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Information technology – Fibre channel –
Part 312: Avionics environment upper layer protocol (FC-AE 1553)

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FOREWORD

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- type 2, when the subject is still under technical development or where, for any other reason, there is the future but not immediate possibility of an agreement on an International Standard;
- type 3, when the technical committee has collected data of a different kind from that which is normally published as an International Standard, for example ‘state of the art’.

Technical reports of types 1 and 2 are subject to review within three years of publication to decide whether they can be transformed into International Standards. Technical reports of

type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/IEC TR 14165-312, which is a technical report of type 2, was prepared by subcommittee 25: Interconnection of information technology equipment, of ISO/IEC joint technical committee 1: Information technology.

This document is issued in the type 2 technical report series of publications (according to 16.2.2 of the Procedures for the technical work of ISO/IEC JTC 1 (5th edition, 2004)) as a prospective standard for provisional application in the field of avionics, because there is an urgent requirement for guidance on how standards in this field should be used.

This document is not to be regarded as an International Standard. It is proposed for provisional application so that information and experience of its use in practice may be gathered. Comments on the content of this document should be sent to IEC Central Office.

A review of this type 2 technical report will be carried out not later than three years after its publication with the option of extension for a further three years, conversion into an International Standard or withdrawal.

This Technical Report has been approved by vote of the member bodies, and the voting results may be obtained from the address given on the second title page.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

INTRODUCTION

This part of ISO/IEC 14165 defines a set of features necessary to implement a real-time Fibre Channel network (point-to-point, switched fabric, or arbitrated loop) supporting the FC-AE-1553 Upper Level Protocol.

FC-AE-1553 is intended to support bi-directional communication between two or more N_Ports in a constrained and carefully defined environment, typical of avionics applications. The intended usage is avionic command, control, instrumentation, simulation, signal processing, file distribution, and sensor/video data distribution. These application areas are characterized by a variety of requirements, among them a need for high reliability, fault tolerance, and deterministic behavior to support real-time command/response.

The FC-AE-1553 protocol is based on MIL-STD-1553B Notice 2 with extensions in bandwidth, address space, and data transfer size in order to support low-latency, low overhead communication between elements of a mission-critical avionics system. Some of the key features of FC-AE-1553 are its command/response protocol; options for acknowledged or unacknowledged messaging, RDMA transfers, file transfers; along with the capability to bridge to legacy MIL-STD-1553 terminals.

This part of ISO/IEC 14165 is divided into 4 clauses:

Clause 1 is the scope of this part of ISO/IEC 14165.

Clause 2 enumerates the normative references that apply to this part of ISO/IEC 14165.

Clause 3 describes the definitions, abbreviations, and conventions used in this part of ISO/IEC 14165.

Clause 4 defines the FC-AE-1553 Upper Level Protocol. This clause indicates whether features are Required, Prohibited, Allowed, or Invocable in FC-AE-1553.

This part of ISO/IEC 14165 has three annexes:

Annex A is a normative annex which defines Process Login for the FC-AE-1553 upper layer protocol.

Annex B is an informative annex that contains a profile of the FC-FS and FC-AL-2 standards as an example for avionics Fibre Channel network which uses FC-AE-1553.

Annex C is an informative annex providing information regarding bridging between FC-AE-1553 Fibre Channel networks and MIL-STD-1553 buses.

INFORMATION TECHNOLOGY – FIBRE CHANNEL –

Part 312: Avionics environment upper layer protocol (FC-AE 1553)

1 Scope

This part of ISO/IEC 14165 is intended to serve as an implementation guide to maximize the likelihood of interoperability between conforming implementations. This part of ISO/IEC 14165 Prohibits or Requires features that are optional, and Prohibits the use of some non-optional features in the referenced specifications (see Clause 2).

In addition, this part of ISO/IEC 14165 simplifies implementations and their associated documentation, testing, and support requirements.

This Technical Report does not define internal characteristics of conformant implementations. This part of ISO/IEC 14165 incorporates features from the normative references in Clause 2.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

The provisions of the referenced specifications other than ISO/IEC, IEC, ISO and ITU documents, as identified in this clause, are valid within the context of this document. The reference to such a specification within this document does not give it any further status within ISO or IEC. In particular, it does not give the referenced specification the status of an International Standard.

ISO/IEC 14165-122, *Information technology – Fibre channel – Part 122: Arbitrated loop–2 (FC-AL-2)* [INCITS 332-1999]

ISO/IEC 14165-251, *Information technology – Fibre channel – Part 251: Framing and signalling (FC-FS)* [ANSI INCITS 373:2003]

ISO/IEC 14165-261, *Information technology – Fibre Channel – Part 261: Link Services (FC-LS)* (in preparation)

ANSI INCITS 424, *Information technology – Fibre channel – Framing and Signaling-2 (FC-FS-2)*

3 Terms, definitions and conventions

3.1 General considerations

For FC-AE-1553 (this document), the following terms and definitions, conventions, abbreviations, and acronyms apply. Words used that are defined in referenced standards shall use that definition. Words not defined here or in the referenced standards shall have the standard technical English meaning. See 3.3 for typographical conventions in order to distinguish words or phrases that have special definitions.

Some definitions from the glossary or body of other standards are included here for easy reference.

3.2 Terms and definitions

For the purposes of this document the following terms and definitions apply.

3.2.1
Command Sequence
FC-AE-1553 Fibre Channel Sequence that is always the first Sequence of any FC-AE-1553 Exchange and is always issued by a Network Controller (NC); Command Sequences always have the Information Category bits in the R_CTL field set to 0110'b

NOTE Some profiles may require that all Command Sequences be transmitted as single frames.

3.2.2
Data Sequence
FC-AE-1553 Fibre Channel Sequence that is sent by either an NT or NC; Data Sequences always have the Information Category bits in the R_CTL field set to 0100'b

3.2.3
exchange
basic mechanism which transfers information consisting of one or more related non-concurrent Sequences which may flow in the same or opposite directions

3.2.4
First/Middle/Last
FML
provides an indication of Sequence position within Exchange, where F = first, M = middle, and L = last

3.2.5
frame
information contained in a frame between its Start-of-Frame and End-of-Frame delimiters, excluding the delimiters

3.2.6
Information Category
frame header field indicating the category to which the frame payload belongs (e.g., Solicited Data, Unsolicited Data, Solicited Control and Unsolicited Control)

3.2.7
Network Controller
NC
Fibre Channel Node that transmits FC-AE-1553 Command Sequences (akin to a Bus Controller or BC in MIL-STD-1553)

3.2.8
Network Terminal
NT
Fibre Channel Node that responds to commands issued by the Network Controller (NC) using FC-AE-1553 protocol (akin to a Remote Terminal or RT in MIL-STD-1553)

3.2.9
sequence
set of one or more Data frames with a common Sequence_ID (SEQ_ID), transmitted unidirectionally from one N_Port to another N_Port with a corresponding response, if applicable, transmitted in response to each Data frame

3.2.10
Sequence Initiative
within an Exchange, a Sequence Initiator may either hold Sequence Initiative by transmitting the next Sequence in the Exchange, or transfer Sequence Initiative to the current Sequence recipient; in the latter case, the consecutive sequence recipient transmits the next Sequence in the Exchange

NOTE Abbreviations include: SI = Sequence Initiative, H = hold, and T = transfer. The Sequence Initiative is bit 16 in the Exchange/Sequence Control (F_CTL) field of the Fibre Channel header.

3.2.11
Status Sequence
FC-AE-1553 Fibre Channel Sequence that in most cases is the first Sequence transmitted by an FC-AE-1553 NT

NOTE 1 Status Sequences have the Information Category bits in the R_CTL field set to 0111'b. Some Status Sequences provide an indication of the maximum number of data bytes that the NT is able to receive in the next Data Sequence.

NOTE 2 Some profiles may require that all Status Sequences be transmitted as single-frame Sequences.

3.3 Conventions

3.3.1 General

In this document, a number of conditions, mechanisms, sequences, parameters, events, states, or similar terms that do not have their normal English meaning are printed with the following conventions.

- The first letter of each word in uppercase and the rest lowercase (e.g., Exchange, Class, etc.).
- A term consisting of multiple words, with the first letter of each word in uppercase and the rest lowercase, and each word separated from the other by an underscore (_) character. A word may consist of an acronym or abbreviation, which would be printed in uppercase. (e.g., NL_Port, Transfer_Length, etc.).

All terms and words not conforming to the conventions noted above have the normal technical English meanings.

Numbered items in this part of ISO/IEC 14165 do not represent any priority. Any priority is explicitly indicated.

In all of the figures, tables, and text of this Technical Report, the most significant bit of a binary quantity is shown on the left side. Exceptions to this convention are indicated in the appropriate subclauses.

The term “shall” is used to indicate a mandatory rule. If such a rule is not followed, the results are unpredictable unless indicated otherwise.

The fields or control bits that are not applicable shall be set as required by the appropriate technical report.

If a field or a control bit is specified as not meaningful, the recipient shall not check that field or control bit. The Sequence Initiator shall set all such fields or control bits to zero.

In several tables within this document, there is a column on the right side of the table labelled “Notes”. These notes are NORMATIVE and shall be considered requirements of this Technical Report.

In the event of conflict between the text, tables, and figures in this document, the following precedence shall be used: tables (highest), text and figures (lowest).

3.3.2 Binary notation

Binary notation may be used to represent some fields. Single bit fields are represented using the binary values 0 and 1. For multiple bit fields, the binary value is enclosed in single quotation marks followed by the letter b. For example, a four-byte field containing a binary value may be represented as '00000000 11111111 10011000 11111010'b.

3.3.3 Hexadecimal notation

Hexadecimal notation may be used to represent some fields. When this is done, the value is enclosed in single quotation marks and preceded by the word hex. For example, a four-byte field containing a binary value of '00000000 11111111 10011000 11111010'b is shown in hexadecimal format as hex '00 FF 98 FA'.

3.3.4 Abbreviations and acronyms

Abbreviations and acronyms applicable to this part of ISO/IEC 14165 are listed below. Abbreviations and acronyms for commonly used terms defined in referenced standards are not listed here (e.g., LIP is defined in FC-AL-2).

FC-AE-1553	The mnemonic used to define this FC-AE-1553 profile
NC	Network Controller
NC1 to NC7	Network Controller Information Units
NT	Network Terminal
NT1 to NT8	Network Terminal Information Units

3.4 Applicability and use of this document

Since the nature of this document is a profile, the usual definitions of the following words do not apply. These definitions need to be read carefully.

Required: If a feature or parameter value is Required, it means that it shall be used between compliant implementations. Compliant implementations are required to implement the feature. An implementation may use the feature or other features to communicate with non-compliant implementations. Interoperability is not guaranteed if Required features are not implemented. Each Required feature will include a note that describes the condition(s) in which the feature must be used.

Invocable: If a feature or parameter value is Invocable, it means that it may be used between compliant implementations. Compliant implementations are required to implement the feature. Invocable is different from Required in that an implementation may invoke the feature if needed, but is not required to invoke it. No discovery process is necessary prior to use of an Invocable feature.

Allowed: If a feature or parameter value is Allowed, it means that it may be used between compliant implementations. Compliant implementations are not required to implement the feature. Typically, the potential user of an Allowed feature may determine through a negotiation or discover process if an implementation supports it via an Invocable discovery process.

Prohibited: If a feature is Prohibited, it means that it shall not be used between compliant implementations. An implementation may use the feature to communicate with non-compliant implementations. This document **does not** Prohibit the implementation of features, only their use between compliant implementations. However, interoperability is not guaranteed if Prohibited features are used.

Table 1 summarizes the above definitions.

Table 1 – Summary and use of features

Term	Implementation	Use
Required	Shall	Shall
Invocable	Shall	May
Allowed	May	May
Prohibited	May	Shall Not

The tables in the following clauses list features described in the various technical reports specific to the operations described in the clause. These tables indicate whether the feature is Required, Prohibited, Invocable, or Allowed for compliance with this report; or whether a parameter is Required to be a particular value for compliance with this report. Features or parameters that are not listed do not affect the interoperability of FC-AE devices.

The following legend is used for table entries in these clauses:

‘R’ Required

‘I’ Invocable

‘A’ Allowed

‘P’ Prohibited

‘n’ the parameter shall be set to this value

‘X’ this parameter has no required value; any value is Allowed

‘-’ this parameter or feature is not meaningful

4 FC-AE-1553 profile

4.1 General

This clause describes an FC-4 mapping layer intended to provide a deterministic command/response protocol for use in real-time flight critical and mission critical avionics applications. One of the primary motivations for this ULP mapping is to enable the leveraging of existing system designs, hardware, and software written for MIL-STD-1553 avionics networks. The mnemonic for this upper layer protocol is FC-AE-1553.

This clause includes a description of the differences between MIL-STD-1553B and FC-AE-1553, information relating to mapping and bridging to legacy 1553 devices, a description of the FC-AE-1553 Exchange formats, a profile delineating the required and optional FC-AE-1553 features, a delineation of Exchange validation criteria, the mapping from the FC-AE-1553 ULP to Fibre Channel FC-FS and FC-AL-2, and a profile section specifying the required, optional and prohibited FC-FS and FC-AL-2 Fibre Channel features.

4.2 FC-AE-1553 elements

Some of the key FC-AE-1553 elements are the Network Controller or NC, the Network Terminal or NT, the Fibre Channel network itself; and in cases where legacy MIL-STD-1553 data buses are connected to the network, FC-AE-1553 to MIL-STD-1553 bridges, MIL-STD-1553 buses, and MIL-STD-1553 RT devices. There may be one or multiple active Network Controllers on an FC-AE-1553 network. One of the main functions of the Network Controllers is to provide the scheduling of all FC-AE-1553 transmissions on the network.

Like MIL-STD-1553, FC-AE-1553 defines a command/response protocol, with an added (controller) option to suppress status responses. The Network Terminal (NT) consists of a Fibre Channel interface located inside a subsystem or sensor connected to a Fibre Channel

network. The NT's primary function is to perform data transfers between the subsystem and the Fibre Channel network as directed by the Network Controller(s).

Individual nodes on an FC-AE-1553 network may function as NCs and NTs simultaneously.

While FC-AE-1553 is based largely on MIL-STD-1553B Notice 2 constructs, it includes extensions that provide capability beyond standard MIL-STD-1553. These extensions include the ability to allow for a substantially larger maximum number of terminals (2^{24}), increased word counts (2^{32} bytes), and a larger subaddress space (2^{32}).

FC-AE-1553 includes an option for RDMA (remote DMA) functionality, in which the subaddress field is used as the starting byte address for a transfer to or from a remote NT's address space. For an RDMA type of Exchange, the value of the subaddress represents an address on a 32-bit boundary. FC-AE-1553 also includes capabilities for file transfers. These include multiple options enabling NTs or NCs receiving files to be able to regulate the timing and size of individual transmitted Data Sequences.

Table 2 provides a comparison between terminology used in MIL-STD-1553 and FC-AE-1553.

Table 2 – Terminology equivalents between MIL-STD-1553 and FC-AE-1553

MIL-STD-1553	FC-AE-1553
Bus Controller (BC)	Network Controller (NC)
Remote Terminal (RT)	Network Terminal (NT)
RT Address	Network Terminal Address
RT Subaddress	NT Subaddress (NT_SA)
MIL-STD-1553 Message	FC-AE-1553 Exchange
Command Word	Command Sequence
Status Word	Status Sequence

FC-AE-1553 also takes full advantage of the network topology offered by Fibre Channel (as opposed to MIL-STD-1553's bus topology), allowing simultaneous data traffic across the network and multiple Network Controller entities. This mapping also supports the aggregation of multiple MIL-STD-1553 buses into a common FC-AE-1553 network, while maintaining an equivalent functionality of individual MIL-STD-1553 buses.

Unless otherwise stated, all references to data field sizes for FC-AE-1553 are in bytes, rather than 16-bit words. However, for FC-AE-1553 Exchanges which are bridged to MIL-STD-1553 messages, there are specific references to 16-bit words transmitted over MIL-STD-1553 buses.

4.3 Mapping legacy 1553 applications to FC-AE-1553

4.3.1 General

A fundamental purpose of the FC-AE-1553 mapping is to enable interoperability for interfacing legacy MIL-STD-1553 remote terminals to a Fibre Channel network.

The FC-AE-1553 protocol supports the mapping of legacy MIL-STD-1553 16-bit command words to FC-AE-1553 header extension fields (see Table 7). The use of the Fibre Channel frame header and FC-AE-1553 header extension fields in FC-AE-1553 applications supports larger RT address and subaddress spaces, and larger data payload sizes than MIL-STD-1553. These differences are summarized in Table 3.

Table 3 – Comparison of MIL-STD-1553 and FC-AE-1553 Command Field Sizes

MIL-STD-1553		FC-AE-1553	
RT Address	5 bit	NT Address (D_ID / S_ID)	24 bit
Subaddress	5 bit	NT Subaddress (NT_SA)	32 bit
Word Count/Mode Code	5 bit	Byte Count/Mode Code [a]	32 bit
[a] The Mode Code field is the lower 5 bit of the Byte Count/Mode Code field.			

While FC-AE-1553 applications will be able to leverage the increased command field sizes, the following provisions accommodate the mapping of legacy MIL-STD-1553 applications to FC-AE-1553.

