X3T9.2/87-17

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February 11, 1987

Mr. William E. Burr
Chairman, X3T9.2

Dear Mr. Burr:

At the December 8, 1986 meeting of the X3T9.2 committee, I was given an action item to prepare a proposal covering optical disk changers. I have prepared this proposal and have attached a copy for your review.

Interested persons who have suggestions or criticisms to offer can either speak to me at the April 27 meeting of X3T9.2 in San Jose or contact me directly.

Best regards,

Michael Rudy

Michael Rudy

MR:mc

Enclosure

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Automatic Medium Changers - Preface 2/11/87

The following is a proposal for a command set for use in controlling automatic medium changers. This preface describes the reasons for some of the assumptions and decisions that were made in coming up with this specific set of commands.

The first assumption that was made is that the automatic medium changer would have its own SCSI address independent of that for the drives. Whether this is done at the controller level or the logical unit level is up to the discretion of the Implementor. The main reason for this assumption is that the automatic medium changer may contain a number of read/write devices. Trying to come up with a single command set that would allow both the medium transport device and an arbitrary number of read/write devices to be controlled seemed to be prohibitively complicated.

In an attempt to come up with a generalized command that would allow units of media to be moved about inside the changer, a decision was made to use a single address range from which addresses would be chosen for all of the internal elements in the medium changer. Because earlier proposals for command sets had been criticized for not allowing enough elements to be addressed, a two byte address was selected. This allows over 65,000 elements to be addressed. In the case of an optical disk changer, "element" may refer to a storage cell for an optical disk cartridge, or to an optical disk drive, or to a cartridge input/output portal, or to the cartridge transport mechanism itself.

This addressing scheme allowed a command called "Move Medium" to be defined. This command causes a unit of media to be moved between two elements in the changer where the two elements may be two storage cells, a storage cell and a drive, or any other combinations of elements whose addresses have been defined. This command was defined as a mandatory command in group 1.

Some changer devices have the capability of handling two units of media at a time. This allows them to take a disk to a drive and swap it with the disk that was previously being used there. Without this capability, the disk would have to be removed from the drive and stored and the new disk would have to be retrieved and loaded into the drive before use of the drive could begin again. Rather than add another layer of complexity to the Move Medium command to also handle this operation, an additonal command was defined. This is the "Exchange Medium" command which was defined as optional in group 0. This command assumes that the transport is holding a disk when the command is received and directs the transport to move to a particular element in the machine and exchange the disk it is carrying for the one that it will find there.

The last of the new commands that was defined is the "Read Element Status" command. This command provides a means for the changer device to report the status of any of its internal elements to the host. Because all element types are addressed in the same manner but may have different types of status information to report, a decision was made to include an "element type code" as part of the status data. This type code indicates how the following status data should be interpreted.

It was also desired that a means be provided for the changer to inform the

host of the address assignments given to its internal elements. After a discussion with Bill Burr, it was decided to use the Mode Select and Mode Sense commands for this rather than the Inquiry command. This allows for the use of general purpose configurable controllers. What is included here is an edited version of the Mode Sense and Mode Select command descriptions from the section of the SCSI 2 spec dealing with direct access storage devices. It has been modified to leave out the block descriptors and the pages have been redefined to report the addresses of the internal elements of the changer.

Comments on this proposal or suggestions for ways in which it can be improved should be directed to:

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Command Descriptions for Automatic Medium Changers

Group 0 Commands for Automatic Medium Changers

The Group 0 commands for automatic medium changers shall be as shown in Table 12-1.

Group 0 Commands for Automatic Medium Changers

Operation Code	Type	Command Name	Section	Page
00h	O	TEST UNIT READY	7.1.1	
01h	O	REZERO UNIT	8.1.1	
02h	V			
03h	M	REQUEST SENSE	7.1.2	
04h	R			
05h	V			
06h	V			
07h	V			
08h	O	EXCHANGE MEDIUM	_.1.1	
09h	V			
0Ah	V			
0Bh	V			
0Ch	V			
0Dh	V			
0Eh	V			
0Fh	V			
10h	R			
11h	R			
12h	M	INQUIRY	7.1.3	
13h	R			
14h	R			
15h	O	MODE SELECT	_.1.2	
16h	R			
17h	R			
18h	R			
19h	R			
1Ah	O	MODE SENSE	_.1.3	
1Bh	R			
1Ch	O	RECEIVE DIAGNOSTIC RESULTS	7.1.5	
1Dh	O	SEND DIAGNOSTIC	7.1.6	
1Eh	O	PREVENT/ALLOW MEDIUM REMOVAL	8.1.12	
1Fh	R			

Key: M = Command implementation is mandatory.
O = Command implementation is optional.
R = Operation code is reserved for future standardization.
V = Operation code is available for vendor unique commands.

