockEnabled column is TRUE; and
b) the value of the ReadLocked column is TRUE,

then the Verify command SHALL fail with a status of Data Protection Error.

5.6.10 Interactions with the Compare command

The Compare command MAY be supported on an NVM subsystem that contains an SP that incorporates the Locking Template.

If

a) MBR shadowing (see [26]) is supported by the TPer;
b) the Locking SP is owned;
c) the `MBRControl` Enable column value is True; and
d) the `MBRControl` Done column value is False,

then any Compare command that targets an LBA Range within the MBR Shadow region SHALL process the command using data from the MBR table.

If the Locking SP is owned, then for any Compare command that targets an LBA Range associated with a Locking Object for which:

a) the value of the ReadLockEnabled column is TRUE; and
b) the value of the ReadLocked column is TRUE,

then the Compare command SHALL fail with a status of Data Protection Error.

5.6.11 Locking Template interactions with the Copy command

The Copy command is both a read command and a write command.

If the Locking SP is owned, then for any Copy command that:

a) targets a source LBA Range associated with a Locking Object for which:
   a. the value of the ReadLockEnabled column is TRUE; and
   b. the value of the ReadLocked column is TRUE;

   or

b) targets a destination LBA Range associated with a Locking Object for which:
   a. the value of the WriteLockEnabled column is TRUE; and
   b. the value of the WriteLocked column is TRUE,

then the Copy command SHALL fail with a status of Data Protection Error.

5.6.12 Locking Template interactions with Reservations

See section 2.5.

5.6.13 Locking Template interactions with other NVMe commands

Table 47 specifies the interactions of NVMe commands not already described by other subclauses.

6 *e*•MMC Interface

See [16] for details on *e*•MMC architecture, commands and transports. In addition, details relating to the mapping provided below are found in [29].

6.1 TPer scope

In the context of the *e*•MMC interface, the scope of the TPer is the *e*•MMC device.

6.2 Mapping of Resets

Table 28 specifies the *e*•MMC events that are mapped to TCG resets.

Table 28 – e•MMC Events Mapped to TCG reset_type

***e*•MMC Event**	**Maps to TCG reset_type**	**Reference**
Power On	Power cycle	[16]
H/W Reset (Pin, Reset Signal)	Hardware Reset	[16]
GO_IDLE_STATE (CMD0)	Hardware Reset	[16]
GO_PRE_IDLE_STATE (CMD0)	Hardware Reset	[16]
GO_INACTIVE_ STATE (CMD15)	Power cycle	[16]
HPI (High Priority Interrupt)	None	[16]

6.3 Mapping of IF-SEND and IF-RECV

6.3.1 IF-SEND

IF-SEND is implemented with the combination of a CMD23 (i.e., SET_BLOCK_COUNT), followed by a CMD54 (PROTOCOL_WR), with additional requirements on the inputs as described in Table 29.

CMD23 command is used to set the transfer block count for the CMD54. See [16] for details regarding CMD23 and CMD54.

Table 29 – IF-SEND command parameters (*e*•MMC)

Security Protocol	SP_Specific	Transfer Length
`0x00`	Security Protocol `0x00` is not defined for IF-SEND	
`0x01`	a ComID	Non-zero[a] number of 512 byte data units as defined in CMD23
`0x02`	a ComID	Non-zero[a] number of 512 byte data units as defined in CMD23
`0x06`	Protocol `0x06` is not defined for *e*•MMC.	
[a] If the Transfer Length parameter ("number of blocks") in CMD23 is zero or if CMD23 was not successfully received, then the e•MMC device SHALL report SEC_INVALID_COMMAND_PARAMETER (see section 6.4).		

6.3.2 IF-RECV

IF-RECV is implemented with the combination of a CMD23 (SET_BLOCK_COUNT), followed by a CMD53 (PROTOCOL_RD), with additional requirements on the inputs as described in Table 30.
CMD23 command is used to set the transfer block count for the CMD53. See [16] for details regarding CMD23 and CMD53.

Table 30 – IF-RECV command parameters (*e*•MMC)

Security Protocol	SP_Specific	Allocation Length
`0x00`	See [16] [b]	Non-zero[a] number of 512 byte data units as defined in CMD23
`0x01`	a ComID	Non-zero[a] number of 512 byte data units as defined in CMD23
`0x02`	a ComID	Non-zero[a] number of 512 byte data units as defined in CMD23
`0x06`	Protocol `0x06` is not defined for *e*•MMC.	
[a] If the Transfer Length parameter ("number of blocks") in CMD23 is zero or if CMD23 was not successfully received, then the e•MMC device SHALL report SEC_INVALID_COMMAND_PARAMETER (see section 6.4) [b]When receiving CMD53 (PROTOCOL_RD) with Security Protocol value equal to 00h the SD SHALL return the list of supported protocols.		

6.3.3 *e*•MMC Command Structure for TCG IF-SEND and IF-RECV

6.3.3.1 *e*•MMC Block Allocation Overview

The *e*•MMC protocol uses the CMD23 SET_BLOCK_COUNT command (see section 6.3.3.2) to set the block count for the CMD54 command or the CMD53 command (see section 6.3.3.3) that immediately follows it. The block count of the CMD54 command or the CMD53 command is specified in 512-byte blocks (i.e., Allocation Length maps to the number of blocks in the payload multiplied by 512). Payload padding to the specified number of 512 byte blocks SHALL consist of zeros.

For TCG on the *e*•MMC transport, the IF-SEND command consists of the combination of a CMD23, followed by a CMD54.

In TCG on the *e*•MMC transport, the IF-RECV command consists of the combination of a CMD23, followed by a CMD53.

6.3.3.2 *e*•MMC CMD23 SET_BLOCK_COUNT command

CMD23 SET_BLOCK_COUNT is sent before CMD54 or CMD53 to set a transfer length of one or more 512-byte block. See Table 31.

Table 31 – e•MMC CMD23 Command Block

Bit Byte	7	6	5	4	3	2	1	0
0	[47] Start Bit	[46] Transition Bit	[45:40] Command Index					
1	[39] Reliable Write Request	[38] ‘0’ non-packed	[37] tag request	[36:33] context ID				[32]: forced programming
2	[31:24] set to 0							
3	[23:16] Number of Blocks (15:8)							
4	[15:8]: Number of Blocks (7:0)							
5	[7:1] CRC7							[0] Stop Bit

The value of Command Index is defined as 23 for this command. See [16] for more information.
The value in the Number of Blocks field specifies how many blocks are to be transferred in the next command. See [16] for more information.

All other fields are defined in [16].

6.3.3.3 *e*•MMC CMD54 PROTOCOL_WR and CMD53 PROTOCOL_RD commands

CMD54 PROTOCOL_WR and CMD53 PROTOCOL_RD commands are used to send the Security Protocol and the Security Protocol Specific parameters of the TCG IF-SEND and IF-RECV commands. See Table 32.