4.3.2 NT address

Any port on a FC-AE-1553 network may operate as a Network Controller (NC), akin to a MIL-STD-1553 Bus Controller, or BC; a Network Terminal (NT), akin to a MIL-STD-1553 Remote Terminal or RT; or both. For Command and Data Sequences transmitted by Network Controllers, the 24-bit Fibre Channel D_ID or NT Address field performs the function of the MIL-STD-1553 5-bit RT address field, while the Fibre Channel S_ID field is used to specify an NT address for the Network Controller. For Status and Data Sequences transmitted by Network Terminals, the 24-bit S_ID field provides acknowledgement by indicating the terminal's "NT Address", while the value of the D_ID field is the port address of the destination NC or, for an NT-to-NT transfer Exchange, the destination NT.

FC-AE-1553 includes provisions to support bridging to existing MIL-STD-1553 (1 MHz) RTs. To enable this bridging, the upper 22 bit (31 to 10) of the FC-AE-1553 Subaddress field may be used to identify a specific FC-AE-1553-to-MIL-STD-1553 bridge that's built into an N_Port or NL_Port. If Subaddress bits (31 to 10) identify a bridge, then, for a particular FC-AE-1553 Exchange, bits (9 to 5) identify the MIL-STD-1553 RT address of the bridged RT, while bits (4 to 0) identify the Subaddress of the bridged MIL-STD-1553 RT.

FC-AE-1553 supports multiple options for implementing broadcast and multicast:

a) all FC-AE-1553 NTs and NCs shall recognize the Fibre Channel well known broadcast address of hex 'FF FF FF';

b) all FC-AE-1553 NTs and NCs on an arbitrated loop shall recognize the broadcast replicate AL_PA address of hex 'FF';

c) to support broadcast functionality for RTs on a MIL-STD-1553 bus bridged from an FC-AE-1553 port, the NC may specify a value of hex '1F' (the MIL-STD-1553 broadcast address) for (9 to 5) of the FC-AE-1553 Subaddress field. For such an Exchange, the value of the FC-AE-1553 D_ID field **is** not required to be 'FF FF FF';

d) FC-AE-1553 Network Terminals on a fabric shall respond to arbitrary alias addresses (multicast groups);

e) FC-AE-1553 Network Terminals on an arbitrated loop shall support selective replicate.

4.3.3 NT subaddress

As shown in Table 7, words 6 through 11 of all FC-AE-1553 Command Sequences following the Fibre Channel Header comprise the FC-AE-1553 Command Sequence header extension. For all Command Sequences, word 7 in Table 7 is used to specify the FC-AE-1553 subaddress. The FC-AE-1553 subaddress values of either hex '00 00 00 00' or hex 'FF FF FF FF' shall specify an FC-AE-1553 mode code Exchange, akin to hex '00' and hex '1F' for the MIL-STD-1553 subaddress field. For all Exchanges involving data transfers, FC-AE-1553 provides an option for RDMA (remote direct memory access). When this option is

invoked, the subaddress field is used to designate the 32-bit starting byte address for a transmitting and/or receiving NT. For an NT-to-NT transfer, the NC has the option of using either or both of the receive and/or transmitting subaddresses to specify DMA starting address(es) in NT memory.

A FC-AE-1553 NT (N_Port or NL_Port) may connect to one or more Fibre-Channel-to-MIL-STD-1553 bridges. To enable FC-AE-1553 Exchanges to be bridged to messages to MIL-STD-1553 RTs, the upper 22 bit of the FC-AE-1553 subaddress field may be used to designate a particular MIL-STD-1553 bus (bridge) connected with a specific NT. To prevent conflicts with FC-AE-1553 mode code Exchanges, values of the subaddress field for which the upper 22 bit are all zeros or all ones shall not be used to designate the 1553 bus number for a bridge device. For bridged Exchanges, the MIL-STD-1553 RT address maps to bits (9 to 5) of the FC-AE-1553 Subaddress field, while the MIL-STD-1553 Subaddress field maps to the lower 5 bit (4 to 0) of the FC-AE-1553 Subaddress field.

4.3.4 Byte Count/Mode code

For all Exchanges, the MIL-STD-1553 Data Word Count/Mode Code field is mapped to FC-AE-1553 Command Sequence word 8 in Table 7, the Byte Count/Mode Code. MIL-STD-1553B specifies 5 bits for this function, allowing a transfer of a maximum of 32 16-bit words (64 bytes) to be transmitted or received by an RT. FC-AE-1553 allocates 32 bits for this function, enabling data transfers exceeding 4 billion bytes for a single FC-AE-1553 Exchange.

For Exchanges involving bridges to MIL-STD-1553 RTs, the upper 25 bits of the FC-AE-1553 Byte Count/Mode Code field shall all have values of ‘0’b. For an Exchange to be bridged to a MIL-STD-1553 bus or RT, the value of the FC-AE-1553 Byte Count field shall be formulated by means of a one bit left-shift of the MIL-STD-1553 word count, and the LSB of the byte count shall be assigned a value of ‘0’b. If the MIL-STD-1553 word count is an odd number, a value of 2 (10b) shall be assigned to the Fill Bytes bits in the F_CTL field. If the MIL-STD-1553 word count is an even number, a value of 0 (00b) shall be assigned to the Fill Bytes bits in the F_CTL field.

For all FC-AE-1553 mode code Exchanges involving the mode codes defined by 4.4.4.2.1 through 4.4.4.2.17, the upper 27 bit of the FC-AE-1553 word count/mode code field shall have values of ‘0’b. For these Exchanges, the values of the lower five bits shall be equal to those for the respective MIL-STD-1553 mode code, as described in 4.4.4.2.2 through 4.4.4.2.18.

4.4 FC-AE-1553 ULP features

4.4.1 Information units

This section details the FC-AE-1553 Information Units. For FC-AE-1553, all information units (IUs) are defined as full Sequences.

Table 4 defines the Information Units (IUs) transmitted from a FC-AE-1553 Network Controller to one or more Network Terminals, along with the IUs transmitted by the transmitting NT for NT-to-NT or NT-to-multiple NTs transfers. Table 5 defines the Information Units transmitted from Network Terminals to Network Controllers or to other Network Terminals. For FC-AE-1553, all information units are defined as full Sequences.

If an NC or NT transmits data in a Command or Status Sequence to be followed by one or more Data Sequences, the number of data bytes transmitted in the Command or Status Sequence shall be a multiple of four. If an NC or NT transmits multiple Data Sequences, then the number of data bytes transmitted in all Data Sequences except for the last one shall be a multiple of four.

Table 4 – Information units transmitted by the Network Controller to Network Terminal, and transmissions by the transmitting NT for NT-to-NT or NT-to-NTs transfers

IU	FC-AE-1553 primitive	CAT	Content	F/M/L	SI
NC1	- Command Sequence for NC-to-NT transfers with Suppress Status = '0'b; consists of FC-AE-1553 command header extension plus up to 2 048 data bytes. Not followed by a Data Sequence. - Command Sequence for NC-to-NT transfers with no data bytes with NT Burst Size Request ='1'b and Delayed NT Burst Size Request ='0'b. - Command Sequence for NC-to-NT transfers with no following Data Sequence, and Suppress Status = '0'b. - Command Sequence with no data bytes sent by transmitting NT for NT-to-NT transfer with NT Burst Size Request ='1'b and Delayed NT Burst Size Request ='0'b. - Command Sequence for NT-to-NC transfers. - Command Sequence for originating NC for NT-to-NT(s) transfers, with Suppress Status = '0'b. - Command Sequence for mode code Exchanges (with or without data word). - Command Sequence for transmitting NT for NT-to-NT transfer Exchanges with Suppress Status = '0'b; consists of FC-AE-1553 command header extension plus up to 2 048 data bytes. Not followed by a Data Sequence.	6	Command, or Command + Data	F	T
NC2	- Command Sequence for NC-to-NT transfers; consists of FC-AE-1553 command header extension plus up to 2 048 data bytes, and is followed by one or more Data Sequences. - Command Sequence with no data bytes sent by NC with NT Burst Size Request = '1'b and Delayed NT Burst Size Request = '0'b. - Command Sequence with no data bytes sent by the transmitting NT of an NT-to-NT transfer, with NT Burst Size Request = '1'b and Delayed NT Burst Size Request = '0'b. - Command Sequence sent by transmitting NT for NT-to-NT or NT-to-NTs transfer Exchanges; consists of FC-AE-1553 command header extension plus up to 2 048 data bytes , and is followed by one or more Data Sequences. - Command Sequence for NC-to-NT transfers, followed by a Data Sequence. - Command Sequence for transmitting NT for NT-to-NT transfer Exchanges with Suppress Status = '1'; consists of FC-AE-1553 command header extension plus up to 2 048 data bytes . Not followed by a Data Sequence.	6	Command, or Command + Data	F	H

IU	FC-AE-1553 primitive	CAT	Content	F/M/L	SI
NC3	- Single Data Sequence that is not the last of a number of Data Sequences with either NT Burst Size Request = '1'b or Delayed NT Burst Size Request = '1', transmitted for an NC-to-NT transfer Exchange. - Data Sequence that's not the last of a number of Data Sequences with either NT Burst Size Request = '1'b or Delayed NT Burst Size Request = '1'b, transmitted by the transmitting NT for an NT-to-NT transfer Exchange. - Single Data Sequence, or the last of a number of Data Sequences (with NT Burst Size Request = '1'b or Delayed NT Burst Size Request = '1'b) transmitted for an NC-to-NT transfer Exchange with Suppress Status = '0'b. - Single Data Sequence, or the last of a number of Data Sequences (with NT Burst Size Request = '1'b or Delayed NT Burst Size Request = '1'b) sent by the transmitting NT for an NT-to-NT(s) transfer Exchange with Suppress Status = '0'b. - Single Data Sequence sent by NC for NC-to-NTs transfers with Suppress Status = '0'b.	1	Data	M	T
NC4	- Command Sequence for NC-to-Multiple NTs transfers, with Suppress Status = '1'b. Consists of FC-AE-1553 command header extension plus up to 2 048 data bytes. Not followed by NC Data Sequence. - Command Sequence for originating NC for NT-to-NT(s) transfers with Suppress Status = '1'b. - Command Sequence for transmitting NT for NT-to-NT(s) transfers with no following Data Sequence, and Suppress Status = '1'b. - Mode Command Sequence (with or without data word) to multiple NTs Exchanges. - Command Sequence for non-broadcast mode code Exchanges with Suppress Status = '1'b (with or without data word).	6	Command, or Command + Data	F & L	H

IU	FC-AE-1553 primitive	CAT	Content	F/M/L	SI
NC5	- Data Sequence for NC-to-NT transfer, with Suppress Status = '1'b and NT Burst Size Request = '0'b and Delayed NT Burst Size Request = '0'b. - Single Data Sequence with Suppress Status = '1'b. - Last Data Sequence for NC-to-NT transfer, with Suppress Status = '1'b, and either NT Burst Size Request = '1'b or Delayed NT Burst Size Request = '1'b. - Single Data Sequence following the Command Sequence for NC-to-NTs transfers. - Single Data Sequence, or Last Data Sequence with either NT Burst Size Request = '1'b or Delayed NT Burst Size Request = '1'b following the Command Sequence for the transmitting NT for NT-to-multiple NTs transfer Exchanges. - Single Data Sequence sent by NC for NC-to-NTs transfers, with Suppress Status = '1'b.	1	Data	L	H
NC6	- Data Sequence other than the last Data Sequence, for NC-to-NT transfer with NT Burst Size Request = Delayed NT Burst Size Request = '0'b. - Data Sequence other than the last Data Sequence, for the transmitting NT of an NT-to-NT transfer with NT Burst Size Request = Delayed NT Burst Size Request = '0'b.	1	Data	M	H
NC7	- For an NT-to-NT transfer for the case where the originating NC is also the receiving NT and Suppress Status = '1'b, last Data Sequence transmitted by the transmitting NT. - For an NC-to-multiple NTs or NT-to-multiple NTs transfers, and Suppress Status = '0'b, the last Data Sequence transmitted by the NC or transmitting NT.	1	Data	L	T

Key
IU = Information Unit
CAT = Information Category
F/M/L = Sequence position within Exchange, where F = first, M = middle, and L = last
SI = Sequence Initiative (H = hold, T = transfer; this bit is only valid for the last frame of each Sequence)

Table 5 – Information Units Initiated from the Network Terminal, Excluding Transmissions by the Transmitting NT for NT-to-NT or NT-to-NTs Transfers

IU	FC-AE-1553 Primitive	CAT	Content	F/M/L	SI
NT1	- Status Sequence, response to NC-to-NT transfer with Suppress Status = '0'b; consists of FC-AE-1553 Status Sequence header extension, but no data. - Status + Data Sequence, in response to NT-to-NC transfer; consists of FC-AE-1553 Status Sequence header extension plus up to 2 048 data bytes . Not followed by an NT Data Sequence. - Status Sequence, response from receiving NT to transmitting NT for NT-to-NT transfer; consists of FC-AE-1553 status header extension, but no data bytes. - Status Sequence, response from transmitting NT to NC for NT-to-NT transfer; consists of FC-AE-1553 status header extension, but no data bytes. - Status Sequence; response to mode command, with or without data. - Status Sequence, response to NT-to-Multiple NTs transfer command from transmitting NT; consists of FC-AE-1553 Status Sequence header extension, but no data bytes.	7	Status, or Status + Data	L	T
NT2	- Status Sequence, response to NT-to-NC transfer; consists of FC-AE-1553 Status header extension plus up to 2 048 data bytes , followed by an NT Data Sequence.	7	FC-AE-1553 Status + Data	M	H
NT3	- Final Data Sequence transmitted by NT for NT-to-NC transfer Exchanges following the Status Sequence.	1	Data	L	T
NT4	Reserved				
NT5	- Status Sequence comprising single-Sequence Exchange; comprises the response Exchange from receiving NTs for NC-to-Multiple NTs or NT-to-Multiple NTs transfer; only sent if Suppress Status = '0'b.	7	Status	F & L	T
NT6	- Status Sequence with no data bytes, in response to a command sent by an NC or originating NT for NT-to-NT transfer, with either NT Burst Size Request = '1'b or Delayed NT Burst Size Request = '1'b.	7	Status	M	T
NT7	- Data Sequence, other than the last Data Sequence, for NT-to-NC transfer.	1	Data	M	H
Key IU = Information Unit Type CAT = Information Category F/M/L = Sequence position within Exchange, where F = first, M = middle, and L = last SI = Sequence Initiative (H = hold, T = transfer; this bit is only valid for the last frame of each Sequence)					

4.4.2 Exchange formats

4.4.2.1 General

The following subclauses describe the MIL-STD-1553B message formats as they are mapped to FC-AE-1553 Exchanges.

In all cases, an NT shall not respond with a Status Sequence following reception of any Command Sequence, Data Sequence, or Status Sequence that it determines to be invalid.

If a valid and allowable response does not occur within the specified timeouts below, an NC or an NT that detects the error shall determine that the exchange is invalid due to a link or protocol error.

For either an NC or an NT, any previous and/or future data received for the Exchange shall be discarded.

In the case of an NC or transmitting NT for an NT-to-NT transfer, if an NC or transmitting NT determines an Exchange to be invalid or detects a timeout, it shall terminate the Exchange by truncating any further transmission to the NT(s), and ignoring any subsequent data or status received from the NT. In addition, the NC may invoke the ABTS-LS Basic Link Service (see 4.4.4.7).

In the case of an NT (except for the transmitting NT for an NT-to-NT transfer), if an NT determines an Exchange to be invalid or detects a timeout, the NT shall not transmit any additional Status Sequence(s) for that Exchange, and shall terminate the Exchange.

4.4.2.2 FC-AE-1553 Network Controller to Network Terminal transfers (write-type commands)

4.4.2.2.1 NC-to-NT

The NC shall initiate a NC-to-NT receive Command Sequence. The same process shall be used for an Exchange involving transmitting and receiving NTs for an NT-to-NT transfer.

4.4.2.2.2 NT Burst Size Request = '0'b and delayed NT Burst Size Request = ‘0’b

For the case where NT Burst Size Request is set to '0'b and Delayed NT Burst Size Request is set to ‘0’b (see Figure 1), the Network Controller transmits the command IU, or the command and data IUs without any data IU pacing by the NT. The Network Controller shall transmit a Command Sequence (NC1 IU, NC2 IU or NC4 IU, as appropriate), including or followed by the specified number of data bytes. If the Command Sequence contains all of the data, an NC1 IU (for Suppress Status = ‘0’) or NC4 IU ((for Suppress Status = ‘1’) is transmitted. The maximum number of data bytes that may be transmitted in the Command Sequence is 2048.

If some or all of the data is to be transmitted in one or more separate Data Sequences, an NC2 IU shall be transmitted first followed by one or more Data Sequences. The Data Sequence(s) are comprised of zero or more NC6 IUs that shall be followed by an NC3 IU (for Suppress Status = ‘0’) or an NC5 IU (for Suppress Status = ‘1’).