EXCHANGE MEDIUM Command

Peripheral Device Type: Automatic Medium Changer
Operation Code Type: Optional

EXCHANGE MEDIUM Command

Bit / Byte	7	6	5	4	3	2	1	0
0	Operation Code (08h)							
1	Logical Unit Number			Reserved				
2	(MSB)							
3	Destination Address							(LSB)
4	Reserved						Inv1	Inv2
5	Vendor Unique		Reserved				Flag	Link

The EXCHANGE MEDIUM Command (Table _-_) provides a means for commanding automatic medium changers that are capable of handling two units of media at the same time to exchange the unit of media in the transport element with one located at the destination address. The target shall return a CHECK CONDITION status with the sense key set to ILLEGAL REQUEST if this command is received while the transport element is not holding one unit of media.

The destination address specifies the location that the unit of media is moved to. This address may represent a storage element, an input/output element or a data transfer element. The target shall return a CHECK CONDITION status with the sense key set to ILLEGAL REQUEST if the address specified has not been assigned to a specific element of the automatic medium changer.

The Inv1 bit is used to specify that the transport element is to be placed in its inverted orientation prior to withdrawning the unit of media from the destination.

The Inv2 bit is used to specify that the transport element is to be placed in its inverted orientation prior to depositing the new unit of media into the destination.

If the automatic medium changer does not support medium rotation for handling double sided media, the Inv1 and Inv2 bits are reserved.

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MODE SELECT Command

Peripheral Device Type: Automatic Medium Changer
Operation Code Type: Optional

MODE SELECT Command

Bit / Byte	7	6	5	4	3	2	1	0
0	Operation Code (15h)							
1	Logical Unit Number			Reserved				SP
2	Reserved							
3	Reserved							
4	Parameter List Length							
5	Vendor Unique		Reserved				Flag	Link

The MODE SELECT command (Table _-_) provides a means for the initiator to specify logical unit or peripheral device parameters to the target. Targets that implement the MODE SELECT command shall also implement the MODE SENSE command.

A save parameters (SP) bit of zero indicates the target shall not save the saveable pages to nonvolatile memory. A SP bit of one indicates that the target shall save the saveable pages (if any) sent during the DATA OUT phase to nonvolatile memory. (Saveable pages are identified by the PS bit that is returned in the page header by the MODE SENSE command.)

The parameter list length specifies the length in bytes of the MODE SELECT parameter list that shall be transferred from the initiator to the target. A parameter list length of zero indicates that no data shall be transferred. This condition shall not be considered as an error.

The MODE SELECT parameter list (Table .-.) contains a four-byte header followed by the vendor unique parameters, if any.

MODE SELECT Parameter List

Bit / Byte	7	6	5	4	3	2	1	0
0	Reserved							
1	Reserved							
2	Reserved							
3	Reserved							
	Page(s)							
0	Reserved		Page Code					
1	Page-Specific Parameter Length							
2 - n	Page-Specific Parameters							

Each page descriptor specifies parameters for the target to use for subsequent operations on the specific logical unit. The format of each page descriptor depends on the peripheral device type but is always a multiple of four. The page codes for automatic medium changers are given in Table _-_. The parameter length field specifies the length in bytes of the parameters that follow for the specified page. The initiator should set this value to the value that is returned in the parameter length field for the same page by the MODE SENSE command. If this condition is not met, the target may return the CHECK CONDITION status and set the sense key to ILLEGAL REQUEST. (Note that the parameter length value returned by the MODE SENSE command may be less than the full page.)