Table 32 – *e*•MMC CMD54 and CMD53 Structure

Bit Byte	7	6	5	4	3	2	1	0
0	[47] Start Bit	[46] Transition Bit	[45:40] Command Index					
1	[39:32] Security Protocol Specific (15:8)							
2	[31:24] Security Protocol Specific (7:0)							
3	[23:16] Security Protocol							
4	[15:8] Reserved							
5	[7:1] CRC7							[0] Stop Bit

See Table 29 and Table 30 for usage of Bytes 1 and 2, the Security Protocol Specific fields and the Security Protocol field.

All other fields are defined in [16].

6.4 Handling Common TPer Errors

Security related errors are detected by the *e*•MMC interface or by the TPer. Table 33 describes how they are reported by the *e*•MMC interface.

See [16] for details.

Table 33 – TPer Errors (*e*•MMC)

TPer Error ID	*e*•MMC Device Status	EXCEPTION EVENTS STATUS [a]	EXT SECURITY ERR [b]	Comments
Good	No error	No error	No error	Normal command completion.
Invalid Security Protocol ID parameter	EXCEPTION EVENT=1	EXTENDED SECURITY FALURE =1	SEC INVALID COMMAND PARAMETERS=1	No data SHALL be transferred.
Invalid Transfer Length parameter on IF-SEND	EXCEPTION EVENT=1	EXTENDED SECURITY FALURE =1	SEC INVALID COMMAND PARAMETERS=1	No data SHALL be transferred.
Other Invalid Command Parameter	EXCEPTION EVENT=1	EXTENDED SECURITY FALURE =1	SEC INVALID COMMAND PARAMETERS=1	No data SHALL be transferred.
Synchronous Protocol Violation	EXCEPTION EVENT=1	EXTENDED SECURITY FALURE =1	SEC INVALID COMMAND PARAMETERS=1	No data SHALL be transferred.
Data Protection Error	EXCEPTION EVENT=1	EXTENDED SECURITY FALURE =1	ACCESS DENIED=1	No user data SHALL be transferred.

[a] EXCEPTION_EVENTS_STATUS field of the EXT_CSD register

[b] EXT_SECURITY_ERR field of the EXT_CSD register

6.5 Discovery of Security Capabilities

6.5.1 Discovery of Security Capabilities

6.5.1.1 Security Protocol Information

In order to discover whether the extended protocol pass through commands are supported, the host should verify that Command Class 10 is supported by the device (in CCC field in CSD Register).

In order to receive and send extended protocol information CMD53 and CMD54 SHALL be used.

Refer to Security Protocol Information (see [16]) for the discovery of which security feature set is supported.

When receiving PROTOCOL_RD (CMD53) with Security Protocol value equal to 00h, the SD SHALL return the list of supported protocols.

6.6 Miscellaneous

6.6.1 Partition Management

The Locking Template SHALL be associated with and manage only the User Data Area partition (see [16]).

7 NVDIMM-N Interface

DDR4 NVDIMM-N modules provide DRAM that is made non-volatile through the use of NAND flash (see [15]). The NVDIMM-N controller interface is via I2C registers and is called the Byte Addressable Energy Backed Interface (BAEBI) (see [13] and [14]).

DDR4 NVDIMM-N shall include either zero or one TPers. The TPer, if any, shall incorporate the Locking Template.

7.1 TPer scope

The scope of the TPer is the NVDIMM-N device.

7.2 Mapping of Resets

Table 34defines how various DDR or BAEBI events map to various TCG resets.

Table 34 - DDR or BAEBI Events Events Mapped to TCG reset_type

DDR or BAEBI event	TCG reset_type	Notes
Power on for V_12, VDD, VTT, VPP, and VREFCA	Power Cycle	Causes LockOnReset, DoneOnReset
Power on for VDDSPD	none	
RESET_n assertion while not armed	none	
RESET_n assertion while armed	none	Per BAEBI, the module masks RESET_n while armed
I2C interface reset due to SCL timeouts	none	
Factory Default operation	none	
Reset Controller operation	Hardware	

7.3 Mapping of IF-SEND and IF-RECV

7.3.1 IF-SEND

The IF-SEND function is implemented as writing to the Security Typed Block Data area (4h) defined in BAEBI (see [13] and [14]).

The Operational Unit Size is 32 bytes for devices compliant with JESD245D (see [13]). The Operational Unit Size is 256 bytes for devices compliant with JESD245E (see [14]). See section 7.6 for how to determine the Operational Unit Size.

Table 35 - IF-SEND command parameters (NVDIMM-N)

SECURITY PROTOCOL TYPE	SECURITY PROTOCOL SPECIFIC0 & SECURITY PROTOCOL SPECIFIC1	TYPED BLOCK DATA SIZE0, TYPED BLOCK DATA SIZE1, & TYPED BLOCK DATA SIZE2
`0x00`	Security Protocol `0x00` is not defined for IF-SEND	
`0x01`	a ComID	Number of bytes to transfer.
`0x02`	a ComID	Number of bytes to transfer.
`0x06`	Security Protocol `0x06` is not defined for IF-SEND	

7.3.2 IF-RECV

The IF-RECV function is implemented as reading from the Security Typed Block Data area (4h) defined in BAEBI (see [13] and [14]). Note this the Type Block Data area is not a read-write memory; reading does not return the values that were written.

The Operational Unit Size is 32 bytes for devices compliant with JESD245D (see [2]). The Operational Unit Size is 256 bytes for devices compliant with JESD245E (see [14]). See section 7.5 for how to determine the Operational Unit Size.

Table 36 - IF-RECV command parameters (NVDIMM-N)

SECURITY PROTOCOL TYPE	SECURITY PROTOCOL SPECIFIC0 & SECURITY PROTOCOL SPECIFIC1	TYPED BLOCK DATA SIZE0, TYPED BLOCK DATA SIZE1, & TYPED BLOCK DATA SIZE2
`0x00`	(see [29] for details)	Number of bytes to transfer.
`0x01`	a ComID	Number of bytes to transfer.
`0x02`	a ComID	Number of bytes to transfer.
`0x06`	Security Protocol `0x06` is not defined for IF-SEND	

7.4 Handling Common TPer Errors

Table 37describes how errors detected by the TPer are reported on NVDIMM-N modules.