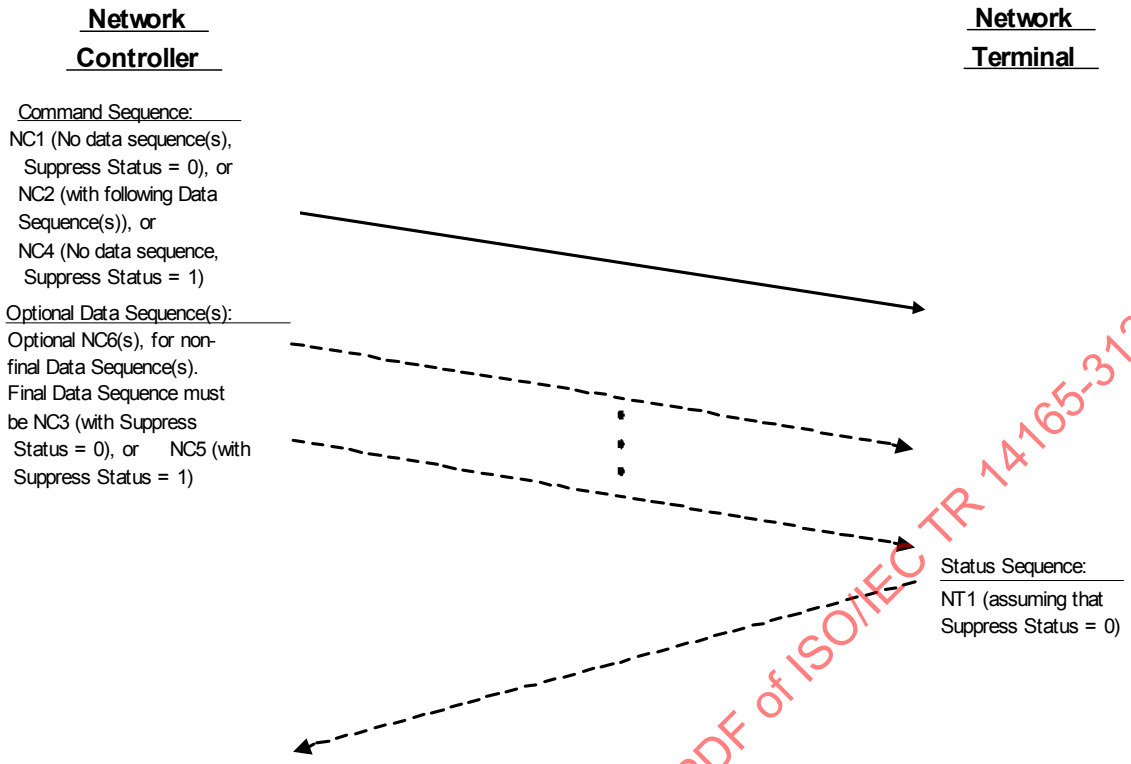

Figure 1 – Network Controller To Network Terminal transfers: NT Burst Size Request = '0'b, Delayed NT Burst Size Request = '0'b

If Suppress Status is set to '0'b in the Command Sequence (NC2 or NC1 IU) and after all data has been received and validated in accordance with 4.4.4.5 (when NC2 is sent, the NT receives zero or more NC6 IUs followed by one NC3 IU), the NT shall transmit a Status Sequence (NT1 IU) to the Network Controller within the time NT_C/S_TOV and shall terminate the Exchange. The maximum time between the end of the Command Sequence and the start of the first Data Sequence, as well as the maximum time between Data Sequences, shall be C/S_D_TX_TOV.

If Suppress Status is set to '1'b in the Command Sequence (NC2 IU or one NC4 IU only), the Network Controller shall terminate the Exchange when the NC4 IU or last Data Sequence is transmitted. When an NC2 IU is transmitted, zero or more NC6 IUs may be transmitted followed by the transmission of one NC5 IU.

4.4.2.2.3 NT Burst Size Request = '1'b and Delayed NT Burst Size Request = '0'b

For the case where NT Burst Size Request = '1' and Delayed NT Burst Size Request = '0' (see Figure 2), the Network Controller is requesting the NT to perform Data IU pacing. The Network Controller shall transmit a Command Sequence (NC1). This IU shall not contain any data bytes. If the NT receives a valid Command Sequence, it shall respond with a Status Sequence (NT6 IU) with the Busy bit in the Status Sequence set appropriately within NT_C-D/S_BURST_TOV.

A Busy bit set to a value of '1'b indicates that the NT is not ready to receive data and terminates the Exchange with this Status Sequence.

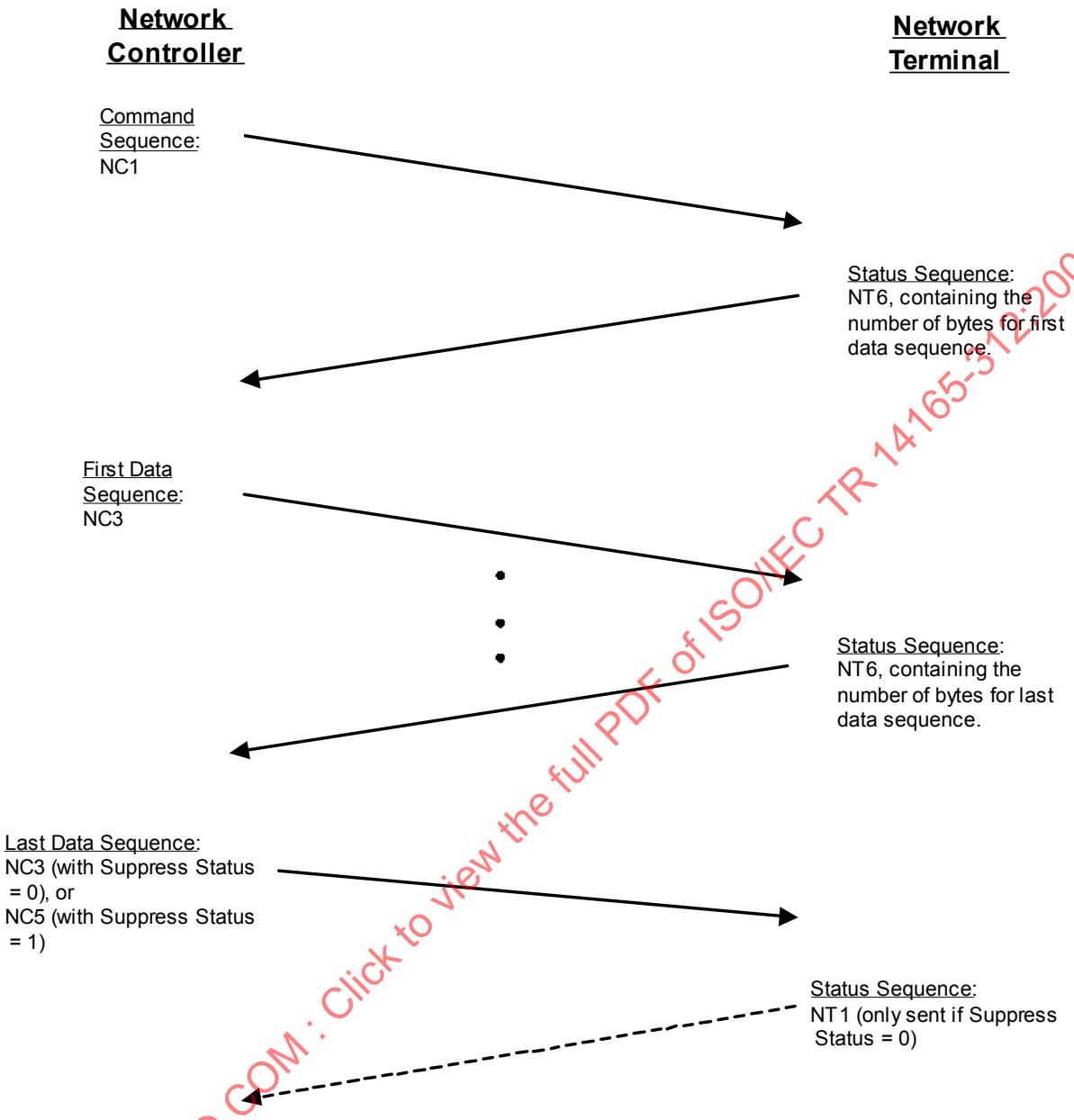

Figure 2 – Network Controller To Network Terminal Transfers: NT Burst Size Request = '1'b, Delayed NT Burst Size Request = '0'b

A Busy bit set to '0'b and Burst Size Acknowledge set to '1'b within NT_C-D/S_BURST_TOV indicates that the value in word 7 of the Status Sequence is the maximum number of data bytes that the NT is able to receive in the first Data Sequence. Following reception and validation of the NT6 (Status) IU within NC_CD_BURST_TOV, the NC shall transmit an appropriate Data Sequence (NC3 IU or NC5 IU) of less than or equal to the maximum length. When the NC determines that the requested Data Sequence will have transferred the total number of data bytes indicated in the Command Sequence, the last or only Data Sequence shall transfer Sequence Initiative with an NC3 IU if Suppress Status in the Command Sequence = '0' or terminate the Exchange with an NC5 IU if Suppress Status = '1'. All intermediate Data Sequences, if any, shall be NC3 IUs.

To elaborate on this case, following reception and validation of the Status Sequence within NC_C-D/S_BURST_TOV, the NC shall transmit a Data Sequence with a total payload length of the indicated size. When the NT has received and validated this Data Sequence and not all data has been received and the NT is ready to receive an additional Data Sequence, it shall transmit a second Status Sequence, again within NT_C-D/S_BURST_TOV and indicating the

number of bytes that it is able to receive in the next Data Sequence. This process is repeated until the NT has requested and received the total number of data bytes indicated in the Command Sequence.

After all data has been received and validated, the NT shall respond based on the setting of the Suppress Status bit in the Command Sequence.

If Suppress Status is set to '0'b in the Command Sequence and after all data has been received and validated, the NT shall transmit a Status Sequence (NT1 IU) to the Network Controller within the time NT_C/S_TOV and shall terminate the Exchange. For this final Status Sequence, the value of Burst Size Acknowledge shall be set to '0'b.

If Suppress Status is set to '1'b in the Command Sequence, the NC shall terminate the Exchange on the last Data Sequence (NC5 IU) that fulfills the byte count requested. In this case, there is no response from the NT.

4.4.2.2.4 Delayed NT Burst Size Request = '1'b and NT Burst Size Request = '0'b

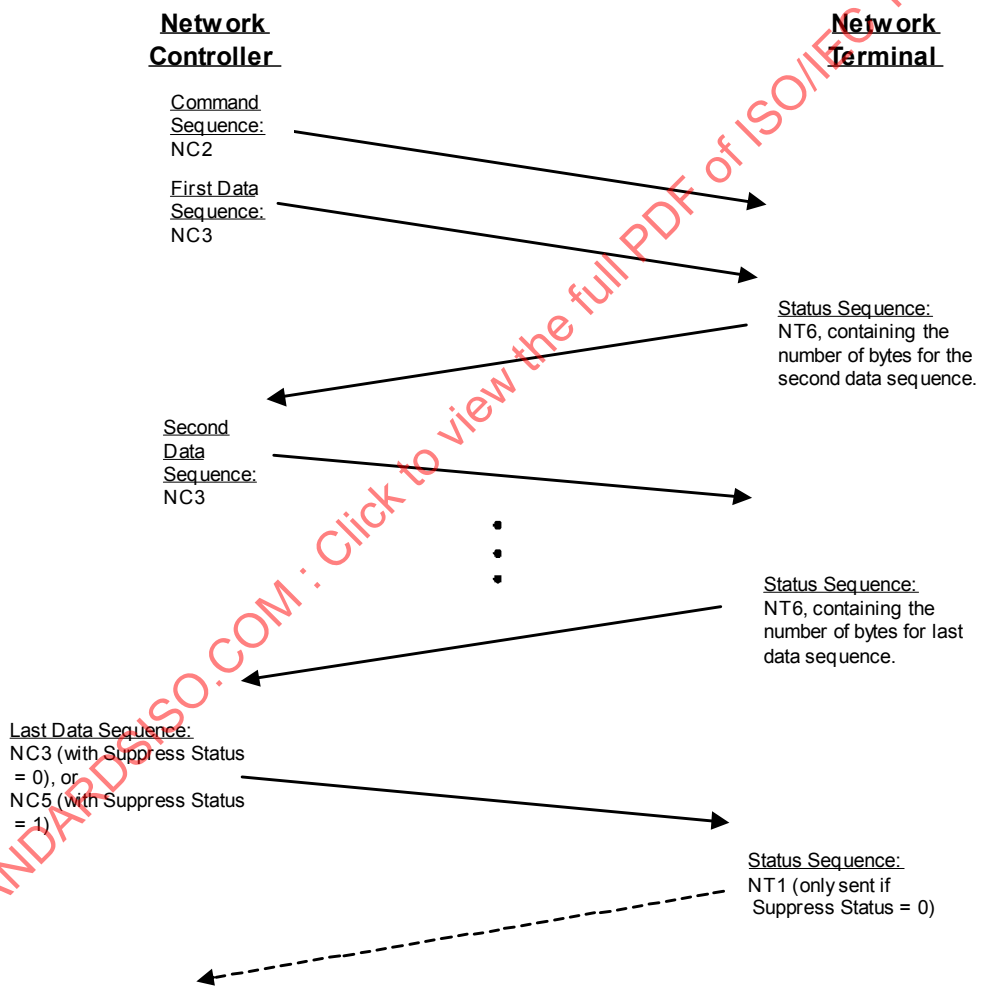

Figure 3 – Network Controller to Network Terminal transfers: NT Burst Size Request = '0'b, Delayed NT Burst Size Request = '1'b

For the case where Delayed NT Burst Size Request (see 4.4.4.1.12) is set to '1'b and NT Burst Size Request (see 4.4.4.1.11) is set to '0'b (see Figure 3), the Network Controller shall transmit an NC2 Command Sequence containing up to 2 048 data bytes, followed within C/S_D_TX_TOV by an NC3 Data Sequence. The maximum number of bytes transmitted in the Command Sequence and in the first Data Sequence shall be specified by the NT, by means of implicit or explicit FC-AE-1553 Process Login.

Assuming the NT receives a valid Command Sequence followed by a valid Data Sequence, the NT shall respond with an NT6 Status Sequence within NT_C-D/S_BURST_TOV. If the Busy bit in the Status Sequence has a value of '1'b, this indicates that the NT isn't ready to receive data, thereby terminating the Exchange. The NT shall not process the received data, and the NC shall assume that none of the data transmitted was processed.

If the NT responds with Busy set to '0' and a value of Burst Size Acknowledge set to '1'b, then word 7 of the NT Status Sequence shall indicate the maximum number of data bytes that the NT is able to receive within the next single Data Sequence from the NC. If Burst Size Acknowledge is set to '0'b, the NC transmits no Data Sequence and terminates the Exchange.

In the case where the NT responds with Busy set to '0' and Burst Size Acknowledge set to '1'b, following the NC's reception and validation of the Status Sequence within NC_C-D/S_BURST_TOV, the NC shall transmit an NC3 Data Sequence of less than or equal the indicated size. When the NT has received and validated this Data Sequence and is ready to receive a subsequent NC3 or NC5 Data Sequence, it shall transmit another NT6 Status Sequence, again within NT_C-D/S_BURST_TOV and indicating the maximum number of bytes that it is able to receive in the next Data Sequence. This process is repeated until the NT has received the total number of data bytes indicated in the Command Sequence. The last Data Sequence transmitted by the NC shall be an NC3 IU if Suppress Status in the Command Sequence was set to '0', or an NC5 IU if Suppress Status was set to '1'.

After all data has been received and validated, the NT shall respond based on the setting of the Suppress Status bit in the Command Sequence.

If Suppress Status is set to '0'b in the Command Sequence and after all data has been received and validated, the NT shall transmit a Status Sequence (NT1 IU) to the Network Controller within the time NT_C/S_TOV and shall terminate the Exchange. For this final Status Sequence, the value of Burst Size Acknowledge shall be set to '0'b.

If Suppress Status is set to '1'b in the Command Sequence, the NC shall terminate the Exchange on the last (NC5 IU) Data Sequence that fulfills the byte count in the Command Sequence. In this case, there shall be no response from the NT.

Similarly, the NC shall terminate the Exchange when the full data byte count has not been transmitted, and a valid Status Sequence with the Busy bit set to '0' and the Burst Size Acknowledge bit set to '1'b is not received within NC_C-D/S_BURST_TOV, or when the NC does not receive a valid final Status Sequence (when requested) within NT_C/S_TOV, or when the NC detects any invalid Status Sequence.

4.4.2.3 Network Terminal to Network Controller transfers (Read-Type Commands)

Network Terminal to Network Controller transfers is shown in Figure 4.

The NC shall send an NT-to-NC transmit Command Sequence (NC1 IU) to the NT.

Within NT_C/S_TOV following command verification, the NT shall transmit a Status Sequence back to the Network Controller. If all of the NTs transmitted data bytes (2 048 maximum in this case) are contained in the Status Sequence, then this shall be an NT1 IU. However, if the NT transmits one of more Data Sequences after the Status Sequence, then the Status Sequence shall be an NT2 IU.

If the NT transmits one or more Data Sequences following the Status Sequence, then all Data Sequences except for the last one shall be NT7 IUs, while the last Data Sequence shall be an NT3 IU. In this case, the maximum allowable time between the end of the NT's Status Sequence and the start of its first Data Sequence, as well as the maximum time between Data Sequences, shall be C/S_D_TX_TOV.