Page Codes for Automatic Medium Changers

Page Code	Description	Section
00h	Vendor Unique (does not require page format)	
01h	Reserved	
02h	Reserved	
03h	Device Geometry Parameters	
04h - 1Fh	Reserved	
20h - 3Eh	Vendor Unique	
3Fh	(Defined for MODE SENSE only)	

Device Geometry Parameters

Bit / Byte	7	6	5	4	3	2	1	0
0	Reserved			Page Code (03h)				
1				Parameter Length (12h)				
2	(MSB)							
3	First Storage Element Address							(LSB)
4	(MSB)							
5	Number of Storage Elements							(LSB)
6	(MSB)							
7	First Input/Output Element Address							(LSB)
8	(MSB)							
9	Number of Input/Output Elements							(LSB)
10	(MSB)							
11	Medium Transport Element Address							(LSB)
12	Reserved					grip2	grip1	Invert
13	(MSB)							
14	First Data Transfer Element Address							(LSB)
15	(MSB)							
16	Number of Data Transfer Elements							(LSB)
17	Reserved							
18	Reserved							
19	Reserved							

The First Storage Element Address specifies a sixteen bit number that identifies the first medium storage cell contained in the automatic medium changer. The Number of Storage Elements is a sixteen bit number that defines the total number of medium storage cells contained in the automatic medium changer. The target shall return a CHECK CONDITION status with the sense key set to ILLEGAL REQUEST if the Number of Medium Storage Elements field is greater than the default value returned in the MODE SENSE parameter data.

The First Input/Output Element Address is a sixteen bit number that identifies the first medium portal that is accessible both by the medium transport device and also by an operator from outside the automatic medium changer.

The Number of Input/Output Elements is a sixteen bit number that defines the total number of Input/Output elements contained in the automatic medium changer and accessible to the medium transport device. Note: this number may be zero. The target shall return a CHECK CONDITION status with the sense key set to ILLEGAL REQUEST if the Number of Input/Output elements field is greater than the default value returned in the MODE SENSE parameter data.

The medium transport element address is a sixteen bit number that identifies the medium transport.

The gripl bit is set to one and the grip2 bit is set to zero if the medium transport is capable of handling only one unit of media at one time. If the medium transport is capable of handling two units of media at a time, both the gripl bit and the grip2 bit are set to one. (Implementor's note: If the changer has two medium gripping devices and supports changeable parameter values, these bits can be used for enabling or disabling the use of either of the gripping devices.)

If the medium transport element supports medium rotation for handling double sided media, the invert bit is set to one. If it does not provide for medium rotation for handling double sided media, the invert bit is set to zero.

The First Data Transfer Element Address is a sixteen bit number that identifies the first data transfer device contained in the automatic medium changer. The data transfer elements may be either read/write or read only devices. The Number of Data Transfer Elements is a sixteen bit number that defines the total number of data transfer devices contained within the automatic medium changer and accessible to the medium transport device.The target shall return a CHECK CONDITION status with the sense key set to ILLEGAL REQUEST if the Number of Data Transfer Elements field is greater than the default value returned in the MODE SENSE parameter data.

Each element in the automatic medium changer must have a unique address. The target shall return a CHECK CONDITION status with the sense key set to ILLEGAL REQUEST if the address ranges defined for any of the element types overlap.

MODE SENSE Command

Peripheral Device Type: Automatic Medium Changer
Operation Code Type: Optional

MODE SENSE Command

Bit / Byte	7	6	5	4	3	2	1	0
0	Operation Code (1Ah)							
1	Logical Unit Number			Reserved				
2	PC		Page Code					
3	Reserved							
4	Allocation Length							
5	Vendor Unique		Reserved				Flag	Link

The MODE SENSE command (Table _-_) provides a means for a target to report its logical unit or peripheral device parameters to the initiator. It is a complementary command to the MODE SELECT command for support of devices that may allow different operating modes.

The page control (PC) field defines the type of parameter values to be returned as defined below.

DB(7)	DB(6)	Type of Parameter Values	Section
0	0	Current Values	
0	1	Changeable Values	
1	0	Default Values	
1	1	Saved Values	

The page code specifies which page or pages to return. The page codes are as defined in Table _-_.