Table 37 – TPer Errors (NVDIMM-N)

TPer Error ID	NVDIMM-N Error Register	Comments
Good	OPERATIONAL_UNIT_OPS_STATUS	OPERATIONAL_UNIT_OPS_SUCCESS bit
Invalid Security Protocol ID parameter	OPERATIONAL_UNIT_OPS_STATUS	OPERATIONAL_UNIT_OPS_ERROR bit
	OPERATIONAL_UNIT_FAIL_INFO	INVALID_SEC_PROTOCOL bit [1]
Invalid Transfer Length parameter on IF-SEND	OPERATIONAL_UNIT_OPS_STATUS	OPERATIONAL_UNIT_OPS_ERROR bit
	OPERATIONAL_UNIT_FAIL_INFO	SEC_TRANSFER_LENGTH_ERROR bit [1]
Other Invalid Command Parameter	OPERATIONAL_UNIT_OPS_STATUS	OPERATIONAL_UNIT_OPS_ERROR bit
	OPERATIONAL_UNIT_FAIL_INFO	INVALID_SEC_CMD bit [1]
Synchronous Protocol Violation	OPERATIONAL_UNIT_OPS_STATUS	OPERATIONAL_UNIT_OPS_ERROR bit
	OPERATIONAL_UNIT_FAIL_INFO	IF_SEND_CMD_ERROR bit [1]
Data Protection Error	N/A	

[1] This information is only available in devices compliant with JESD245E (see [14]).

7.5 Discovery of Security Capabilities

To discover if the NVIDMM-N supports the TCG Storage protocol and if so, to determine the operational unit size:

1) Set the TYPED_BLOCK_DATA register in page 3 to the value of 4h (i.e., Security Typed Block Data); and
2) Read the TYPED_BLOCK_DATA_SIZE0, TYPED_BLOCK_DATA_SIZE1 and TYPED_BLOCK_DATA_SIZE2 registers in page 3. TYPED_BLOCK_DATA_SIZE0 indicates bit 0 to bit 7 of the operational unit size, TYPED_BLOCK_DATA_SIZE1 indicates bit 8 to bit 15 of the operational unit size, and TYPED_BLOCK_DATA_SIZE2 indicates bit 16 to bit 23 of the operational unit size.

If the operational unit size from step 2 is 0, then the NVDIMM-N does not support the TCG Storage protocol.

7.6 Miscellaneous

Table 38 describes how various BAEBI operations are impacted by the TPer.

NVDIMM-N modules do not support separate locking for reads and writes.

Table 38 - Authenticated and unauthenticated BAEBI operations

Catastrophic Save via register	Owner, Admin, User	CSAVE_ERROR and CSAVE_REJECT in the CSAVE_STATUS register and SECURITY_ERROR in the CSAVE_FAIL_INFO1 register	Encrypts using DEK
Catastrophic Save via trigger	Admin, User	Not possible; the arm would have been rejected	Encrypts using DEK
Restore	Admin, User	RESTORE_ERROR in the RESTORE_STATUS register and SECURITY_ERROR in the RESTORE_FAIL_INFO register	Decrypts using unwrapped DEK
Arm	Admin, User	ARM_ERROR in the ARM_STATUS register and SECURITY_ERROR in the ARM_FAIL_INFO register	Deletes the wrapped DEK (providing instant secure erase) and generate a new DEK.
Erase	Admin, User	ERASE_ERROR in the ERASE_STATUS register and SECURITY_ERROR in the ERASE_FAIL_INFO register	Deletes the wrapped DEK (providing instant secure erase)
Reset Controller	none	allowed	none
Clear <various>	none	allowed	none
Deassert EVENT_n	none	allowed	none
Set Energy Source Policy	none	allowed	none
Set Event Notification	none	allowed	none
Factory Default	Owner, Admin, User	FACTORY_DEFAULT_ERROR in the FACTORY_DEFAULT_STATUS register and SECURITY_ERROR in the FACTORY_DEFAULT_STATUS_FAIL_INFO register	Deletes the wrapped DEK (providing instant secure erase)
Firmware	Owner, Admin	FIRMWARE_OPS_ERROR in the FIRMWARE_OPS_STATUS register and SECURITY_ERROR in the FIRMWARE_OPS_STATUS register	none
Operational Unit – Firmware Image Data	Admin, User	OPERATIONAL_UNIT_OPS_ERROR in the OPERATIONAL_UNIT_OPS_STATUS register and SECURITY_ERROR in the OPERATIONAL_UNIT_FAIL_INFO register	none

Operational Unit – Vendor Log Page	Owner	OPERATIONAL_UNIT_OPS_ERROR in the OPERATIONAL_UNIT_OPS_STATUS register and SECURITY_ERROR in the OPERATIONAL_UNIT_FAIL_INFO register	none
Operational Unit – Label Data	Admin, User	OPERATIONAL_UNIT_OPS_ERROR in the OPERATIONAL_UNIT_OPS_STATUS register and SECURITY_ERROR in the OPERATIONAL_UNIT_FAIL_INFO register	none
Operational Unit – Security Protocol	none	allowed	none
Abort	none	allowed	none

8 SD-Interface

See [34] for details on SecureDigital Card architecture, commands, and transports. Additonal details relating to the mapping provided below may be found in [31].

Note that for SecureDigital Express cards that include both the PCIe/NVMe interface and the SD-interface, the access to the TCG function through the PCIe/NVMe interface should be handled as defined for any standard NVMe device (see section 5). The following additions relates to the case of accessing TCG functionality through the SD-interface.

8.1 TPer scope

In the context of the SD-interface, the scope of the TPer is the SecureDigital Card.

8.2 Mapping of Resets

Table 39 specifies the SecureDigital events that are mapped to TCG resets.

Table 39 - SD Card Events Mapped to TCG reset_type

SecureDigital Card Event	Maps to TCG reset_type
Power On	Power cycle
GO_IDLE (CMD0)	Hardware Reset
GO_IDLE_STATE (CMD0)	Hardware Reset
GO_INACTIVE_ STATE (CMD15)	Power cycle
Card in SD mode and VDD2/3 turns on (SD to PCIe mode switch)	None
Card in PCIe Linkup and SD CLK or CMD is accepted (PCIe to SD mode switch)	None

8.3 Mapping of IF-SEND and IF-RECV

8.3.1 IF-SEND

IF-SEND is implemented with the combination of a CMD23 (see section 8.3.3.2), followed by ACMD54 (see section 8.3.3.3), with additional requirements on the inputs as described in Table 40.

CMD23 is used to set the transfer block count for ACMD54. See [34] for details about CMD23 and ACMD54.

Table 40 – IF-SEND command parameters (SD-interface)

Security Protocol	Extended Security Protocols	Transfer Length
0x00	Security protocol 0x00 is not defined for IF-SEND	
0x01	a ComID	Non-zero[1] number of 512 byte data units as defined in CMD23
0x02	a ComID	Non-zero[1] number of 512 byte data units as defined in CMD23
0x06	Security Protocol 0x06 is not defined for SD Card	

Security Protocol	Extended Security Protocols	Transfer Length
Note 1: If the Transfer Length parameter (“number of blocks”) in CMD23 is zero or if CMD23 was not successfully received, then the SecureDigital card SHALL report SECURE_CMD_STATUS error (see section 8.3.3.2).		