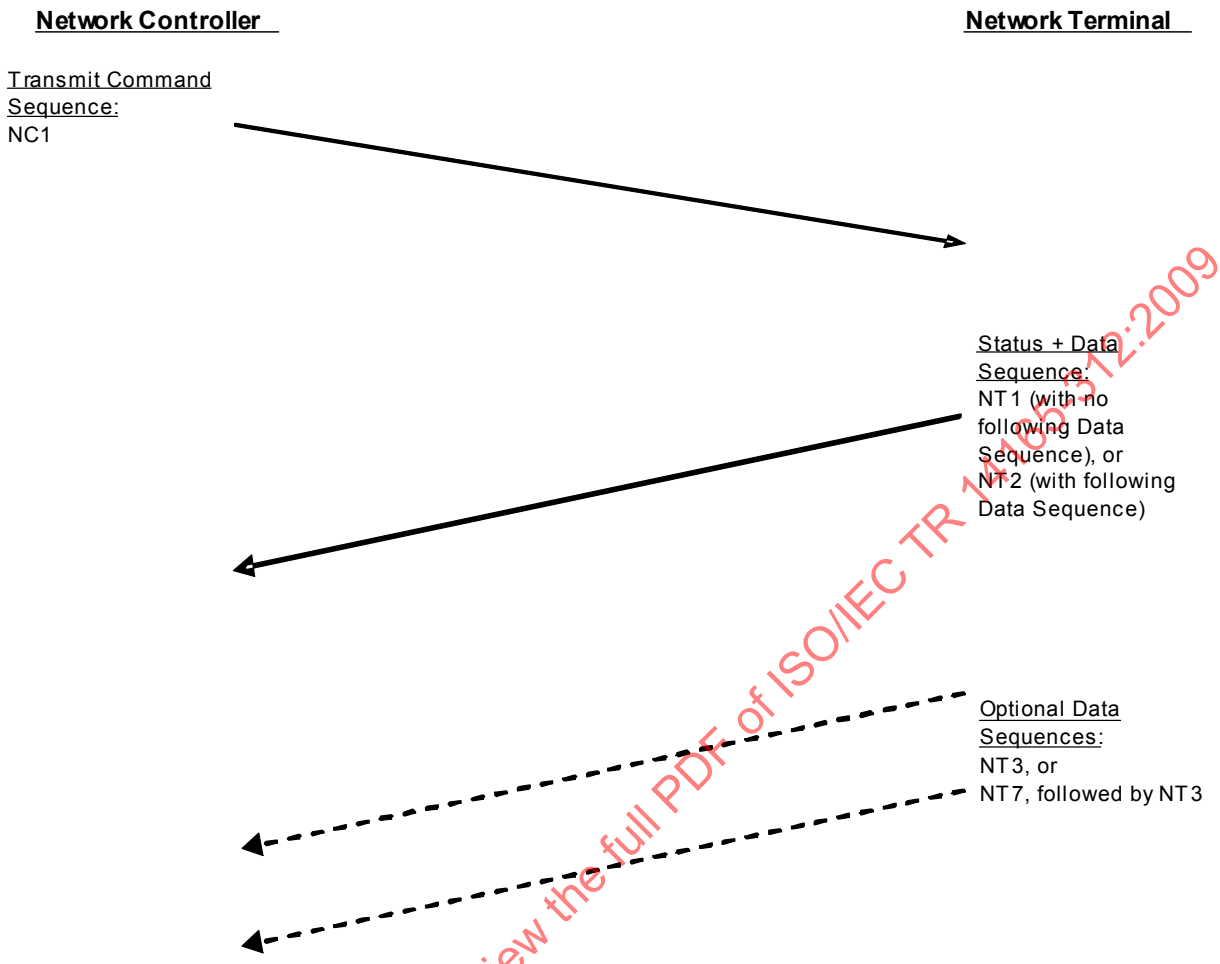

Figure 4 – Network Terminal-to-Network Controller transfers

4.4.2.4 Network Terminal to Network Terminal transfers (Third Party transfers)

4.4.2.4.1 General

Network Terminal to Network Terminal transfers consist of two Exchanges, involving a total of four or more Sequences, as illustrated in Figure 5 through Figure 9 and described as follows.

4.4.2.4.2 Burst Size Request = '0'b, Delayed NT Burst Size Request = '0'b

For the first Exchange (see Figure 5), the originating Exchange, the NC sends a transmit Command Sequence to the transmitting NT. If Suppress Status is set to '0', the Command Sequence shall be an NC1 IU. If Suppress Status is set to '1', the Command Sequence shall be an NC4 IU. This Command Sequence includes the Port_ID and Subaddress for the receiving NT in the Multicast or Other Port_ID and Other Subaddress fields respectively.

Within NT_C/S_TOV following the reception of the transmit Command Sequence (NC1 IU or NC4 IU) from the NC, the transmitting NT shall initiate the second Exchange, which is the Responding Exchange, by transmitting a receive Command Sequence to the receiving NT. The value of bits 8 through 3, 1, and 0 in Word 6 of this receive Command Sequence shall be the same as the corresponding bits in Word 6 of the transmit Command Sequence sent by the originating NC. If Suppress Status is set to '0' and all of the transmitting NT's data bytes (up to 2 048 maximum) are contained in the Command Sequence, then the Command Sequence shall be an NC1 IU. If the transmitting NT transmits one or more Data Sequences, then the Command Sequence shall be an NC2 IU. If Suppress Status is set to '1' and all of the

transmitting NT's data bytes (up to 2 048 maximum) are contained in the Command Sequence, then the Command Sequence shall be an NC4 IU.

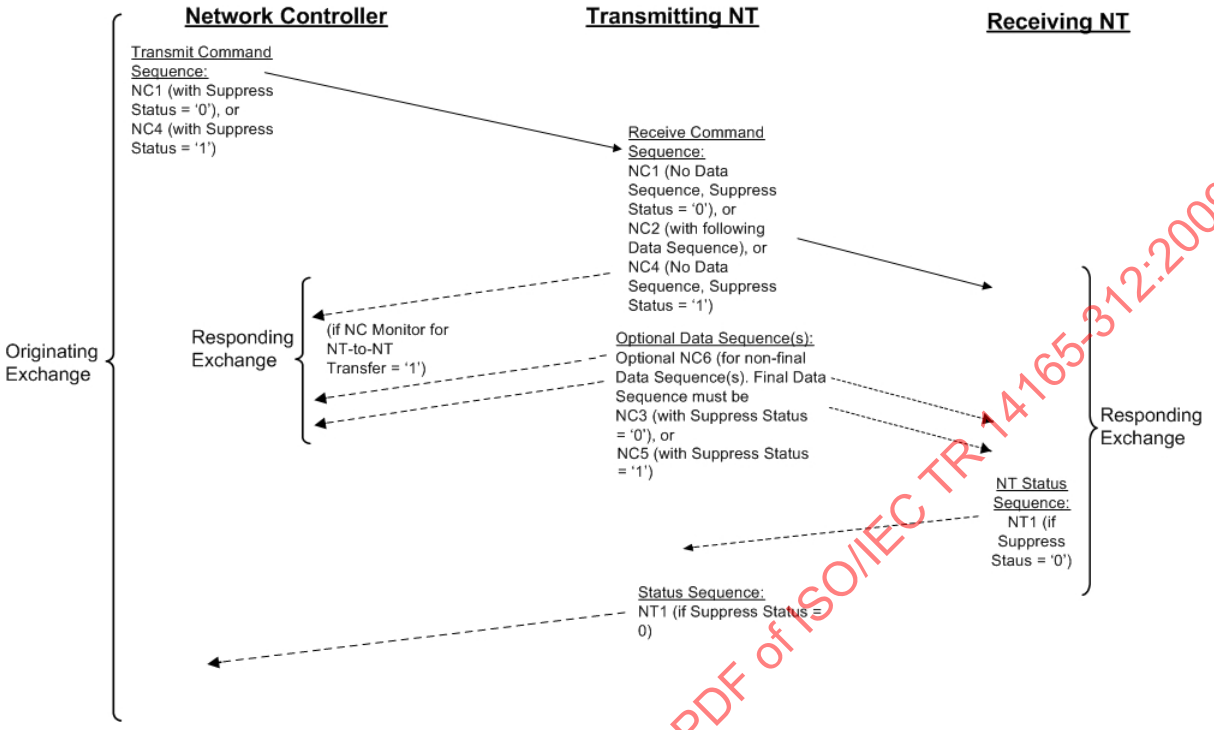

Figure 5 – NT-to-NT Transfers: NT Burst Size Request = '0'b, Delayed *NT Burst Size Request = '0'b*

Depending on the operation to be performed, additional data bytes may be transferred after the Responding Exchange Command Sequence has been transmitted by means of one or more Data Sequences sent to the receiving NT. In this case, the maximum allowable time between the end of the transmitting NT's Command Sequence and the start of its first Data Sequence shall be C/S_D_TX_TOV. If Suppress Status is set to '0', then all Data Sequences except for the last one shall be NC6 IUs, while the last Data Sequence shall be an NC3 IU. If Suppress Status is set to '1', then all Data Sequences except for the last one shall be NC6 IUs, while the last Data Sequence shall be an NC5 IU.

For NT-to-NT transfers, there is an option for the NC to monitor the Status Sequence and Data Sequences transmitted by the Transmitting NT to the Receiving NT. This option is invoked by the originating NC, by setting the NC MONITOR FOR NT-TO-NT TRANFER bit to '1'b for the transmit Command Sequence. Otherwise, this bit shall be set to '0'b. If the NC MONITOR FOR NT-TO-NT TRANFER option is used, the Destination_ID for this Sequence shall be an alias address for a multicast group consisting of the receiving NT and the originating NC.

If Suppress Status is set to '0'b in the transmit and receive Command Sequences and after all data has been received and validated, the receiving NT shall transmit a Status Sequence (NT1 IU) to the transmitting NT within the time NT_C/S_TOV, thus terminating the responding Exchange. In this case, within NT_C/S_TOV following reception of the Status Sequence from the receiving NT, the transmitting NT shall transmit a Status Sequence (NT1 IU) to the originating NC, thereby terminating the originating Exchange. This Sequence includes Status information from both the receiving and transmitting NTs.

If Suppress Status is set to '1'b in the transmit and receive Command Sequences, the Exchange is terminated by the transmission of the Command Sequence, or Command and Data Sequences from the transmitting NT to the receiving NT. In this case, no Status Sequences are transmitted by the receiving and transmitting NTs.

4.4.2.4.3 NT Burst Size Request = ‘1’b, Delayed NT Burst Size Request = ‘0’b

Similar to the options for NC-to-NT transfers, for NT-to-NT transfers, the transmitting NT can allow the receiving NT to specify the maximum Data Sequence Size that it is able to receive. If the transmitting NT sets the NT Burst Size Request bit to ‘1’b and Delayed NT Burst Size Request = ‘0’b (see Table 7 and 4.4.4.1.9 and 4.4.4.1.10), the receiving NT is able to specify the number of payload data bytes for all Data Sequences by means of its transmitted Status Sequences, starting with the first one.

For the first Exchange (see Figure 6), the originating Exchange, the NC sends a transmit Command Sequence to the transmitting NT with NT Burst Size Request = ‘1’b and Delayed NT Burst Size Request = ‘0’b. If Suppress Status is set to ‘0’, the Command Sequence shall be an NC1 IU. If Suppress Status is set to ‘1’, the Command Sequence shall be an NC4 IU. This Command Sequence includes the Port_ID and Subaddress for the receiving NT in the Multicast or Other Port_ID and Other Subaddress fields respectively.

Within NT_C/S_TOV following the reception of the transmit Command Sequence (NC1 IU or NC4 IU) from the originating NC, the transmitting NT shall initiate the second Exchange, which is the Responding Exchange, by transmitting a receive Command Sequence (NC1 IU) to the receiving NT. The value of bits 8 through 3, 1, and 0 in Word 6 of this receive Command Sequence shall be the same as the corresponding bits in Word 6 of the transmit Command Sequence sent by the originating NC.

Assuming the receiving NT receives a valid Command Sequence from the transmitting NT, it shall respond with a Status Sequence (NT6 IU) with the Busy bit in the Status Sequence set appropriately within NT_C-D/S_BURST_TOV.

If the Busy bit in the NT Status Sequence has a value of ‘1’b, this indicates that the receiving NT is not ready to receive data, thereby terminating the Exchange. A Busy bit set to ‘0’b and Burst Size Acknowledge set to ‘1’b within NT_C-D/S_BURST_TOV indicates that the value in word 7 of the Status Sequence is the maximum number of data bytes that the receiving NT is able to receive in the first Data Sequence. Following reception and validation of the NT6 IU within NC_CD_BURST_TOV, the transmitting NT shall transmit an appropriate Data Sequence (NC3 IU or NC5 IU) of less than or equal to this maximum allowed length. When the transmitting NT determines that the requested Data Sequence will have transferred the total number of data bytes indicated in the Command Sequence, the last or only Data Sequence shall transfer Sequence Initiative with an NC3 IU if Suppress Status in the Command Sequence = ‘0’ or terminate the Exchange with an NC5 IU if Suppress Status = ‘1’. All intermediate Data Sequences, if any, shall be NC3 IUs.

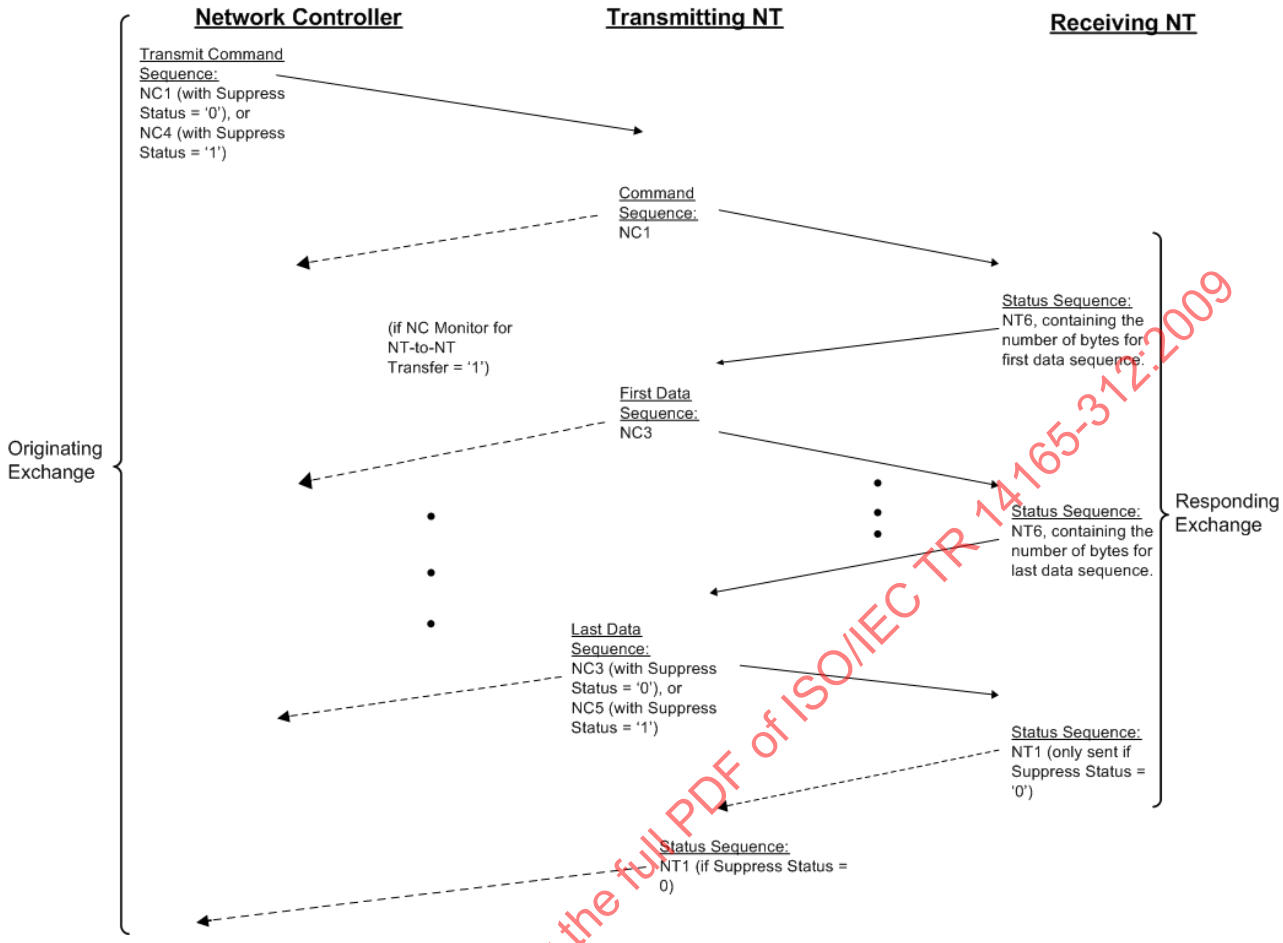

Figure 6 – NT-to-NT transfers: NT Burst Size Request = '1'b, Delayed NT Burst Size Request = '0'b

For NT-to-NT transfers, there is an option for the NC to monitor the Status Sequence and Data Sequences transmitted by the Transmitting NT to the Receiving NT. This option is invoked by the originating NC by setting the NC MONITOR FOR NT-TO-NT TRANFER bit to '1'b for the transmit Command Sequence. Otherwise, this bit shall be set to '0'b. If the NC MONITOR FOR NT-TO-NT TRANFER option is used, the Destination_ID for the Command and Data Sequence(s) sent by the transmitting NT shall be an alias Port_ID representing a multicast group consisting of the receiving NT and the originating NC.

If Suppress Status is set to '0'b in the transmit and receive Command Sequences and after all data has been received and validated, the receiving NT shall transmit a Status Sequence (NT1 IU) to the transmitting NT within the time NT_C/S_TOV, thus terminating the responding Exchange. In this case, within NT_C/S_TOV following reception of the Status Sequence from the receiving NT, the transmitting NT shall transmit a Status Sequence (NT1 IU) to the originating NC, thereby terminating the originating Exchange. This Sequence includes Status information from both the receiving and transmitting NTs.