The allocation length specifies the number of bytes that the initiator has allocated for returned MODE SENSE Data. An allocation length of zero indicates that no MODE SENSE data shall be transferred. This condition shall not be considered as an error. Any other value indicates the maximum number of bytes that shall be transferred. The target shall terminate the DATA IN phase when allocation length bytes have been transferred or when all available MODE SENSE data have been transferred to the initiator, whichever is less.

Current Values

A PC field value of 0h requests the target return the current values for the page code specified. The current values returned are:

1) The parameters set in the last successful MODE SELECT command.
2) The saved values if a MODE SELECT command has not been executed.
3) The default values if saved values are not available or not supported.

If the page code is 3Fh, all implemented pages are requested to be returned by the target.

Implementors note: Page code 0h is vendor unique and may be returned as the last page if it is returned at all during a page code 3Fh request. Normally the pages are returned in ascending order.

Parameters not supported by the target shall be set to zero. The parameter length of each page indicates the length of the parameters that are supported.

Changeable Values

A PC field value of 1h requests the target return the changeable values for the page code specified. The page requested shall be returned with the bits that are allowed to be changed set to one. Parameters that are not changeable shall be set to zero. If any part of a field is changable all bits in that field are set to one.

If the page code is 3Fh, all implemented pages are requested to be returned by the target.

Default Values

A PC field value of 2h requests the target return the default values for the page code specified. The page requested shall be returned with the default parameters set. Parameters not supported by the target shall be set to zero. (Implementors note: The value of the parameters returned is intended to avoid confusion over whether the value of zero is the default or the unsupported value.)

If the page code is 3Fh, all implemented pages are requested to be returned by the target.

Saved Values

A PC field value of 3h requests the target return the saved values for the page code specified. The page requested shall be returned with the saved parameters set. Parameters not supported by the target shall be set to zero. (Implementors note: The value of the parameters returned is intended to avoid confusion over whether the value of zero is the default or the unsupported value.) If saved values are not available or not supported a CHECK CONDITION status shall be returned with the sense key set to ILLEGAL REQUEST and the Additional Sense Code set to Save Parameters Not Supported.

If the page code is 3Fh, all implemented pages are requested to be returned by the target.

Implementors note: The method of saving parameters is vendor unique. The parameters must be preserved in such a manner that they are retained when the

target is powered down. Pages can be considered saved when the Mode Select command with the Save Parameters bit set has returned a status of GOOD.

The MODE SENSE data (Table _-_) contains a four-byte header, followed by zero eight-byte block descriptors, followed by pages of parameter data or vendor unique parameters, if any.

MODE SENSE Data

Bit / Byte	7	6	5	4	3	2	1	0
0	Sense Data Length							
1	Reserved							
2	Reserved							
3	Reserved							
	Pages							
0	PS	Reserved		Page Code				
1	Page-Specific Parameter Length							
2 - - - n	Page-Specific Parameters							

The sense data length specifies the length in bytes of the following MODE SENSE data that is available to be transferred during the DATA IN phase. The sense data length does not include itself.

Blocks of parameters called pages may be sent to the target in the DATA phase of the MODE SELECT command, following the MODE SELECT header.

Each defined Page is preceded by a Header of two bytes defining the Page Code and the length of the page. Following the Header the Pages are separated into sub-blocks containing a list of related flags and/or values.

The Parameters Saveable (PS) bits of each Page Header are set to one by the target to indicate that the supported parameters can be saved by the target. PS bits set to zero indicates that the supported parameters cannot be saved by the target.

The Page Code identifies the meaning of the following bytes in the Page. The parameters in the defined Pages are classified in priority to ease implementation by the target.

The Page-Specific Parameter Length indicates the number of bytes that the target supports in each Page. The Page-Specific Parameter Length value of each defined page, shall not include the Page-Specific Parameter Length byte. The target may return in the pages of the MODE SENSE commands as many consecutive bytes as it supports, for each page that it supports, without splitting

fields of multiple bytes. The page length shall be set in the pages of the MODE SELECT commands to the value returned by the target in the MODE SENSE page length bytes. Otherwise, the target shall create CHECK CONDITION status with the sense key of ILLEGAL REQUEST.

Implementors Note: The initiator shall issue a MODE SENSE command requesting the target to return all Changeable values (PC field configuration 0 1 and Page Code 3Fh in byte 2 of the MODE SENSE CDB) prior to issuing any MODE SELECT commands, in order to find out which Pages are implemented by the target and the length of each Pages for that particular LUN.