8.3.2 IF-RECV

IF-RECV is implemented with the combination of CMD23 (see section 8.3.3.2), followed by ACMD53 (see section 8.3.3.3), with additional requirements on the inputs as described in Table 41.

CMD23 is used to set the transfer block count for ACMD53. See [34] for details about CMD23 and ACMD53.

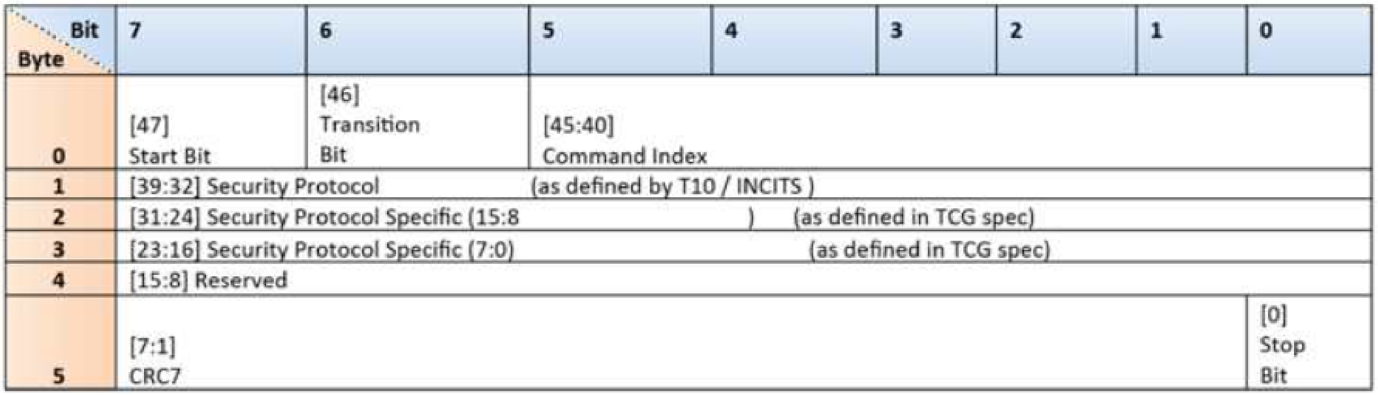
Table 41– IF-RECV command parameters (SD interface)

Security Protocol	Extended Security Protocols	Allocation Length
0x00	(See [34]) [2]	Non-zero[1] number of 512 byte data units as defined in CMD23
0x01	a ComID	Non-zero[1] number of 512 byte data units as defined in CMD23
0x02	a ComID	Non-zero[1] number of 512 byte data units as defined in CMD23
0x06	Security Protocol 0x06 is not defined for SecureDigital Card	
Note 1: If the Transfer Length parameter (“number of blocks”) in CMD23 is zero or if CMD23 was not successfully received, then the SecureDigital card SHALL report SECURE_CMD_STATUS error (see section 8.3.3.2). Note 2: When received ACMD53 (SECURE_RECEIVE) with Security protocol value equal to 00h device shall return the list of supported protocols as defined in the Security Protocol list of INCITS, T10 SPC-4 document.		

8.3.3 SecureDigital Card Command Structure for TCG IF-SEND and IF-RECV

8.3.3.1 SecureDigital Card Block Allocation Overview

SD 9 gives device manufacturers the ability to use an SD memory card for all memory and storage needs, simplifying future device upgrades or repairs and enhancing security capabilities for applications when the cards are tightly bound to specific hosts.



Bit Byte	7	6	5	4	3	2	1	0
0	[47] Start Bit	[46] Transition Bit	[45:40] Command Index					
1	[39:32] Security Protocol (as defined by T10 / INCITS)							
2	[31:24] Security Protocol Specific (15:8) (as defined in TCG spec)							
3	[23:16] Security Protocol Specific (7:0) (as defined in TCG spec)							
4	[15:8] Reserved							
5	[7:1] CRC7							[0] Stop Bit

SECURE_RECEIVE and SECURE_SEND Command Structure

The SecureDigital Card protocol uses the CMD23 SET_BLOCK_COUNT command (see section 8.3.3.2) to set the block count for ACMD54 (see section 8.3.3.3) or ACMD53 (see section 8.3.3.3) that immediately follows it. The block count of ACMD54 or ACMD53 is specified in 512-byte blocks (i.e., Allocation Length maps to the number of blocks in the payload multiplied by 512). Payload padding to the specified number of 512-byte blocks SHALL consist of zeros.

For TCG Storage-compliant storage devices on the SD interface transport, the IF-SEND command consists of the sequence of CMD23, followed by ACMD54.

In TCG Storage-compliant storage devices on the SD interface transport, the IF-RECV command consists of the sequence of CMD23, followed by ACMD53.

8.3.3.2 SecureDigital Card - CMD23 SET_BLOCK_COUNT

CMD23 is sent before ACMD54 or ACMD53 to set a transfer length of one or more 512-byte block. See Table 42.

Table 42 - CMD23 – SET_BLOCK_COUNT structure

Bit Byte	7	6	5	4	3	2	1	0
0	[47] Stat bit='0'	[46] Transmission bit='1'	[45:40] Command Index = 0x17					
1	[39:8] Block Count Field (31:0)							
2								
3								
4								

Bit Byte	7	6	5	4	3	2	1	0
5	[7:1] CRC7							[0] End bit ='1'

The value of Command Index is defined as 0x17 for this command. See [34] for more information.
The value in the Block Count field specifies how many blocks are to be transferred in the next command. See [34] for more information.

All other fields are defined in [34].

8.3.3.3 SecureDigital Card - ACMD54 SECURE_SEND and ACMD53 SECURE_RECEIVE commands

ACMD54 SECURE_SEND and ACMD53 SECURE_RECEIVE commands are used to send the Security Protocol and the Security Protocol Specific parameters of the TCG IF-SEND and IF-RECV commands. See Table 43.

Table 43 – SecureDigital Card ACMD53 and ACMD54 command structure

Bit Byte	7	6	5	4	3	2	1	0
0	[47] Stat bit='0'	[46] Transmission bit='1'	[45:40] Command Index = 0x35 or 0x36 (53 or 54)					
1	[39:32] Security Protocol (from the table defined in T10/BSR INCITS for TCG Security Protocol code; 01h to 06h defined by TCG)							
2	[31:24] Security Protocol Specific							
3	[23:16] Security Protocol Specific							
4	[15:8] Reserved							
5	[7:1] CRC7							[0] End bit (='1)

See Table 40 and Table 41 for usage of Bytes 2 and 3 (i.e., the Security Protocol Specific fields) and Byte 1 (i.e., the Security Protocol field). All other fields are defined in [34] .

8.4 Handling Common TPer Errors

Security related errors are detected by the SD-interface or by the TPer. This section and Table 44 describes how they are reported by the SD interface.