If Suppress Status is set to '1'b in the transmit and receive Command Sequences, the Exchange is terminated by the transmission the Command Sequence, or Command and Data Sequences from the transmitting NT to the receiving NT. In this case, no Status Sequences are transmitted by the receiving or transmitting NTs.

4.4.2.4.4 Originating NC is also receiving NT, with NT Burst Size Request = '1'b, Delayed NT Burst Size Request = '0'b

Figure 7 illustrates the case of an NT-to-NT transfer where the originating NC designates itself to also function as the receiving NT. This allows the originating NC to be able to regulate the sizes of the individual Data Sequences sent by the transmitting NT. In this case, the

originating NC specifies its own Port_ID as that of the receiving NT, and sets the NT Burst Size Request bit to '1'b and Delayed NT Burst Size Request = '0'b (see Table 7 and 4.4.4.1.9 and 4.4.4.1.10).

For the first Exchange (see Figure 7), the originating Exchange, the NC sends a transmit Command Sequence to the transmitting NT with NT Burst Size Request = '1'b and Delayed NT Burst Size Request = '0'b. If Suppress Status is set to '0', the Command Sequence shall be an NC1 IU. If Suppress Status is set to '1', the Command Sequence shall be an NC4 IU. This Command Sequence includes the Port_ID and Subaddress for the originating NC in the Multicast or Other Port_ID and Other Subaddress fields respectively.

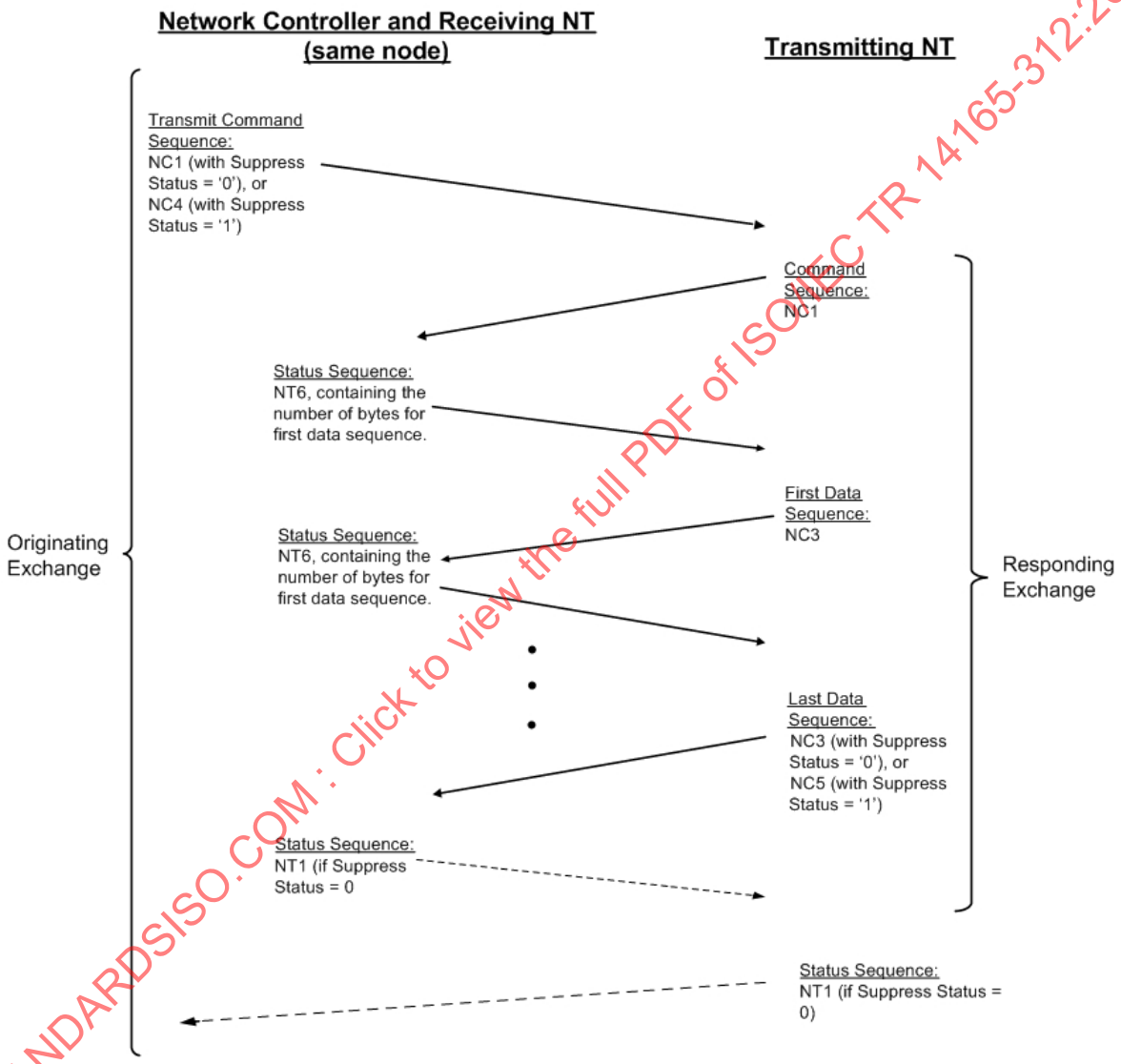

Figure 7 – NT-to-NT Transfers: Originating NC is also receiving NT, with NT Burst Size Request ='1'b, Delayed NT Burst Size Request = '0'b

Within NT_C/S_TOV following the reception of the transmit Command Sequence (NC1 IU or NC4 IU) from the originating NC, the transmitting NT shall initiate the second Exchange, which is the Responding Exchange, by transmitting a receive Command Sequence (NC1 IU) to the originating NC. The value of bits 8 through 3, 1, and 0 in Word 6 of this receive Command Sequence shall be the same as the corresponding bits in Word 6 of the transmit Command Sequence sent by the originating NC.

Assuming the originating NC receives a valid Command Sequence from the transmitting NT, it shall respond with a Status Sequence (NT6 IU). A Busy bit set to '0'b and Burst Size Acknowledge set to '1'b within NT_C-D/S_BURST_TOV indicates that the value in word 7 of

the Status Sequence is the maximum number of data bytes that the originating NC is able to receive in a single Data Sequence. Following reception and validation of the NT6 IU within NC_CD_BURST_TOV, the transmitting NT shall transmit an appropriate Data Sequence (NC3 IU or NC5 IU) of less than or equal to the maximum allowed length. When the transmitting NT determines that the requested Data Sequence will have transferred the total number of data bytes indicated in the Command Sequence, the last or only Data Sequence shall transfer Sequence Initiative with an NC3 IU if Suppress Status in the Command Sequence = '0' or terminate the Exchange with an NC7 IU if Suppress Status = '1'. All intermediate Data Sequences, if any, shall be NC3 IUs.

If Suppress Status is set to '0'b in the transmit and receive Command Sequences and after all data has been received and validated, the originating NC shall transmit a Status Sequence (NT1 IU) to the transmitting NT within the time NT_C/S_TOV, thus terminating the responding Exchange. In this case, within NT_C/S_TOV following reception of the Status Sequence from the receiving NT, the transmitting NT shall transmit a Status Sequence (NT1 IU) to the originating NC, thereby terminating the originating Exchange.

If Suppress Status is set to '1'b in the transmit and receive Command Sequences, the Exchange is terminated by the transmission of the Command Sequence, or Command and Data Sequence(s) from the transmitting NT to the originating NC. In this case, no Status Sequences are transmitted by the originating NC or transmitting NT.

4.4.2.4.5 Delayed NT Burst Size Request = '1'b, NT Burst Size Request = '0'b

Alternatively, if the originating NC and thereby the transmitting NT set the Delayed NT Burst Size Request bit to '1'b and the NT Burst Size Request bit to '0'b (see Table 7 and 4.4.4.1.9 and 4.4.4.1.10), then the maximum number of bytes transmitted in the first Data Sequence from the transmitting NT (immediately following the Command Sequence) shall be specified by the receiving NT, by means of implicit or explicit FC-AE-1553 Process Login. For all subsequent Data Sequences if any following the first one, the receiving NT specifies the number of payload data bytes that it can receive for each by means of its Status Sequence.

For the first Exchange (see Figure 8), the originating Exchange, the originating NC sends a transmit Command Sequence to the transmitting NT with NT Delayed Burst Size Request = '1'b and NT Burst Size Request = '0'b. If Suppress Status is set to '0', the Command Sequence shall be an NC1 IU. If Suppress Status is set to '1', the Command Sequence shall be an NC4 IU. This Command Sequence includes the Port_ID and Subaddress for the receiving NT in the Multicast or Other Port_ID and Other Subaddress fields respectively.

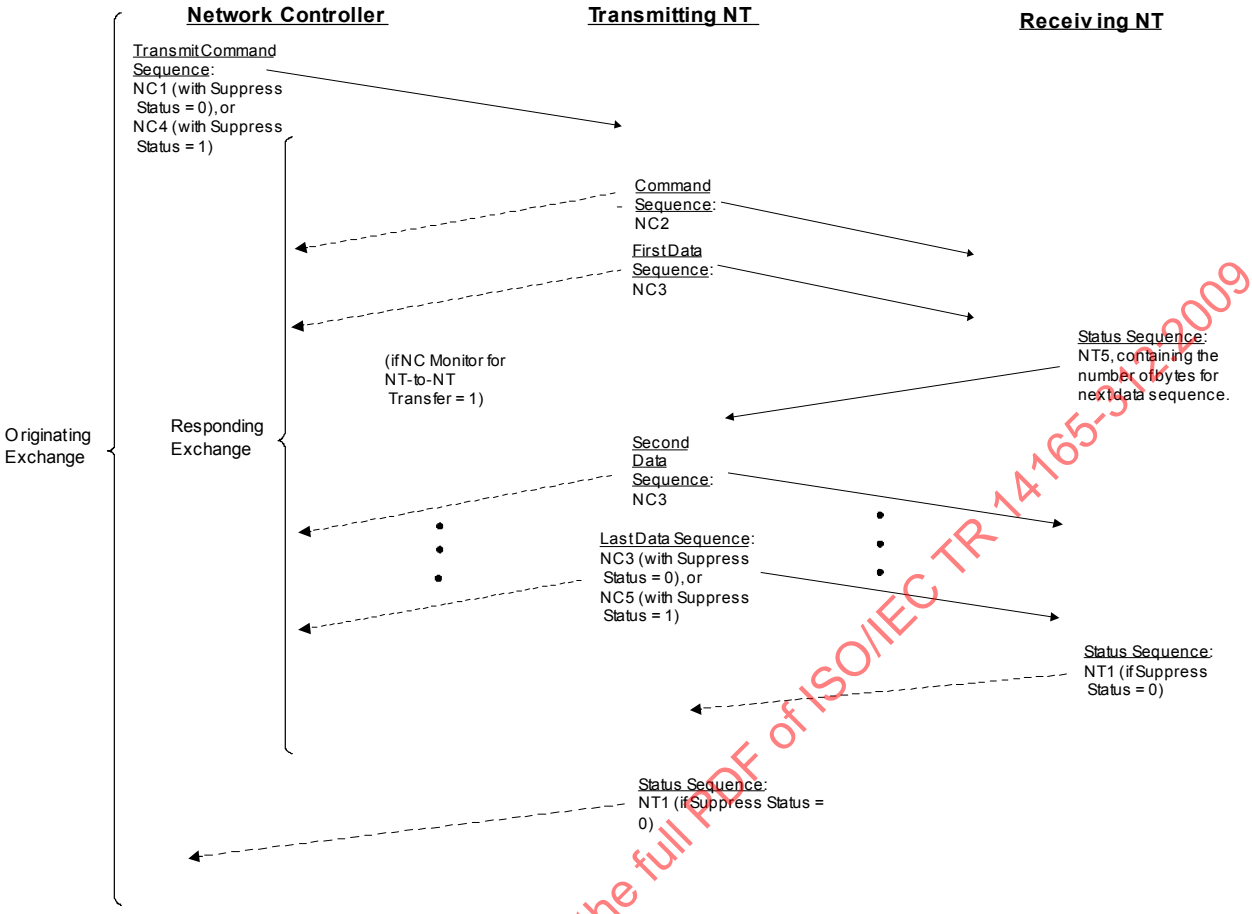

Figure 8 – NT-to-NT transfers: Delayed NT Burst Size Request = '1'b, NT Burst Size Request = '0'b

Within NT_C/S_TOV following reception and validation of the transmit Command Sequence (NC1 IU or NC4 IU) from the originating NC, the transmitting NT shall initiate the second Exchange, which is the Responding Exchange, by transmitting a receive Command Sequence (NC2 IU) containing up to 2 048 data bytes followed within C/S_D_TX_TOV by an NC3 Data Sequence to the receiving NT. The value of bits 8 through 3, 1, and 0 in Word 6 of this receive Command Sequence shall be the same as the corresponding bits in Word 6 of the transmit Command Sequence sent by the originating NC. The maximum total number of bytes transmitted in the Command Sequence and in the first Data Sequence shall be specified by the NT, by means of implicit or explicit FC-AE-1553 Process Login.

Assuming the receiving NT receives a valid Command Sequence followed by a valid Data Sequence, it shall respond with an NT6 Status Sequence within NT_C-D/S_BURST_TOV. If the Busy bit in this Status Sequence has a value of '1'b, this indicates that the receiving NT isn't ready to receive data, thereby terminating the Exchange. In this case, the receiving NT shall not process the received data and the transmitting NT shall assume that none of the data transmitted was processed.

If the receiving NT responds with the Busy bit set to '0' and a value of '1'b for Burst Size Acknowledge, then word 7 of the receiving NT's Status Sequence (NT6 IU) shall indicate the maximum number of data bytes that the receiving NT is able to receive within the next Data Sequence from the transmitting NT. If Burst Size Acknowledge is set to '0'b, the NC transmits no Data Sequence and terminates the Exchange.

In the case where the receiving NT's Status Sequence's Busy bit is set to '0' and its Burst Size Acknowledge bit is set to '1'b, then following the transmitting NT's reception and validation of the Status Sequence within NC_C-D/S_BURST_TOV, the transmitting NT shall

then transmit an NC3 or NT5 Data Sequence of less than or equal to the indicated maximum size. When the receiving NT has received and validated this Data Sequence and is ready to receive a subsequent NC3 or NC5 Data Sequence, it shall transmit another NT6 Status Sequence, again within NT_C-D/S_BURST_TOV and indicating the maximum number of bytes that it is able to receive in the next Data Sequence. This process is repeated until the receiving NT has received the total number of data bytes indicated in the Command Sequence. The last Data Sequence transmitted by the transmitting NT shall be an NC3 IU if Suppress Status in the Command Sequence was set to '0', or an NC5 IU if Suppress Status was set to '1'.

If Suppress Status is set to '0'b in the transmit and receive Command Sequences and after all data bytes for the Exchange have been received and validated, the receiving NT shall transmit a Status Sequence (NT1 IU) to the transmitting NT within the time NT_C/S_TOV, thus terminating the responding Exchange. In this case, within NT_C/S_TOV following reception of the Status Sequence from the receiving NT, the transmitting NT shall transmit a Status Sequence (NT1 IU) to the originating NC, thereby terminating the originating Exchange. This Sequence includes Status information from both the receiving and transmitting NTs.

If Suppress Status is set to '1'b in the transmit and receive Command Sequences, the Exchange is terminated by the transmission of the final Data Sequence from the transmitting NT to the receiving NT. In this case, no Status Sequences are transmitted by the receiving or transmitting NTs.

4.4.2.4.6 Case where originating NC is also receiving NT, with Delayed NT Burst Size Request = '1'b, NT Burst Size Request ='0'b

Similar to the scenario in Figure 7, Figure 9 illustrates the case of an NT-to-NT transfer where the originating NC designates itself to also function as the receiving NT. This allows the originating NC to be able to regulate the sizes of the individual Data Sequences sent by the transmitting NT. In this case, the originating NC specifies its own Port_ID as that of the receiving NT, and sets the NT Delayed Burst Size Request bit to '1'b and NT Burst Size Request = '0'b (see Table 7 and 4.4.4.1.9 and 4.4.4.1.10) in its Command Sequence.

For the first Exchange (see Figure 9), the originating Exchange, the originating NC sends a transmit Command Sequence to the transmitting NT with NT Delayed Burst Size Request = '1'b and NT Burst Size Request = '0'b. If Suppress Status is set to '0', the Command Sequence shall be an NC1 IU. If Suppress Status is set to '1', the Command Sequence shall be an NC4 IU. This Command Sequence includes the Port_ID and Subaddress for the originating NC in the Multicast or Other Port_ID and Other Subaddress fields respectively.