After a power up condition or hard SCSI reset condition, the following is required of the target in response to a MODE SENSE command.

If Default Values are requested report the default values.

If Saved Values are requested, report the valid restored parameters, or restore the parameters and report them. If the saved parameters are not able to be accessed in non-volatile memory terminate the command with a CHECK CONDITION status and the sense key set to NOT READY.

If the current values are requested, report a valid set of saved parameters, or restore the parameters and report them. If the current parameters are not able to be accessed in non-volatile memory terminate the command with a CHECK CONDITION status and the sense key set to NOT READY. An attempt may be made to identify the parameters if the target is unable to save parameters. At the targets option it may report default values.

Group 1 Commands for Automatic Medium Changers

The Group 1 commands for automatic medium changer shall be as shown in Table 12-8.

Group 1 Commands for Automatic Medium Changers

Operation Code	Type	Command Name	Section	Page
20h	V			
21h	V			
22h	V			
23h	V			
24h	V			
25h	V			
26h	V			
27h	V			
28h	V			
29h	V			
2Ah	V			
2Bh	R			
2Ch	R			
2Dh	R			
2Eh	R			
2Fh	R			
30h	R			
31h	R			
32h	R			
33h	R			
34h	R			
35h	R			
36h	R			
37h	M	MOVE MEDIUM	n.2.1	
38h	O	READ ELEMENT STATUS	n.2.2	
39h	R			
3Ah	R			
3Bh	R			
3Ch	R			
3Dh	R			
3Eh	R			
3Fh	R			

Key: M = Command implementation is mandatory.
O = Command implementation is optional.
R = Operation code is reserved for future standardization.
V = Operation code is available for vendor unique commands.

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MOVE MEDIUM Command

Peripheral Device Type: Automatic Medium Changer
Operation Code Type: Mandatory

MOVE MEDIUM Command

Bit / Byte	7	6	5	4	3	2	1	0
0	Operation Code (37h)							
1	Logical Unit Number			Reserved				
2	(MSB)							
3	Source Address							(LSB)
4	(MSB)							
5	Destination Address							(LSB)
6	Reserved							
7	Reserved							
8	Reserved							Invert
9	Vendor Unique			Reserved			Flag	Link

The MOVE MEDIUM Command (Table _-_) requests that the target move a unit of media between two elements of the automatic medium changer.

The source address specifies the location that the unit of media is taken from. This address may represent a storage element, an input/output element, a data transfer element or a medium transport element. The target shall return a CHECK CONDITION status with the sense key set to ILLEGAL REQUEST if the address specified has not been assigned to a specific element of the automatic medium changer.

The destination address specifies the location that the unit of media is moved to. This address may represent a storage element, an input/output element, a data transfer element or a medium transport element. The target shall return a CHECK CONDITION status with the sense key set to ILLEGAL REQUEST if the address specified has not been assigned to a specific element of the automatic medium changer.

The invert bit is used to specify that the orientation of the unit of media should be reversed prior to placing it at the destination. If the automatic medium changer does not support medium rotation for handling double sided media, this bit is reserved.

READ ELEMENT STATUS Command

Peripheral Device Type: Automatic Medium Changer
Operation Code Type: Optional

READ ELEMENT STATUS Command

Bit / Byte	7	6	5	4	3	2	1	0
0	Operation Code (38h)							
1	Logical Unit Number			Reserved				
2	(MSB)			Starting Element Address				
3								(LSB)
4	(MSB)			Number of Elements				
5								(LSB)
6	Reserved							
7	Reserved							
8	Reserved							
9	Vendor Unique			Reserved			Flag	Link

The READ ELEMENT STATUS Command Table (_-_) provides a means for the target to report the status of its internal elements to the initiator.

The starting element address specifies the first element whose status is to be reported.

The number of elements specifies the number of elements whose status is to be reported.

ELEMENT STATUS Data

Bit / Byte	7	6	5	4	3	2	1	0
0	(MSB)			Starting Cell Address				
1								(LSB)
2	(MSB)			Number of Cells				
3								(LSB)
4	Reserved							
5	Reserved							
	Status Report Data							
2n+4	Element Type Code						Reserved	
2n+5	Vendor Unique			Data Mask				

The starting element address specifies the first element whose status is to be reported.