Note: A security related error reported by the SD-interface, is flagged by SECURE_CMD_STATUS error field in the SD Status register. Security related errors may not be reported in the response of the immediate IF-SEND or IF-RECV command. In such case, the error is reported in the response of a subsequent valid SD_STATUS (ACMD13) command [34].

Table 44 – SD-interface reporting of security-related errors

TPer Status ID	SECURE_CMD_STATUS field in SD Status register	Status Code	Comments
Good	00h	No errors indicated	Normal command completion
Invalid Security protocol ID parameter	01h	Invalid Field In Command	Note 1
Invalid Transfer Length parameter on IF-SEND	01h	Invalid Field In Command	Note 1
Other Invalid Command Parameter	01h	Invalid Field In Command	Note 1
Synchronous Protocol Violation	02h	Command Sequence Error	Note 1
Data Protection Error	03h	Access Denied	No User Data SHALL be transferred
Note 1: During IF-SEND command session host shall not transfer any data after reception of the TPer Error ID (i.e., when SECURE_CMD_STATUS is not 00h). Though, host may transfer data to device before the host receives such TPer Error ID notification. In such case, the device shall ignore the data received during that session during IF-RECV – no data shall be transferred by card.			

8.5 Discovery of Security Capabilities

8.5.1 Security Protocol Information

In order to discover whether the extended SecureDigital protocol pass through commands and TCG function are supported the host should issue CMD23 (see section 8.3.3.2) and read the SD Configuration Register (SCR) using ACMD51:

- Bit 36 of SCR field shall return a value of ‘1’ to indicate support of SECURE_RECEIVE and SECURE_SEND commands.
- Bit 45 of SCR register shall return value of ‘1’ to indicate that TCG is supported by the card.

In order to receive and send extended protocol information, ACMD53 and ACMD54 shall be used.
Refer to Security Protocol Information (see [34]) for the discovery of which security feature set it supported.

When received SECURE_RECEIVE (ACMD53) command with Security protocol value equal to 00h, the device shall return the list of supported protocols.

8.6 Miscellaneous

8.6.1 Partition Management

The SD specification defines that only the user partition (User Data Area) may be used for TCG and associated with the TPer.

9 Appendix: Locking SP Interactions with Other Commands

9.1 SCSI Command Interactions

Table 45 specifies the interactions of SCSI commands not already described by other subclauses.

The commands in Table 45 MAY be supported on an SD that incorporates the Locking Template. Table 45 identifies whether a SCSI command is considered as a Read command or a Write command for the purposes of interactions with ReadLockEnabled, WriteLockEnabled, ReadLocked, and WriteLocked column values in the `Locking` table.

Commands identified in Table 45 as Read commands SHALL behave as defined in the Interface Read Command Access table (see [26]).

Commands identified in Table 45 as Write commands SHALL behave as defined in the Interface Write Command Access table (see [26]).

Table 45 – SCSI command interactions with the Locking SP

SCSI command interactions with the Locking SP				
SCSI Command	**Service Action / Special Cases**	**Reference**	**Read Command**	**Write Command**
BACKGROUND CONTROL		SBC-4	No	No
BIND		SPC-5	No	No
CHANGE ALIASES		SPC-5	No	No
CLOSE ZONE		ZBC	No	Yes
COMPARE AND WRITE		SBC-4	Yes	Yes
COPY OPERATION ABORT		SPC-5	No	No
EXTENDED COPY		SPC-5	See section 3.6.10	
FINISH ZONE		ZBC	No	Yes
FORMAT UNIT		SBC-4	No	See section 3.6.8
FORMAT WITH PRESETS		SBC-4	No	See section 3.6.19
GET LBA STATUS		SBC-4	Yes	No
GET PHYSICAL ELEMENT STATUS		SBC-4	No	No

SCSI command interactions with the Locking SP				
SCSI Command	**Service Action / Special Cases**	**Reference**	**Read Command**	**Write Command**
GET STREAM STATUS		SBC-4	No	No
INQUIRY		SPC-5	No	No
LOG SELECT		SPC-5, SBC-4	No	No
LOG SENSE		SPC-5, SBC-4	No	No
MODE SELECT (6/10)		SPC-5, SBC-4	No	No
MANAGEMENT PROTOCOL IN		SPC-5	No	No
MANAGEMENT PROTOCOL OUT		SPC-5	No	No
MODE SENSE (6)		SPC-5, SBC-4	No	No
MODE SENSE (10)		SPC-5, SBC-4	No	No
OPEN ZONE		ZBC	No	Yes
ORWRITE (16)		SBC-4	No	Yes
ORWRITE (32)		SBC-4	No	Yes
PERSISTENT RESERVE IN		SPC-5	No	No
PERSISTENT RESERVE OUT		SPC-5	No	No
POPULATE TOKEN		SBC-4	See section 3.6.10	No
PRE-FETCH (10)		SBC-4	Yes	No
PRE-FETCH (16)		SBC-4	Yes	No
PREVENT ALLOW MEDIUM REMOVAL		SBC-4	No	No

SCSI command interactions with the Locking SP				
SCSI Command	**Service Action / Special Cases**	**Reference**	**Read Command**	**Write Command**
READ (6)		SBC-4	Yes	No
READ (10)		SBC-4	Yes	No
READ (16)		SBC-4	Yes	No
READ (32)		SBC-4	Yes	No
READ ATTRIBUTE		SPC-5	No	No
READ BUFFER (10) READ BUFFER (16)	Except modes 0Ah, 0Bh, and 1Ch	SPC-5	No	No
	Mode 0Ah and 0Bh - Echo Buffer Mode		No	No
	Mode 1Ch - Error Retrieval Mode		No	No
READ CAPACITY (10)		SBC-4	No	No
READ CAPACITY (16)		SBC-4	No	No
READ DEFECT DATA (10)		SBC-4	No	No
READ DEFECT DATA (12)		SBC-4	No	No
READ LONG (10)		SBC-4	See section 3.6.6	
READ LONG (16)		SBC-4	See section 3.6.6	
READ MEDIA SERIAL NUMBER		SPC-5	No	No
REASSIGN BLOCKS		SBC-4	Yes	Yes
RECEIVE COPY DATA		SPC-5	Yes	No
RECEIVE DIAGNOSTIC RESULTS		SPC-5	No	No
RECEIVE ROD TOKEN INFORMATION		SPC-5, SBC-4	Yes	No

SCSI command interactions with the Locking SP				
SCSI Command	**Service Action /** **Special Cases**	**Reference**	**Read Command**	**Write Command**
REMOVE ELEMENT AND MODIFY ZONES		ZBC-2	No	Yes See section 3.6.14 and section 3.6.15
REMOVE ELEMENT AND TRUNCATE		SBC-4	No	Yes See section 3.6.12 and section 3.6.13
REMOVE I-T NEXUS		SPC-5	No	No
RELEASE (6)		SPC-5	No	No
RELEASE (10)		SPC-5	No	No
REPORT ALIASES		SPC-5	No	No
REPORT ALL ROD TOKENS		SPC-5	No	No
REPORT IDENTIFYING INFORMATION		SPC-5	No	No
REPORT LUNS		SPC-5	No	No
REPORT PRIORITY		SPC-5	No	No
REPORT PROVISIONING INITIALIZATION PATTERN		SBC-4	No	No
REPORT REFERALS		SBC-4	No	No
REPORT SUPPORTED TASK MANAGEMENT FUNCTIONS		SPC-5	No	No
REPORT TARGET PORT		SPC-5	No	No
REPORT TIMESTAMP		SPC-5	No	No