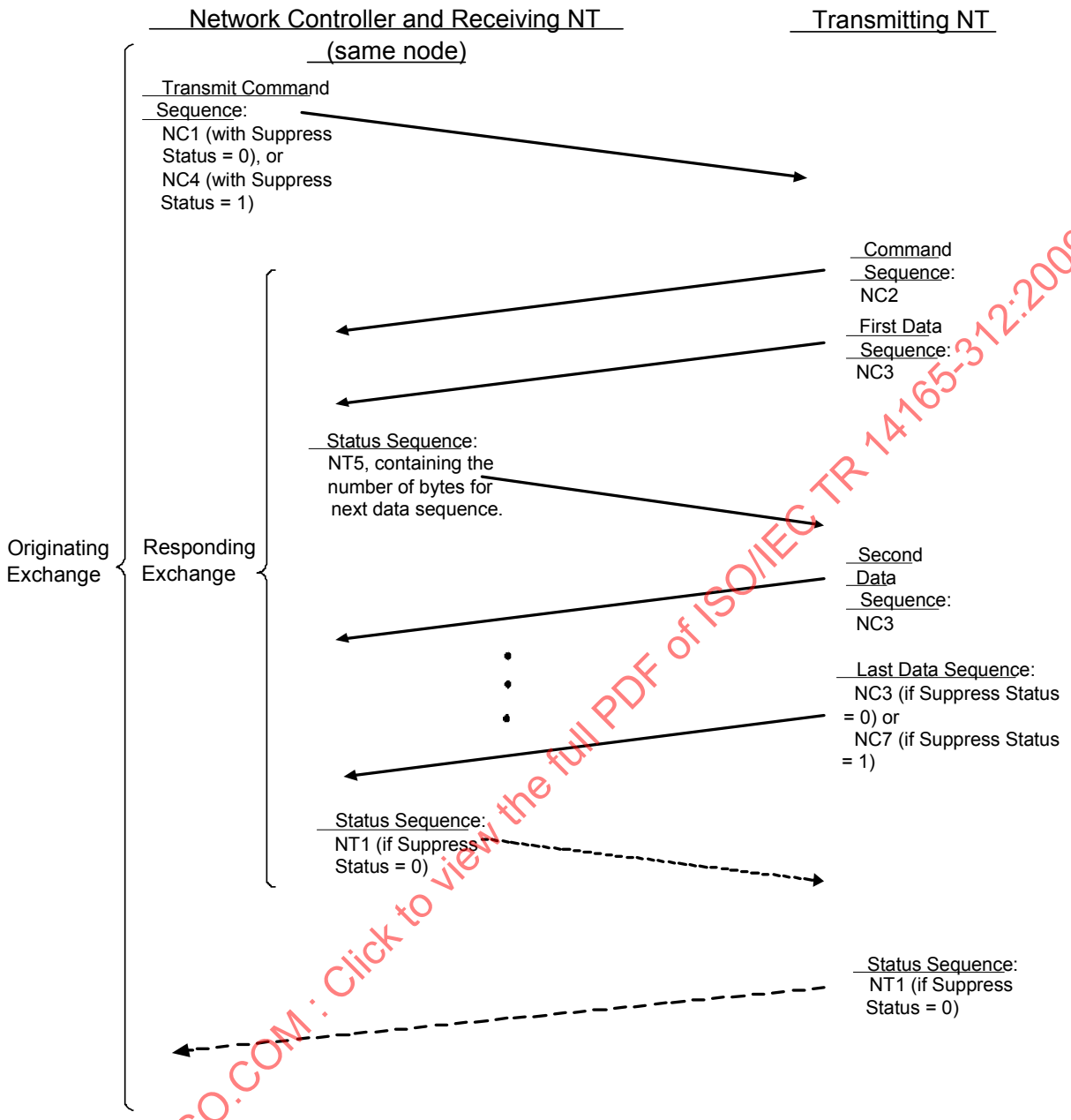

Figure 9 – NT-to-NT transfers: originating NC is also receiving NT, with delayed NT Burst Size Request = '1'b, NT Burst Size Request ='0'b

Within NT_C/S_TOV following the reception of the transmit Command Sequence (NC1 IU or NC4 IU) from the originating NC, the transmitting NT shall initiate the second Exchange, which is the Responding Exchange, by transmitting a receive Command Sequence (NC2 IU) containing up to 2 048 data bytes followed within C/S_D_TX_TOV by an NC3 Data Sequence to the originating NC. The value of bits 8 through 3, 1, and 0 in Word 6 of this receive Command Sequence shall be the same as the corresponding bits in Word 6 of the transmit Command Sequence sent by the originating NC. The maximum number of data bytes transmitted in the Command Sequence and in the first Data Sequence shall be specified by the originating NC, by means of implicit or explicit FC-AE-1553 Process Login.

Assuming the originating NC receives a valid Command Sequence followed by a valid Data Sequence, it shall respond within NT_C-D/S_BURST_TOV with an NT6 Status Sequence. Assuming that the originating NC responds with its Busy bit set to '0'b and a value of Burst Size Acknowledge set to '1'b, then word 7 of its Status Sequence shall indicate the maximum number of data bytes that the originating NC is able to receive in the next Data Sequence

from the transmitting NT. If Busy is set to '1'b and/or Burst Size Acknowledge is set to '0'b, the transmitting NT transmits no Data Sequence and terminates the Exchange.

In the case where the originating NC responds with Busy set to '0'b and Burst Size Acknowledge set to '1'b, then within NC_C-D/S_BURST_TOV following the transmitting NT's reception and validation of the Status Sequence, the transmitting NT shall transmit an NC3 Data Sequence of less than or equal the indicated size. When the originating NC has received and validated this Data Sequence and is ready to receive a subsequent Data Sequence, it shall transmit another NT6 Status Sequence, again within NT_C-D/S_BURST_TOV and indicating the maximum number of bytes that it is able to receive in the next Data Sequence. This process is repeated until the originating NC has received the total number of data bytes indicated in the Command Sequence. When the transmitting NT determines that the requested Data Sequence will have transferred the total number of data bytes indicated in the Command Sequence, the last or only Data Sequence shall transfer Sequence Initiative with an NC3 IU if Suppress Status in the Command Sequence = '0' or terminate the Exchange with an NC7 IU if Suppress Status = '1'. All intermediate Data Sequences, if any, shall be NC3 IUs.

If Suppress Status is set to '0'b in the transmit and receive Command Sequences and after all data has been received and validated, then within NT_C/S_TOV, the originating NC shall transmit a Status Sequence (NT1 IU) to the transmitting NT, thus terminating the responding Exchange. In this case, within NT_C/S_TOV following reception of the Status Sequence from the originating NC, the transmitting NT shall transmit a Status Sequence (NT1 IU) to the originating NC, thereby terminating the originating Exchange.

If Suppress Status is set to '1'b in the transmit and receive Command Sequences, the Exchange is terminated by the transmission of the final (NC7) Data Sequence from the transmitting NT to the originating NC. In this case, no Status Sequences are transmitted by the originating NC or transmitting NT.

4.4.2.5 Mode command without Data Word Transfers

The NC shall issue a transmit mode Command Sequence to the NT using a mode code specified in 4.4.4.2. If the value of Suppress Status is '0', then this Command Sequence shall be an NC1 IU. If the value of Suppress Status is '1', then this Command Sequence shall be an NC5 IU.

Assuming that Suppress Status = '0', the NT shall respond within NT_C/S_TOV after command reception with a Status Sequence (NT1 IU). If Suppress Status = '1', the NT shall not respond with a Status Sequence. Figure 10 illustrates this exchange.

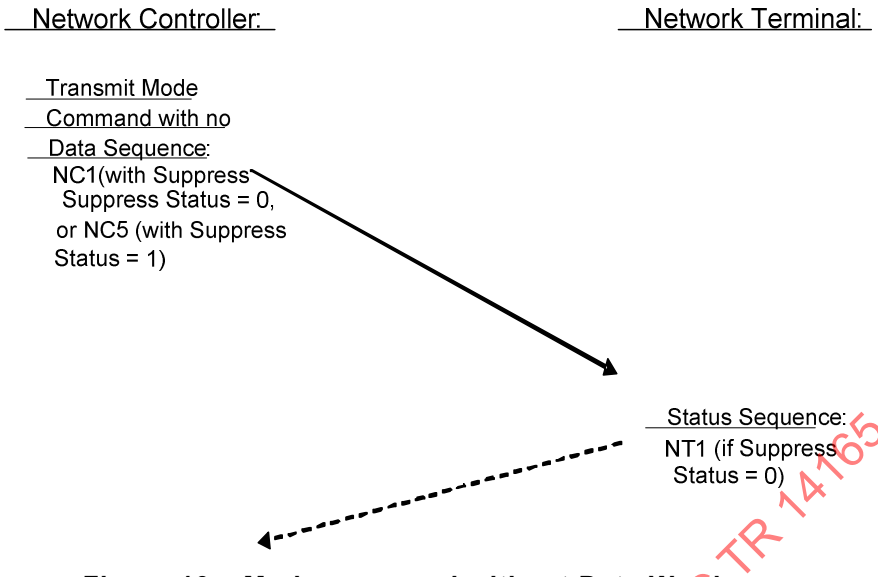

Figure 10 – Mode command without Data Word

4.4.2.6 Transmit Mode command with Data Word transfers

The NC shall issue a transmit mode Command Sequence to the NT (NC1 IU) using a mode code specified in section 4.4.4.2. The NT shall respond within NT_C/S_TOV after command reception with a Status Sequence including a single 16-bit data word (NT1 IU). Figure 11 illustrates this Exchange.

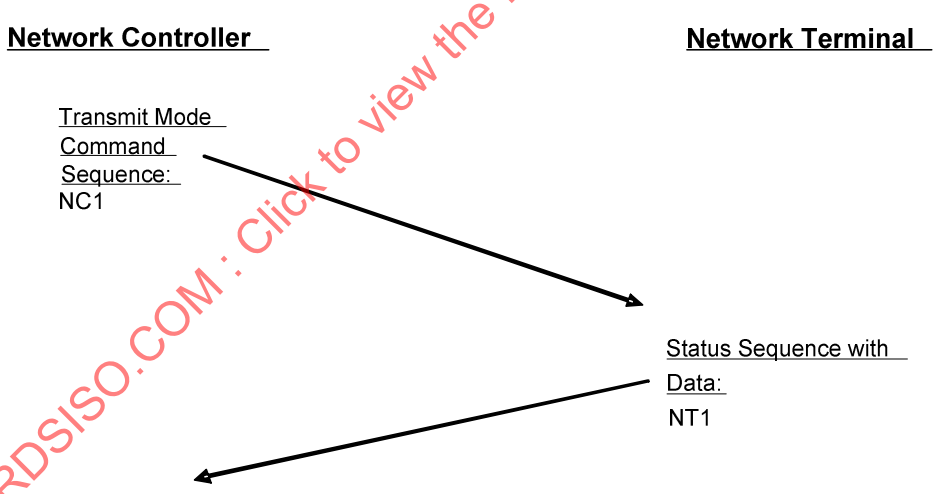

Figure 11 – Transmit Mode Command with Data Word

4.4.2.7 Receive Mode command with Data Word transfers

The NC shall issue a receive mode Command Sequence containing a single 16-bit data word to the NT using a mode code specified in 4.4.4.2. If the value of Suppress Status is '0', then this Command Sequence shall be an NC1 IU. If the value of Suppress Status is '1', then this Command Sequence shall be an NC5 IU.

Assuming that Suppress Status = '0', the NT shall respond within NT_C/S_TOV after command reception and validation with a Status Sequence (NT1 IU). If Suppress Status = '1', the NT shall not respond with a Status Sequence. Figure 12 illustrates this Exchange.

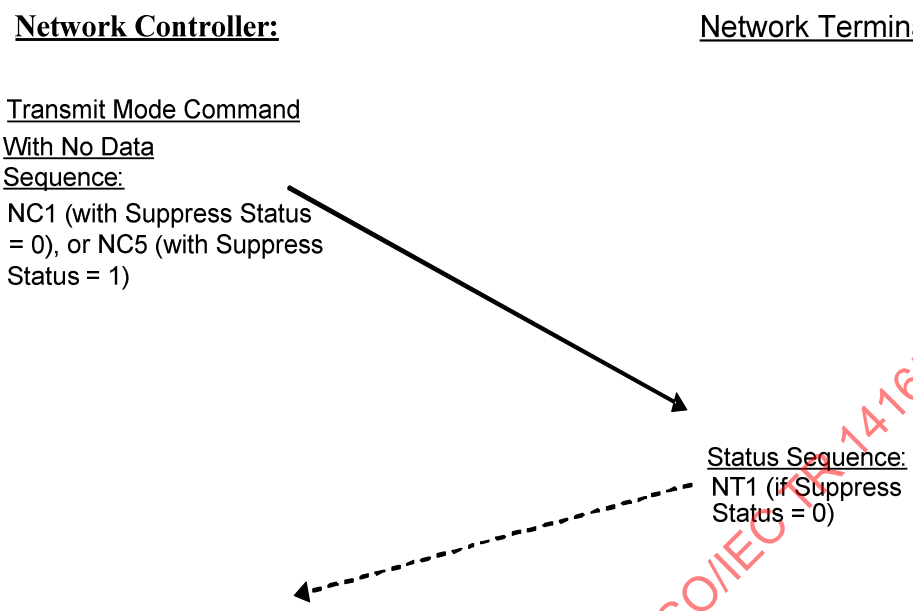

Figure 12 – Receive Mode command with Data Word

4.4.2.8 Network Controller to Multiple Network Terminals transfers (broadcast or multicast)

This exchange format (reference Figure 13) enables transmission by a Network Controller to multiple NTs on a network (multicast) or all NTs on a network (broadcast). In the case of multicast, it is necessary to implicitly or explicitly establish a multicast alias group consisting of two or more NTs prior to the transmission of a multicast exchange. In FC-AE-1553, there are options supporting both acknowledged and unacknowledged multicast and broadcast transfers.

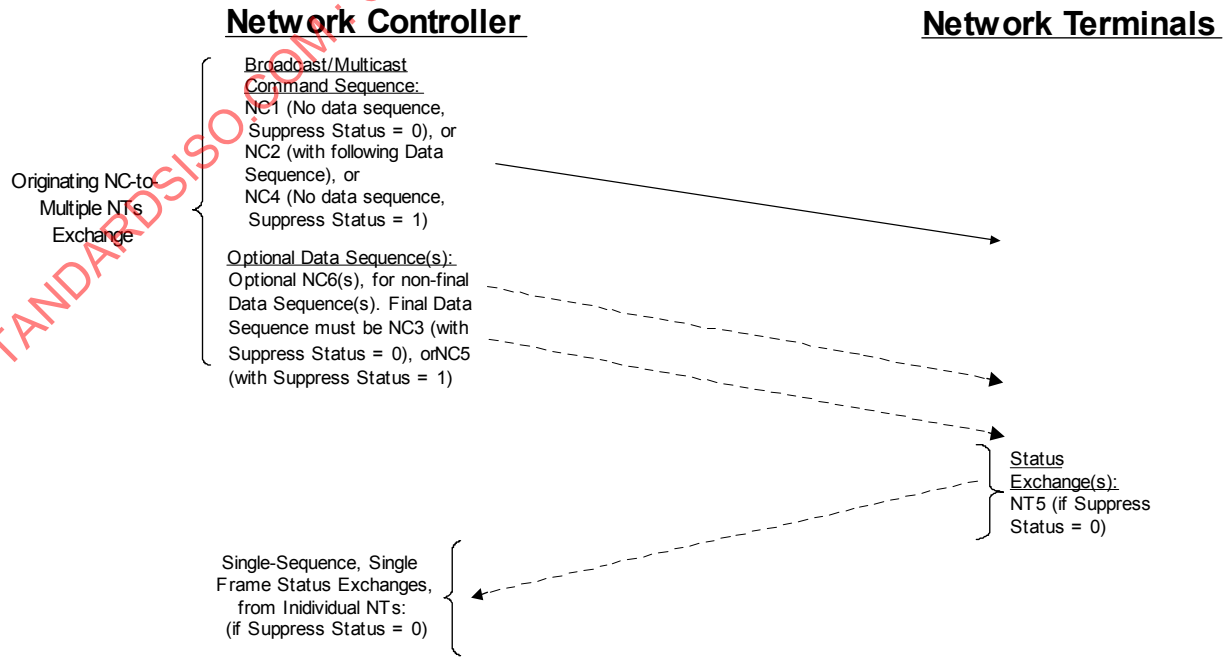

Figure 13 – NC-to-NTs transfers (broadcast or multicast)

In this Exchange format, the Network Controller shall transmit a Command Sequence (NC1 IU, NC2 IU or NC4 IU, as appropriate), including or followed by the specified number of data bytes. If the Command Sequence contains all of the data bytes for the Exchange, an NC1 IU (for Suppress Status = '0') or NC4 IU ((for Suppress Status = '1') is transmitted. The maximum number of data bytes that may be transmitted in the Command Sequence is 2 048. If some or all of the data is to be transmitted in one or more separate Sequences, an NC2 IU shall be transmitted first followed by one or more Data Sequences. In this case, the maximum allowable time between the end of the NC's Command Sequence and the start of the first Data Sequence, as well as the maximum time between Data Sequences, shall be C/S_D_TX_TOV. The Data Sequence(s) are comprised of zero or more NC6 IUs that shall be followed by one NC7 IU (for Suppress Status = '0') or one NC5 IU (for Suppress Status = '1').

If Suppress Status is set to '0'b in the Command Sequence and after all data bytes have been received and validated, then each receiving NT shall transmit its own single-sequence (NT5 IU) Status Exchange to the Network Controller within the time NT_C/S_TOV and shall terminate the Exchange. If Suppress Status is set to '1'b in the Command Sequence, the Network Controller shall terminate the Exchange after the NC4 IU or last Data Sequence (NC5 IU) has been transmitted.

4.4.2.9 Network Terminal to Multiple Network Terminal transfers

This exchange format allows transmission by a Network Terminal to multiple NTs on a network (multicast) or all NTs on a network (broadcast). In the case of multicast, it is necessary to implicitly or explicitly establish a multicast alias group consisting of two or more NTs prior to the transmission of a multicast exchange. In FC-AE-1553, there are options supporting both acknowledged and unacknowledged multicast and broadcast transfers.