The number of elements specifies the number of elements whose status is to be reported.

The Element Type Code defines the type of element whose status is being reported. This is used in selecting the proper mask for interpreting the status data being returned.

Element Type Code

Code	Description	Section
0h	No element defined for indicated address	
1h	Storage element	
2h	Input/Output element	
3h	Medium transport element	
4h	Data transfer element	
5h-Fh	Reserved	

The data mask varies depending on the element type as defined below.

No Element Defined for Indicated Address

Data Mask - Element Type Code 0h

Bit	5	4	3	2	1	0
	Reserved					

Some of the addresses within the range specified by the initiator may not have been assigned to any element type. This shall not be considered to be an error. Instead, the target shall respond with the type code bits set to 0h.

Storage Element

Data Mask - Type Code 1h

Bit	5	4	3	2	1	0
	Reserved		Access	Error	Resv'd	Full

The full bit is set to one to indicate that the storage element contains a unit of media. The full bit is set to zero to indicate that the storage element does not contain a unit of media.

The error bit is set to one to indicate that the storage element is in an abnormal state. This bit is set to zero if the storage element is in its normal state.

The access bit is set to one if access to the storage element by the medium transport element is allowed. This bit is set to zero if access to the storage element by the medium transport element is denied.

All other bits in this data mask are reserved.

Input/Output Element Address

Data Mask - Type Code 2h

Bit	5	4	3	2	1	0
	Reserved		Access	Error	I/O	Full

The full bit is set to one to indicate that the Input/Output element contains a unit of media. The full bit is set to zero to indicate that the Input/Output element does not contain a unit of media.

The I/O bit is set to one if the unit of media in the Input/Output element was placed there by an operator. This bit is set to zero if the unit of media in the Input/Output element was placed there by the medium transport element.

The error bit is set to one to indicate that the Input/Output element is in an abnormal state. This bit is set to zero if the Input/Output element is in its normal state. An example of an abnormal state would be if the operator placed the unit of media into the Input/Output element incorrectly.

The access bit is set to one if access to the Input/Output element by the medium transport element is allowed. This bit is set to zero if access to the Input/Output element by the medium transport element is denied. (Implementor's note: An example of when access would be denied is when the operator has access to the Input/Output element.)

All other bits in this data mask are reserved.

Medium Transport Element Address

Data Mask - Type Code 3h

Bit	5	4	3	2	1	0
	Reserved			Error	Full2	Full1

If the medium transport element is only capable of holding one unit of media at a time, the full1 bit is set to one if it is holding a unit of media and the full1 bit is set to zero if it is not holding a unit of media. If the medium transport element is capable of handling two units of media at once, the full1 bit is set to one if the medium transport is holding a unit of media in the first of its medium gripping devices and the full1 bit is set to zero if the medium transport is not holding a unit of media in the first of its medium gripping devices.

If the medium transport element is capable of handling two units of media at once, the full2 bit is set to one if the medium transport is holding a unit of media in the second of its medium gripping devices and the full2 bit is set to zero if the medium transport is not holding a unit of media in the second of

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its medium gripping devices. If the medium transport device is only capable of handling one unit of media at a time, the full2 bit is reserved.

The error bit is set to one to indicate that the medium transport element is in an abnormal state. This bit is set to zero if the medium transport element is in its normal state.

All other bits in this data mask are reserved.

Data Transfer Element Address

Data Mask - Type Code 4h

Bit	5	4	3	2	1	0
	Reserved		Access	Error	Reserved	Full

The full bit is set to one to indicate that the data transfer element contains a unit of media. The full bit is set to zero to indicate that the data transfer element does not contain a unit of media.

The error bit is set to one to indicate that the data transfer element is in an abnormal state. This bit is set to zero if the data transfer element is in its normal state.

The access bit is set to one if access to the data transfer element by the medium transport element is allowed. This bit is set to zero if access to the data transfer element by the medium transport element is denied. (Implementor's note: Access to the data transfer element by the medium transport element might be denied if a data transfer operation were underway.)

All other bits in this data mask are reserved.

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