SCSI command interactions with the Locking SP				
SCSI Command	**Service Action / Special Cases**	**Reference**	**Read Command**	**Write Command**
REPORT ZONES		ZBC	No	No
REQUEST SENSE		SPC-5	No	No
RESERVE (6)		SPC-5	No	No
RESERVE (10)		SPC-5	No	No
RESET WRITE POINTER		ZBC	No	Yes
REZERO UNIT		SBC-4	No	No
SANITIZE	BLOCK ERASE	SBC-4	See section 3.6.4 and section 3.6.5	
	CRYPTO ERASE			
	OVERWRITE			
	EXIT FAILURE MODE			
SECURITY PROTOCOL IN		SPC-5	No	No
SECURITY PROTOCOL OUT		SPC-5	No	No
SEEK (6)		SBC-4	No	No
SEEK (10)		SBC-4	No	No
SEND DIAGNOSTIC		SPC-5	Vendor specific [a]	
SET AFFILIATION		SPC-5	No	No
SET PRIORITY		SPC-5	No	No
SET IDENTIFYING INFORMATION		SPC-5	No	No
SET TARGET PORT GROUPS		SPC-5	No	No
SET TIMESTAMP		SPC-5	No	No

SCSI command interactions with the Locking SP				
SCSI Command	**Service Action / Special Cases**	**Reference**	**Read Command**	**Write Command**
STREAM CONTROL		SBC-4	No	No
START STOP UNIT		SBC-4	No	No
SYNCHRONIZE CACHE (10)		SBC-4	No	No
SYNCHRONIZE CACHE (16)		SBC-4	No	No
TEST UNIT READY		SPC-5	No	No
UNBIND		SPC-5	No	No
UNMAP		SBC-4	No	Yes See section 3.6.11
VERIFY (10)	BYTCHK=0	SBC-4	Yes	No
	BYTCHK=1		Yes See section 3.5.9	No
VERIFY (12)	BYTCHK=0	SBC-4	Yes	No
	BYTCHK=1		Yes See section 3.5.9	No
VERIFY (16)	BYTCHK=0	SBC-4	Yes	No
	BYTCHK=1		Yes See section 3.5.9	No
VERIFY (32)	BYTCHK=0	SBC-4	Yes	No
	BYTCHK=1		Yes See section 3.5.9	No
XDWRITEREAD (10)		SBC-4	Yes	Yes

SCSI command interactions with the Locking SP

SCSI Command	Service Action / Special Cases	Reference	Read Command	Write Command
XDWRITEREAD (32)		SBC-4	Yes	Yes
XPWRITE (10)		SBC-4	No	Yes
XPWRITE (32)		SBC-4	No	Yes
WRITE (6)		SBC-4	No	Yes
WRITE (10)		SBC-4	No	Yes
WRITE (16)		SBC-4	No	Yes
WRITE (32)		SBC-4	No	Yes
WRITE AND VERIFY (10)	BYTCHK=0	SBC-4	No	Yes
	BYTCHK=1		No	Yes
WRITE AND VERIFY (12)	BYTCHK=0	SBC-4	No	Yes
	BYTCHK=1		No	Yes
WRITE AND VERIFY (16)	BYTCHK=0	SBC-4	No	Yes
	BYTCHK=1		No	Yes
WRITE AND VERIFY (32)	BYTCHK=0	SBC-4	No	Yes
	BYTCHK=1		No	Yes
WRITE ATOMIC (16)		SBC-4	No	Yes
WRITE ATOMIC (32)		SBC-4	No	Yes
WRITE ATTRIBUTE		SPC-5	No	No
WRITE BUFFER	all modes except those modes associated with Download Microcode and the Echo Buffer mode	SPC-5	No	No

SCSI command interactions with the Locking SP				
SCSI Command	**Service Action / Special Cases**	**Reference**	**Read Command**	**Write Command**
	all modes associated with Download Microcode		No	No
	mode 0Ah - Echo Buffer Mode		No	No
WRITE LONG (10)	WR_UNCOR=0	SBC-4	See section 3.6.6	
	WR_UNCOR=1		No	Yes
WRITE LONG (16)	WR_UNCOR=0	SBC-4	See section 3.6.6	
	WR_UNCOR=1		No	Yes
WRITE SAME (10)		SBC-4	No	Yes
WRITE SAME (16)		SBC-4	No	Yes
WRITE SAME (32)		SBC-4	No	Yes
WRITE STREAM (16)		SBC-4	No	Yes
WRITE STREAM (32)		SBC-4	No	Yes
WRITE USING TOKEN		SBC-4	No	See section 3.6.10

[a] For Vendor Specific commands and for each SCSI command not identified in the table, the command is considered a:

a) Write command, if the command modifies user data; and

b) Read command, if the command accesses user data.

9.2 ATA Command Interactions

Table 46 specifies the interactions of ATA commands not already described by other subclauses.

The commands in Table 46 MAY be supported on an SD that incorporates the Locking Template. Table 46 identifies whether an ATA command is considered as a Read command or a Write command for the purposes of interactions with ReadLockEnabled, WriteLockEnabled, ReadLocked, and WriteLocked column values in the `Locking` table.

Commands identified in Table 46 as Read commands SHALL behave as defined in the Interface Read Command Access table (see [26]).

Commands identified in Table 46 as Write commands SHALL behave as defined in the Interface Write Command Access table (see [26]).