For the first Exchange (see Figure 14) the originating Exchange, the NC sends a transmit Command Sequence to the transmitting NT. If Suppress Status is set to '0', the Command Sequence shall be an NC1 IU. If Suppress Status is set to '1', the Command Sequence shall be an NC4 IU. For a broadcast NT-to-Multiple NTs Exchange, this Command Sequence includes the Broadcast Port_ID hex 'FF FF FF' (or, on a loop, to the AL_PA broadcast replicate address 'FF'), along with the receiving Subaddress in the Multicast or Other Port_ID and Other Subaddress fields respectively. For a multicast NT-to-Multiple NTs Exchange, this Command Sequence includes the alias Port_ID for the pre-established multicast group, along with the receiving Subaddress in the Multicast or Other Port_ID and Other Subaddress fields respectively.

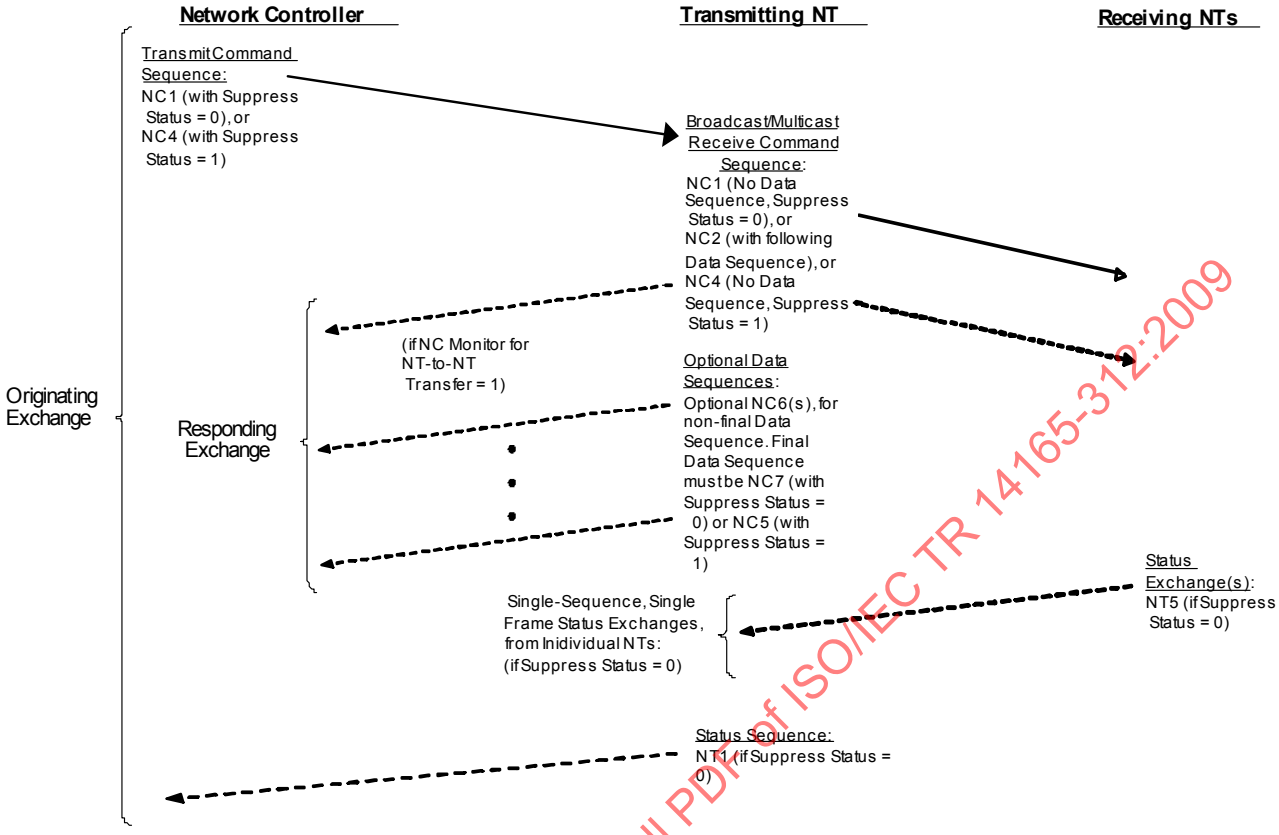

Figure 14 – Network Terminal to Multiple Network Terminals

Within NT_C/S_TOV following reception of the transmit Command Sequence (NC1 IU or NC4 IU) from the originating NC, the transmitting NT shall initiate a second Exchange, which is the Responding Exchange, by transmitting a receive Command Sequence to the receiving NTs. The value of bits 8 through 3, 1, and 0 in Word 6 of this receive Command Sequence shall be the same as the corresponding bits in Word 6 of the transmit Command Sequence sent by the originating NC. If Suppress Status is set to '0' and all of the transmitting NT's data bytes (up to 2 048 maximum) are contained in the Command Sequence, then the Command Sequence shall be an NC1 IU. If the transmitting NT transmits one or more Data Sequences, then the Command Sequence shall be an NC2 IU. If Suppress Status is set to '1' and all of the transmitting NT's data bytes (up to 2 048 maximum) are contained in the Command Sequence, then the Command Sequence shall be an NC4 IU.

Depending on the operation to be performed, additional data bytes may be transferred after the Responding Exchange Command Sequence has been transmitted by means of one or more Data Sequences sent to the receiving NTs. In this case, the maximum allowable time between the end of the transmitting NT's Command Sequence and the start of its first Data Sequence as well as the maximum time between Data Sequences shall be C/S_D_TX_TOV. If Suppress Status is set to '0', then all Data Sequences except for the last one shall be NC7 IUs, while the last Data Sequence shall be an NC7 IU. If Suppress Status is set to '1', then all Data Sequences except for the last one shall be NC6 IUs, while the last Data Sequence shall be an NC5 IU.

For NT-to-NT transfers, there is an option for the NC to monitor the Status Sequence and Data Sequences transmitted by the Transmitting NT to the Receiving NT. This option is invoked by the originating NC, by setting the NC MONITOR FOR NT-TO-NT TRANFER bit to '1'b for the transmit Command Sequence. Otherwise, this bit shall be set to '0'b. If the NC MONITOR FOR NT-TO-NT TRANFER option is used for a multicast NT-to-NTs Exchange, then the NC shall be a member of the multicast alias group which receives the responding Exchange. In the case of an NT-to-broadcast Exchange, the NC will also receive the Command and Data Sequences sent by the transmitting NT.

If Suppress Status is set to '0'b in the transmit and receive Command Sequences and after all data has been received and validated, then each receiving NT shall transmit a single-Sequence (NT5 IU) Status Exchange to the transmitting NT within the time NT_C/S_TOV, thus terminating the responding Exchange. In this case, within NT_C/S_TOV following reception of the Status Sequence from all receiving NTs, the transmitting NT shall transmit a Status Sequence (NT1 IU) to the originating NC, thereby terminating the originating Exchange. For this Sequence, bits 14 through 0 of Word 7 shall represent the 'OR'd combination of the respective bits received in the Status Exchanges for all of the receiving NTs.

NOTE If one or more of bits 14 through 0 in Word 7 are set to '1'b in the Status Sequence received from the transmitting NT, the NC may determine which NT(s) caused the bit(s) to be set by polling the individual receiving NTs by means of Transmit Status mode Command Exchanges.

If Suppress Status is set to '1'b in the transmit and receive Command Sequences, the Exchange is terminated after the transmission the Command Sequence, or Command and Data Sequences from the transmitting NT to the receiving NTs. In this case, no Status Sequences are transmitted by the receiving NTs or transmitting NT.

4.4.2.10 Mode Command to Multiple NTs without Data Word transfers

This exchange format allows transmission of a Mode Code Exchange by a Network Controller to multiple NTs on a network (multicast) or all NTs on a network (broadcast). In the case of multicast, it is necessary to implicitly or explicitly establish a multicast alias group consisting of two or more NTs prior to the transmission of a multicast exchange. In the case of a broadcast, the Command Sequence is sent to the broadcast Port_ID of hex 'FF FF FF' (or, on a loop, to the AL_PA broadcast replicate address hex 'FF').

The NC shall issue a transmit mode Command Sequence to an alias multicast address or the broadcast address hex 'FF FF FF' (or, on a loop, to the AL_PA broadcast replicate address 'FF') using a mode code specified in 4.4.4.2. Figure 15 illustrates this Exchange format. If the Suppress Status bit for this Command Sequence is '0'b, then this Sequence shall be an NC1 IU. If the Suppress Status bit for this Command Sequence is '1'b, then this Sequence shall be an NC4 IU.

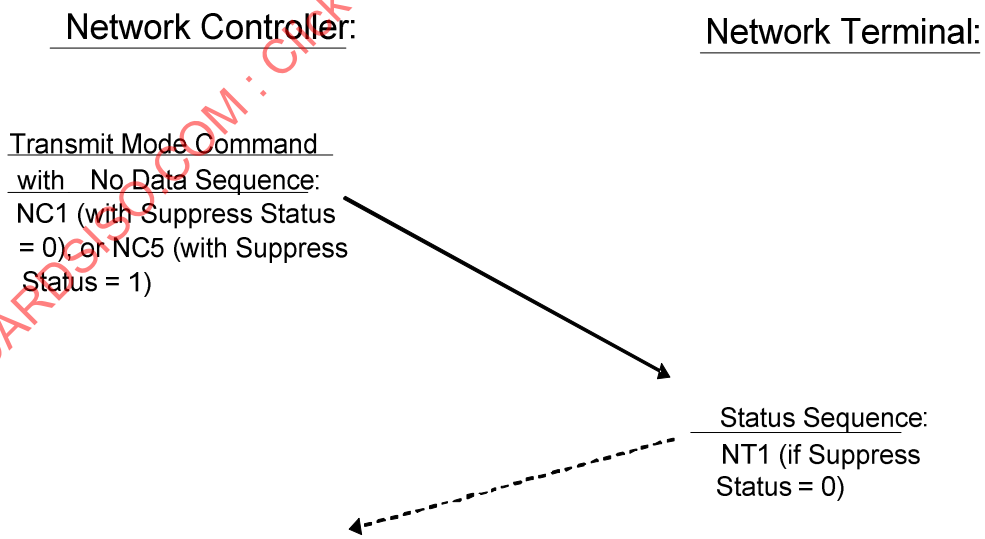

Figure 15 – Transmit mode command without Data Word to Multiple Network Terminals

If Suppress Status = '0', then each receiving NT shall respond with a single-Sequence Status Exchange. If Suppress Status = '1', then the receiving NTs shall not respond.

4.4.2.11 Mode command (receive) to Multiple NTs with Data Word transfers

This exchange format allows the transmission of a receive Mode Code Exchange with data by a Network Controller to multiple NTs on a network (multicast) or to all NTs on a network (broadcast). In the case of multicast, it is necessary to implicitly or explicitly establish a multicast alias group consisting of two or more NTs prior to the transmission of a multicast exchange. In the case of multicast, the Command Sequence is sent to the broadcast Port_ID of hex 'FF FF FF' (or, on a loop, to the AL_PA broadcast replicate address 'FF').

The NC shall issue a transmit mode Command Sequence containing a single 16-bit data word to an alias multicast address or the broadcast address 'FF FF FF' (or, on a loop, to the AL_PA broadcast replicate address 'FF') using a mode code specified in 4.4.4.2. Figure 16 illustrates this Exchange format. If the Suppress Status bit for this Command Sequence is '0'b, then this Sequence shall be an NC1 IU. If the Suppress Status bit for this Command Sequence is '1'b, then this Sequence shall be an NC4 IU.

Figure 16 – Receive mode command with Data Word to Multiple Network Terminals

If Suppress Status = '0', then each receiving NT shall respond with a single-Sequence Status Exchange. If Suppress Status = '1', then the receiving NTs shall not respond.

4.4.3 FC-AE-1553 ULP profile

Table 6 lists the set of features relevant to the FC-AE-1553 Upper Level Protocol. This table indicates whether the feature is Required (R), Prohibited (P), Allowed (A), or Invocable (I) for compliance with this profile. Features that are not listed do not affect the interoperability of FC-AE-1553 devices.

As described in Annex A, all features in this table which are listed as Allowed may be specified as either implemented or not implemented for individual NCs and/or NTs by means of implicit or explicit FC-AE-1553 Process Login.

Table 6 – FC-4 profile for FC-AE-1553

Feature	Nx_Port	Notes
Send Explicit Process Login (PRLI)	I	Either implicit and/or explicit Process Login must be implemented.
Respond to Explicit Process Login (PRLI)	R	
Implicit Process Login (PRLI)	I	
Process Logout (PRLO)	A	Following successful completion of an explicit PRLO, FC-AE-1553 operation shall not be processed until after successful completion of an explicit PRLI.
NT Address	R	D_ID, S_ID fields.
T/R* bit	R	NTs are not required to implement all combinations of T/R, subaddress, and word count/mode code.
Subaddress	R	
Word Count/Mode Code	R	
No Response by MIL-STD-1553 RT = '1'b	A	If individual Status Sequence bits are not used, they shall be set to '0'b.
MIL-STD-1553 Format Error = '1'b	A	
Burst Size Acknowledge = '1'b	A	
Port Login Required = '1'b	A	
Message Error = '1'b	I	See 4.4.4.3.5
Instrumentation = '0'b	R	
Service Request = '1'b	A	If individual Status Sequence bits are not used, they shall be set to '0'b.
Reserved Status Sequence bits = '0'b	R	
Broadcast Command Received = '1'b	I	
Busy = '1'b	A	If individual Status Sequence bits are not used, they shall be set to '0'b.
Subsystem Flag = '1'b	A	
Dynamic Network Acceptance = '1'b	A	
Terminal Flag = '1'b	A	
NC-to-NT Transfer (without NT Burst Size Request or Delayed NT Burst Size Request)	I	
NC-to-NT Transfer (using NT Burst Size Request)	A	
NC-to-NT Transfer (using Delayed NT Burst Size Request)	A	
NT-to-NC Transfer	I	
NT-to-NT Transfer (without NT Burst Size Request or Delayed NT Burst Size Request)	I	
NT-to-NT Transfer (using NT Burst Size Request)	A	
NT-to-NT Transfer, where the NC is the receiving NT (using NT Burst Size Request)	A	
NT-to-NT Transfer (using Delayed NT Burst Size Request)	A	
NT-to-NT Transfer, where the NC is the receiving NT (using Delayed NT Burst Size Request)	A	
Mode Code, no data	I	
NC-to-Multiple NTs	I	
NT-to-Multiple NTs	I	
Receive Mode Code, with data	I	
Transmit Mode Code, with data	I	
Mode Code, no data to Multiple NTs	I	
Receive Mode Code, with data to Multiple NTs	I	

Feature	Nx_Port	Notes
NC-to-NT Transfer (without NT Burst Size Request or Delayed NT Burst Size Request)	I	
NC-to-NT Transfer (using NT Burst Size Request)	A	
NC-to-NT Transfer (using Delayed NT Burst Size Request)	A	
NT-to-NC Transfer	I	
NT-to-NT Transfer	I	
NT-to-NT Transfer (without NT Burst Size Request or Delayed NT Burst Size Request)	I	
NT-to-NT Transfer (using NT Burst Size Request)	A	
NT-to-NT Transfer, where the NC is the receiving NT (using NT Burst Size Request)	A	
NT-to-NT Transfer (using Delayed NT Burst Size Request)	A	
NT-to-NT Transfer, where the NC is the receiving NT (using Delayed NT Burst Size Request)	A	
NC-to-Multiple NTs	I	
NT-to-Multiple NTs	A	
Mode Code with no data	I	
Receive Mode Code, with data	I	
Transmit Mode Code, with data	I	
Mode Code, no data to multiple NTs	I	
Receive Mode Code, with data to Multiple NTs	A	
Dynamic network control – Non-Broadcast	A	
Dynamic network control – Broadcast	P	
Synchronize (without data word) – Non-Broadcast	I	
Synchronize (without data word) – Broadcast	I	
Transmit Status Sequence – Non-broadcast	I	
Transmit Status Sequence – Broadcast	P	
Initiate self-test – Non-broadcast	I	
Initiate self-test – Broadcast	I	
Transmitter shutdown – Non-broadcast	A	
Transmitter shutdown – Broadcast	A	
Override transmitter shutdown – Non-Broadcast	A	
Override transmitter shutdown – Broadcast	A	
Inhibit terminal flag – Non-broadcast	I	
Inhibit terminal flag – Broadcast	I	
Override inhibit terminal flag – Non-Broadcast	I	
Override inhibit terminal flag – Broadcast	I	
Reset remote terminal – Non-broadcast	I	
Reset remote terminal – Broadcast	I	
Transmit vector word – Non-broadcast	I	
Transmit vector word – Broadcast	P	
Synchronize (with data word) – Non-Broadcast	I	
Synchronize (with data word) – Broadcast	I	
Transmit last Command Sequence – Non Broadcast	I	
Transmit last Command Sequence – Broadcast	P	

Feature	Nx_Port	Notes
Transmit BIT word – Non-broadcast	I	
Transmit BIT word – Broadcast	P	
Selected transmitter shutdown – Non-Broadcast	A	
Selected transmitter shutdown – Broadcast	A	
Override selected transmitter Shutdown - Non-broadcast	A	
Override selected transmitter Shutdown – Broadcast	A	
Transmit RT Address – Non-broadcast	A	
Transmit RT Address – Broadcast	P	
Transmit NT_C-D/S_BURST_TOV – Non-broadcast	A	
Transmit NT_C-D/S_BURST_TOV – Broadcast	P	
Dynamic network control – Non-Broadcast	A	
Dynamic network control – Broadcast	P	
Synchronize (without data word) – Non-Broadcast	A	
Synchronize (without data word) – Broadcast	A	
Transmit Status Sequence – Non-broadcast	I	
Transmit Status Sequence – Broadcast	P	
Initiate self-test – Non-broadcast	A	
Initiate self-test – Broadcast	A	
Transmitter shutdown – Non-broadcast	A	
Transmitter shutdown – Broadcast	A	
Override transmitter shutdown – Non-broadcast	A	
Override transmitter shutdown – Broadcast	A	
Inhibit terminal flag – Non-broadcast	A	
Inhibit terminal flag – Broadcast	A	
Override inhibit terminal flag – Non-broadcast	A	
Override inhibit terminal flag – Broadcast	A	
Reset remote terminal – Non-broadcast	I	
Reset remote terminal – Broadcast	I	
Transmit vector word – Non-broadcast	A	
Synchronize (with data word) – Non-broadcast	A	
Synchronize (with data word) – Broadcast	A	
Transmit last Command Sequence – Non-Broadcast	A	
Transmit BIT word – Non-broadcast	A	
Selected transmitter shutdown – Non-Broadcast	A	
Selected transmitter shutdown – Broadcast	A	
Override selected transmitter Shutdown - Non-broadcast	A	
Override selected transmitter Shutdown – Broadcast	A	
Transmit RT Address – Non-broadcast	A	
Transmit RT Address – Broadcast	P	
Transmit NT_C-D/S_BURST_TOV – Non-Broadcast	A	
Transmit NT_C-D/S_BURST_TOV – Broadcast	P	

4.4.4 MIL-STD-1553 ULP mapping to FC-AE-1553

4.4.4.1 MIL-STD-1553 command word mapping to FC-AE-1553

4.4.4.1.1 Introduction

Every FC-AE-1553 Exchange is initated by a Network Controller's transmission of a Command Sequence. FC-AE-1553 command headers are included in this Sequence, and in the Status Sequence of the transmitting NT's response for NT-to-NT transfers. For these Sequences, the FC-AE-1553 Command Sequence header is comprised of the 6-word Fibre Channel Header, along with the 6-word FC-AE-1553 command header extension consisting of words 6 through 11 of the Command Sequence, which are normally the first six words of payload. The Command Sequence header is illustrated in Table 7. All FC-AE-1553 Data Sequences shall use the Parameter in word 5 of the header as a relative offset field.