Table 46 – ATA command interactions with the Locking SP

ATA Command Interactions with the Locking SP				
Command	**Subcommand /** **Special Cases**	**Reference**	**Read Command**	**Write Command**
ABORT NCQ QUEUE		ACS-4	See NCQ NON-DATA	
BLOCK ERASE EXT		ACS-4	See section 4.6.1.4 and section 4.6.1.5	
			No	Yes
CHECK POWER MODE		ACS-4	No	No
CLOSE ZONE EXT		ACS-4, ZAC	See ZAC Management Out	
CONFIGURE STREAM		ACS-4	No	No
CRYPTO SCRAMBLE EXT		ACS-4	See section 4.6.1.4 and section 4.6.1.5	
			No	Yes
DATA SET MANAGEMENT	Trim	ACS-4	No	Yes See section 4.6.5
	Markup LBA Ranges function		No	No

ATA Command Interactions with the Locking SP				
Command	**Subcommand / Special Cases**	**Reference**	**Read Command**	**Write Command**
DATA SET MANAGEMENT XL		ACS-4	See DATA SET MANAGEMENT	
DEADLINE HANDLING		ACS-4	See NCQ NON-DATA	
DEVICE CONFIGURATION OVERLAY (DCO)	FREEZE LOCK	ACS-2	No	No
	IDENTIFY		No	No
	RESTORE		No	No
	SET		No	No
DOWNLOAD MICROCODE		ACS-4	No	No
DOWNLOAD MICROCODE DMA		ACS-4	See DOWNLOAD MICROCODE	
EXECUTE DEVICE DIAGNOSTIC		ACS-4	No	No
FINISH ZONE EXT		ACS-4, ZAC	See ZAC Management Out	
FLUSH CACHE		ACS-4	No	No
FLUSH CACHE EXT		ACS-4	No	No
FREEZE ACCESSIBLE MAX ADDRESS EXT		ACS-4	No	No
GET ACCESSIBLE MAX ADDRESS EXT		ACS-4	No	No
GET NATIVE MAX ADDRESS EXT		ACS-2	No	No
GET PHYSICAL ELEMENT STATUS		ACS-4	No	No
IDENTIFY DEVICE		ACS-4	No	No

ATA Command Interactions with the Locking SP

Command	Subcommand / Special Cases	Reference	Read Command	Write Command
IDLE		ACS-4	No	No
IDLE IMMEDIATE		ACS-4	No	No
MUTATE		ACS-5	No	See section 4.6.13
NCQ NON-DATA	ABORT NCQ QUEUE	ACS-4	No	No
	DEADLINE HANDLING		No	No
	SET FEATURES		See SET FEATURES	
	ZAC Management Out		See ZAC Management Out	
	ZERO EXT		See ZERO EXT	
NOP		ACS-4	No	No
OPEN ZONE EXT		ACS-4, ZAC	See ZAC Management Out	
OVERWRITE EXT		ACS-4	See section 4.6.1.4 and section 4.6.1.5	
			No	Yes
READ BUFFER		ACS-4	No	No
READ BUFFER DMA		ACS-4	No	No
READ DMA		ACS-4	Yes	No
READ DMA EXT		ACS-4	Yes	No
READ FPDMA QUEUED		ACS-4	Yes	No
READ LOG DMA EXT	Except Logs E0, E1	ACS-4	No	No
	Logs E0 & E1		See SCT	
READ LOG EXT		ACS-4	See READ LOG DMA EXT	

ATA Command Interactions with the Locking SP

Command	Subcommand / Special Cases	Reference	Read Command	Write Command
READ MULTIPLE		ACS-3	Yes	No
READ MULTIPLE EXT		ACS-3	Yes	No
READ NATIVE MAX ADDRESS EXT		ACS-2	No	No
READ NATIVE MAX ADDRESS		ACS-2	No	No
READ SECTOR(S)		ACS-4	Yes	No
READ SECTOR(S) EXT		ACS-4	Yes	No
READ STREAM DMA EXT		ACS-4	Yes	No
READ STREAM EXT		ACS-4	Yes	No
READ VERIFY SECTOR(S)		ACS-4	Yes	No
READ VERIFY SECTOR(S) EXT		ACS-4	Yes	No
RECEIVE FPDMA QUEUED	READ LOG DMA EXT	ACS-4	See READ LOG DMA EXT	
	ZAC Management In		See ZAC Management In	
REMOVE ELEMENT AND MODIFY ZONES		ZAC-2	No	Yes See section 4.6.8 and section 4.6.9
REMOVE ELEMENT AND TRUNCATE		ACS-4	No	Yes See section 4.6.6 and section 4.6.7

ATA Command Interactions with the Locking SP

Command	Subcommand / Special Cases	Reference	Read Command	Write Command
REPORT REALMS EXT		ZAC-2	See ZAC Management In	
REPORT ZONE DOMAINS EXT		ZAC-2	See ZAC Management In	
REPORT ZONES EXT		ACS-4, ZAC	See ZAC Management In	
REQUEST SENSE DATA EXT		ACS-4	No	No
RESET WRITE POINTER EXT		ACS-4, ZAC	See ZAC Management Out	
SANITIZE ANTI-FREEZE LOCK EXT		ACS-4	See section 4.6.1.4 and section 4.6.1.5	
			No	No
SANITIZE FREEZE LOCK EXT		ACS-4	See section 4.6.1.4 and section 4.6.1.5	
			No	No
SANITIZE STATUS EXT		ACS-4	See section 4.6.1.4 and section 4.6.1.5	
			No	No
SCT	Data Tables	ACS-4	No	No
	Error Recovery Control		No	No
	Feature Control		No	No
	Status		No	No
	Read Long	ATA8-ACS	See section 4.6.2	
	Write Long		See section 4.6.2	
	Write Same	ACS-4	No	Yes

ATA Command Interactions with the Locking SP				
Command	**Subcommand /** **Special Cases**	**Reference**	**Read Command**	**Write Command**
SECURITY	DISABLE PASSWORD	ACS-4	See section 4.6.1.3	
	ERASE PREPARE		See section 4.6.1.3	
	ERASE UNIT		See section 4.6.1.3	
	FREEZE LOCK		See section 4.6.1.3	
	SET PASSWORD		See section 4.6.1.3	
	UNLOCK		See section 4.6.1.3	
SEND FPDMA QUEUED:	DATA SET MANAGEMENT	ACS-4	See DATA SET MANAGEMENT	
	DATA SET MANAGEMENT XL		See DATA SET MANAGEMENT XL	
	ZAC Management Out		See ZAC Management Out	
SEQUENTIALIZE ZONE EXT		ZAC	See ZAC Management Out	
SET ACCESSIBLE MAX ADDRESS EXT		ACS-4	No	Yes
SET DATE & TIME EXT		ACS-4	No	No
SET FEATURES	many	ACS-4	No	No
SET MAX	ADDRESS	ACS-2	No	No
	ADDRESS EXT		No	No
	FREEZE LOCK		No	No
	LOCK		No	No
	SET PASSWORD		No	No
	UNLOCK		No	No

ATA Command Interactions with the Locking SP

Command	Subcommand / Special Cases	Reference	Read Command	Write Command
SET MULTIPLE MODE		ACS-3	No	No
SET SECTOR CONFIGURATION EXT		ACS-4	See section 4.6.4	
			No	Yes
SLEEP		ACS-4	No	No
SMART	DISABLE OPERATIONS	ACS-3	No	No
	ENABLE OPERATIONS		No	No
	ENABLE/DISABLE AUTOSAVE		No	No
	EXECUTE OFF-LINE IMMEDIATE		Vendor specific [a]	
	READ DATA		No	No
	READ LOG	ACS-4	See READ LOG DMA EXT	
	RETURN STATUS		No	No
	WRITE LOG		See WRITE LOG DMA EXT	
STANDBY		ACS-4	No	No
STANDBY IMMEDIATE		ACS-4	No	No
TRUSTED NON-DATA		ACS-4	No	No
TRUSTED RECEIVE		ACS-4	No	No
TRUSTED RECEIVE DMA		ACS-4	No	No
TRUSTED SEND		ACS-4	No	No

ATA Command Interactions with the Locking SP				
Command	**Subcommand / Special Cases**	**Reference**	**Read Command**	**Write Command**
TRUSTED SEND DMA		ACS-4	No	No
WRITE BUFFER		ACS-4	No	No
WRITE BUFFER DMA		ACS-4	No	No
WRITE DMA		ACS-4	No	Yes
WRITE DMA EXT		ACS-4	No	Yes
WRITE DMA FUA EXT		ACS-4	No	Yes
WRITE FPDMA QUEUED		ACS-4	No	Yes
WRITE LOG DMA EXT	Except Logs E0, E1	ACS-4	No	No
	Logs E0 & E1		See SCT	
WRITE LOG EXT		ACS-4	See WRITE LOG DMA EXT	
WRITE MULTIPLE		ACS-3	No	Yes
WRITE MULTIPLE EXT		ACS-3	No	Yes
WRITE MULTIPLE FUA EXT		ACS-3	No	Yes
WRITE SECTOR(S)		ACS-4	No	Yes
WRITE SECTOR(S) EXT		ACS-4	No	Yes
WRITE STREAM DMA EXT		ACS-4	No	Yes
WRITE STREAM EXT		ACS-4	No	Yes

ATA Command Interactions with the Locking SP

Command	Subcommand / Special Cases	Reference	Read Command	Write Command
WRITE UNCORRECTABLE EXT		ACS-4	No	Yes
ZAC Management In	REPORT REALMS EXT	ZAC-2	No	No
	REPORT ZONE DOMAINS EXT	ZAC-2	No	No
	REPORT ZONES EXT	ACS-4, ZAC	No	No
	ZONE ACTIVATE EXT	ZAC-2	Yes	Yes
	ZONE QUERY EXT	ZAC-2	No	No
ZAC Management Out	CLOSE ZONE EXT	ACS-4, ZAC-2	No	Yes
	FINISH ZONE EXT		No	Yes
	OPEN ZONE EXT		No	Yes
	RESET WRITE POINTER EXT		No	Yes
	SEQUENTIALIZE ZONE EXT	ZAC-2	No	Yes
ZERO EXT		ACS-4	No	Yes
ZONE ACTIVATE EXT		ZAC-2	See ZAC Management In	
ZONE QUERY EXT		ZAC-2	See ZAC Management In	

[a] For Vendor Specific commands and for each ATA command not identified in the table, the command is considered a:

a) Write command, if the command modifies user data; and

b) Read command, if the command accesses user data.

9.3 NVMe Command Interactions

Table 47 specifies the interactions of NVMe commands not already described by other subclauses.

The commands in Table 47 MAY be supported on the TPer that incorporates the Locking Template. Table 47 identifies whether an NVMe command is considered as a Read command or a Write command for the purposes of interactions with ReadLockEnabled, WriteLockEnabled, ReadLocked, and WriteLocked column values in the `Locking` table.

Commands identified in Table 47 as Read commands SHALL behave as defined in the Interface Read Command Access table (see [26]).

Commands identified in Table 47 as Write commands SHALL behave as defined in the Interface Write Command Access table (see [26]).

Table 47 – NVMe command interactions with the Locking SP

Command [b]	**Subcommand**	**Read Command**	**Write Command**
Abort		No	No
Asynchronous Event Request		No	No
Compare		See section 5.6.10	
Copy		See section 5.6.11	
Create I/O Completion Queue		No	No
Create I/O Submission Queue		No	No
Dataset Management	Attribute – Deallocate	See section 5.6.5	
	Attribute – Integral Dataset for Read	No	No
	Attribute – Integral Dataset for Write	No	No
Delete I/O Completion Queue		No	No
Delete I/O Submission Queue		No	No
Doorbell Buffer Config		No	No
Device Self-Test		Vendor specific [a]	
Directive Receive		No	No
Directive Send		No	No
Firmware Commit		No	No
Firmware Image Download		No	No
Flush		No	No
Format NVM		See section 5.6.3	
Get Features		No	No
Get LBA Status		No	No

Command [b]	Subcommand	Read Command	Write Command
Get Log Page		No	No
Identify		No	No
Keep Alive		No	No
Lockdown		No	No
Namespace Attachment		No	No
Namespace Management		See section 5.6.1	
NVMe-MI Receive		See Table 48	
NVMe-MI Send		See Table 48	
Read		Yes	No
Reservation Acquire		No	No
Reservation Register		No	No
Reservation Release		No	No
Reservation Report		No	No
Sanitize		See section 5.6.4	
Security Receive		No	No
Security Send		No	No
Set Features		No	No
Verify		See section 5.6.9	
Write		No	Yes
Write Uncorrectable		No	Yes
Write Zeroes		No	Yes
Virtualization Management		No	No
Zone Append		No	Yes
Zone Management Receive	Report Zones	No	No
	Extended Report Zones	Yes	No
	All other Zone Receive Action values	Note [a]	Note [a]
Zone Management Send	Close Zone	No	Yes
	Finish Zone	No	Yes
	Open Zone	No	Yes
	Reset Zone	No	Yes
	Offline Zone	No	Yes

Command [b]	Subcommand	Read Command	Write Command
	Set Zone Descriptor Extension	No	Yes

[a] For Vendor Specific commands and for each NVMe command not identified in the table, the command is considered a:

a) Write, if command modifies user data; and

b) Read, if command accesses user data.

[b] References the transported NVMe commands (regardless of delivery path)

Table 48 - NVMe-MI command interactions with the Locking SP

Command [b]	**Read Command** [a]	**Write Command** [a]
Read NVMe-MI Data Structure	No	No
NVM Subsystem Health Status Poll	No	No
Controller Health Status Poll	No	No
Configuration Get	No	No
Configuration Set	No	No
VPD Read	No	No
VPD Write	No	No
Reset	No	No
SES Receive	No	No
SES Send	No	No
Management Endpoint Buffer Read	No	No
Management Endpoint Buffer Write	No	No
PCIe Configuration Read	No	No
PCIe Configuration Write	No	No
PCIe Memory Read	No	No
PCIe Memory Write	No	No
PCIe I/O Read	No	No
PCIe I/O Write	No	No
NVMe-MI Send/NVMe-MI Receive	See Table 47 for the transported NVMe command	

[a] For Vendor Specific commands and for each command not identified in the table, the command is considered a:

a) Write, if command modifies user data; and

b) Read, if command accesses user data.

[b] Regardless of delivery path (e.g., in band or out of band)