For Exchanges in which the Network Controller (or transmitting NT for an NT-to-NT transfer) transmits data, the Network Controller or transmitting NT may send up to 2 048 data bytes in the payload of the Command Sequence, starting at word #12. If such an Exchange has more than 2 048 data bytes, the NC shall transmit one or more Data Sequences following the Command Sequence. Alternatively, for an NC-to-NT(s) transfer, if the Network Controller does not transmit any data bytes in its Command Sequence, it shall transmit data bytes in one or more Data Sequences following the Command Sequence.

For an NC-to-NT transfer, the NT shall respond with status unless the Supress Status bit has been set in the Command Sequence. If the Supress Status bit has been set in the Command Sequence, the NT shall not respond.

For an NT-to-NC transfer, the NT shall respond with a Status Sequence. This Sequence may contain up to 2 048 data bytes following the 8-byte FC-AE-1553 Status header extension (reference Table 9). If the NT has more than 2 048 data bytes to send, it shall transmit the remaining data bytes in one or more Data Sequences following the Status Sequence.

Data Sequence headers shall follow the format in Table 7 for words 0 through 5.

4.4.4.1.2 R_CTL

The R_CTL field is divided into two sub-fields, the routing bits and Information Category bits.

4.4.4.1.3 Routing bits

For FC-AE-1553, the values defined for the R_CTL Routing field are hex '0' (FC-4 Device Data), hex '2' (Extended Link Services), hex '8' (Basic Link Services), and hex 'C' (Link_Control).

4.4.4.1.4 Information Category bits

The Information Category bits of the R_CTL field shall be set in accordance with the Categories defined in Table 4 and Table 5. For FC-AE-1553, all information units are defined for full Sequences.

4.4.4.1.5 Destination identifier (D_ID)

The Destination Identifier (D_ID) field contains the Network Terminal (NT) address of the recipient port, a multicast alias address, or a well-known address. Each Fibre Channel port that is functioning as an FC-AE-1553 NT shall recognize Sequences with a D_ID of its native N_Port identifier, along with the well known address of hex 'FF FF FF', to be used with the broadcast option. Similarly, an NC shall recognize both its native N_Port identifier and the broadcast address of hex 'FF FF FF'. In addition, NTs and NCs shall also recognize Sequences containing any or all alias D_IDs denoting implicitly or explicitly pre-established multicast alias groups which include the specific port.

4.4.4.1.6 Broadcast and multicast Exchanges

FC-AE-1553 supports multiple options for implementing broadcast and multicast. For a multicast or broadcast Exchange, if the Suppress Status bit of the FC-AE-1553 command header is '0'b, then all receiving NTs shall respond with a single-Sequence Status Exchange. However, if Suppress Status is '1'b, then all receiving NTs shall **not** respond with a Status Exchange.

The options for broadcast and multicast are as follows:

a) As mentioned above, all FC-AE-1553 NTs and NCs shall recognize the Fibre Channel well known broadcast address of hex 'FF FF FF'.
b) All FC-AE-1553 NTs and NCs on an arbitrated loop shall recognize the broadcast replicate AL_PA address of hex 'FF'.
c) To support broadcast functionality for all MIL-STD-1553 RTs on a bus bridged from an FC-AE-1553 NT, the NC shall specify a value of hex '1F' (the MIL-STD-1553 broadcast address) for bits 9-5 of the Command Sequence Subaddress field.
d) FC-AE-1553 Network Terminals on a fabric shall respond to arbitrary alias addresses (multicast or hunt groups).
e) FC-AE-1553 Network Terminals on an arbitrated loop shall support selective replicate.

Table 7 – FC-AE-1553 command sequence header

Word	Bits			
	31 to 24	23 to 16	15 to 8	7 to 0
0	R_CTL	Destination ID (NT Address)		
1	CS_CTL	Source ID (NC Address)		
2	TYPE	F_CTL		
3	SEQ_ID	DF_CTL	SEQ_CNT	
4	OX_ID	RX_ID		
5	Parameter			
6	Reserved (23)			8: NT Burst Size Request 7: Delayed NT Burst Size Request 6: Receive RDMA 5: Transmit RDMA 4: Suppress Status 3: NT-to-NT Transfer 2: T/R* 1: NC Monitor for NT-to-NT Transfer 0: Multicast
7	Subaddress/Mode			
8	Data Byte Count (WC)/Mode Code			
9	For Command Sequences from originating NC: Reserved			
	For Command Sequence from transmitting NT to receiving NT for NT-to-NT(s) transfers: NT Status bits, as shown below:			
	Reserved (17)			14: No Response by MIL-STD-1553 RT 13: MIL-STD-1553 Format Error 12. Burst Size Acknowledge 11: Port Login Required 10: Message Error 9: Instrumentation 8: Service Request 7-5: Reserved (3 bits) 4: Broadcast Cmd. Rcvd. 3: Busy 2: Subsystem Flag 1: Dynamic Network Ctrl. 0: Terminal Flag
10	Reserved (8)	Multicast Address or Other Port_ID (24)		
11	Other Subaddress (32)			

4.4.4.1.7 CS_CTL

If used, the CS_CTL shall denote frame Priority. Priority is a 7-bit value placed in header Word 1, bits 30:24. Use of Priority is optional and is enabled by setting Priority Enable, bit 17 of Word 2 in the F_CTL field of the Fibre Channel header, to a value of '1'b. All fabrics shall route frames in priority order, highest priority first, when Priority Enable is asserted. Priority proceeds in descending order from 127 as the highest level to 0 as the lowest. If implementing 2 priority levels only, priority level 1 (CS_CTL = hex '01') shall be the high priority and priority level 0 (CS_CTL = hex '00') shall be the low priority. Frames where priority is not enabled (F_CTL field bit-17 assigned a value of '0'b) shall be treated as frames having a priority level of 0.

4.4.4.1.8 Source Identifier (S_ID)

The Source Identifier (S_ID) shall indicate the address identifier of the source Nx_Port. Every NT and NC shall have a unique S_ID.

4.4.4.1.9 TYPE field

The TYPE field shall be hex '48' for all FC-AE-1553 Sequences transferred in compliance with this profile. Other ULPs may run concurrently through the same port with FC-AE-1553.

4.4.4.1.10 Parameter field

For all FC-AE-1553 Sequences, the Parameter Field, word 5 in the Fibre Channel header, shall be used to specify relative offset. For Command and Status Sequences, the value of the Parameter field shall be equal to hex '00 00 00 00'.

NOTE For FC-AE-1553, the operation of the other Fibre Channel header fields is described in Annex B.

4.4.4.1.11 NT Burst Size Request

This bit may be set in the NC Command Sequence for an NC-to-NT transfer, or by the transmitting NT's Command Sequence for an NT-to-NT transfer. If NT Burst Size Request is set, then the Delayed NT Burst Size Request bit shall have a value of '0'b. When the NC or transmitting NT sends a Command Sequence with NT Burst Size Request set, it shall not send any data bytes either within the Command Sequence. Further, it shall not transmit a Data Sequence immediately following the Command Sequence.

If NT Burst Size Request is set, the NC shall wait for at least NC_CD_BURST_TOV until reception of a Status Sequence from the receiving NT before making a determination of a "No Response" condition. If the Status Sequence's Busy bit has a value of '0'b and Burst Size Acknowledge has a value of '1'b, this indicates that word 7 of the Status Sequence represents the maximum number of payload bytes that the NT can receive within a single Data Sequence. If this value is less than the value of the Command Sequence Byte Count field, then the NC or transmitting NT will need to segment its overall payload into multiple Data Sequences. In this case, some time following the reception of the first Data Sequence from the NC, the NT shall respond with a second Status Sequence with Burst Size Acknowledge = '1'b. This is followed by the NC's (or transmitting NT's) transmission of a second Data Sequence. This process is repeated until the NC or transmitting NT has sent the total number of data bytes specified in its Command Sequence.

If at any time the receiving NT cannot receive any additional data bytes, it shall respond with a value of '1'b for the Busy bit and a value of '0'b for Burst Size Acknowledge, thereby terminating the Exchange. Following valid reception of the last Data Sequence, if the Command Sequence Suppress Status bit was '0'b, the receiving NT shall respond with its final Status Sequence. In this Status Sequence, Burst Size Acknowledge shall have a value of '0'b.

4.4.4.1.12 Delayed NT Burst Size Request

This bit may be set in the NC Command Sequence for an NC-to-NT transfer, or by the transmitting NT for an NT-to-NT transfer. If Delayed NT Burst Size Request is set, then the NT Burst Size Request bit shall have a value of '0'b. When the NC or transmitting NT for an NT-to-NT transfer sends a Command Sequence with Delayed NT Burst Size Request set, it may transmit up to 2 048 bytes in the Command Sequence, and shall transmit a Data Sequence immediately following the Command Sequence. In this mode, the maximum number of bytes transmitted in the Command Sequence plus this first Data Sequence is specified by the receiving NT by means of FC-AE-1553 implicit or explicit Process Login. If this number is less than the value of the Byte Count field in the Command Sequence, then the NC will need to segment its total payload into multiple Data Sequences.

Assuming that the number of payload bytes in the Command Sequence plus the first Data Sequence is less than the value of the Byte Count field in the Command Sequence, then following transmission of the Command Sequence and first Data Sequence, the NC or transmitting NT shall wait until reception of the Status Sequence from the receiving NT. Assuming this Status Sequence is received prior to NC_C-D/S_BURST_TOV following transmission of the Data Sequence, the Status Sequence's Busy bit has a value of '0'b and

Burst Size Acknowledge has a value of ‘1’b, this indicates that word 7 of the Status Sequence represents the maximum number of payload bytes that the NT can receive within the second Data Sequence. This is followed by the NC’s (or transmitting NT’s) transmission of the second Data Sequence. This process is repeated until the NC or transmitting NT has transmitted the total number of data bytes specified in its Command Sequence.

If at any time the receiving NT cannot receive any additional data bytes, it shall respond with a value of ‘1’b for the Busy bit and a value of ‘0’b for Burst Size Acknowledge, thereby terminating the Exchange. Following valid reception of the last Data Sequence, if the Command Sequence Suppress Status bit was ‘0’b, the receiving NT shall respond with its final Status Sequence. In this Status Sequence, Burst Size Acknowledge shall have a value of ‘0’b.

4.4.4.1.13 Receive RDMA

The Receive RDMA bit shall be mapped to bit 6 of word 6 of the FC-AE-1553 Command Sequence (refer to Table 7). For NC-to-NT(s), NT-to-NT, and NT-to-Multiple NTs transfer Exchanges, if the NC transmits this bit with a value of ‘1’b, the receiving NT(s) shall interpret its subaddress field as the starting memory (byte) address for received data bytes. In this case, bytes to be received by the NT(s) shall be written to contiguous memory locations starting at this address.

For an NT-to-NT transfer Exchange, if Receive RDMA is set to ‘1’b for the Command Sequence transmitted by the originating NC, then the Other Subaddress field represents the starting memory (byte) address for the receiving NT. This value will subsequently be re-transmitted as the Subaddress field for the transmitting NT’s Command Sequence.

For an NT-to-NC transfer, if the NC transmits this bit with a value of ‘1’b, this indicates that the Other Subaddress field represents the starting byte address in the NC’s local memory space where the NC will store data received from the NT. In this case, this address is provided for advisory purposes only, and is not required to be checked by the NT. For all other Exchange formats, or if the NC transmits this bit with a value of ‘0’b, the receiving NT(s) is not required to interpret the Subaddress field as the starting memory address.

For any Exchange where RDMA is used, the value of the Subaddress and/or Other Subaddress fields shall represent an address on an even 32-bit boundary; i.e., the lower two bits of this field shall have values of ‘0’b.

4.4.4.1.14 Transmit RDMA

The Transmit RDMA bit shall be mapped to bit 5 of word 6 of the FC-AE-1553 Command Sequence (refer to Table 7). For NT-to-NC, NT-to-NT, and NT-to-Multiple NTs transfer Exchanges, if the NC transmits this bit with a value of ‘1’b, the transmitting NT shall interpret its subaddress field as the starting memory (byte) address for transmitted data bytes. In this case, bytes to be transmitted by the NT shall be read from contiguous memory locations starting at this address.

For an NT-to-NT transfer Exchange, if Transmit RDMA is set to ‘1’b for the Command Sequence transmitted by the transmitting NT, then the Other Subaddress field represents the starting memory (byte) address for the transmitting NT. In this case, this address value is provided for advisory purposes only, and is not required to be checked by the receiving NT.

For an NC-to-NT transfer, if the NC transmits this bit with a value of ‘1’b, this indicates that the Other Subaddress field represents the starting byte address in the NC’s local memory space from where the NC will read data to be transmitted to the NT. In this case, this address is provided for advisory purposes only, and is not required to be checked by the NT. For all other Exchange formats, or if the NC transmits this bit with a value of ‘0’b, the transmitting NT is not required to interpret the subaddress field as the starting memory address.

For an RDMA type of Exchange, the value of the subaddress field shall represent an address on an even 32-bit boundary; i.e., the lower two bits of this field shall have values of '0'b.

4.4.4.1.15 Suppress status

The Suppress Status bit shall be mapped to bit 4 of word 6 of the FC-AE-1553 Command Sequence (refer to Table 7). For NC-to-NT transfers and non-broadcast mode code Exchanges, if the NC transmits this bit with a value of '1'b, the NT receiving the Sequence(s) from the NT shall not respond with status. If the NC transmits this bit with a value of '0'b and for all other Exchange formats requiring an NT response, the NT shall respond with status. For NT-to-NT transfer exchanges, the value of the Suppress Status bit transmitted by the transmitting NT in its Command Sequence shall be the same value as that transmitted in the originating NC's Command Sequence. If Suppress Status is set to '1'b for an NT-to-NT transfer Exchange, then the neither transmitting NT nor the receiving NT shall transmit a Status Sequence.

4.4.4.1.16 NT-to-NT

The NT-to-NT bit shall be mapped to bit 3 of word 6 of the FC-AE-1553 Command Sequence (refer to Table 7). This bit shall be '1'b to initiate NT-to-NT or NT-to-Multiple NTs transfer Exchanges, and '0'b to initiate all other Exchanges. For NT-to-NT transfer exchanges, the value of the NT-to-NT bit transmitted by the transmitting NT in its Command Sequence shall be the same value as that transmitted in the originating NC's Command Sequence.

4.4.4.1.17 T/R*

The T/R* bit, which is mapped to bit 2 of word 6 of the FC-AE-1553 Command Sequence header (refer to Table 7), is used to indicate the direction of data transfer, with respect to the NT or multiple NTs. This bit shall be set to '0'b to initiate Exchanges in which the NT or multiple NTs will receive data, and '1'b to initiate Exchanges in which the NT will transmit data.

4.4.4.1.18 NC MONITOR FOR NT-TO-NT TRANSFERS

The NC Monitor bit shall be mapped to bit 1 of word 6 of the FC-AE-1553 Command Sequence (refer to Table 7). For an NT-to-NT transfer, if this bit is '0'b, the NC does not monitor the data transmission by the transmitting NT. The value of the NC MONITOR FOR NT-TO-NT TRANSFERS bit transmitted by the transmitting NT in its Command Sequence shall be the same value as that transmitted in the originating NC's Command Sequence.

For an NT-to-NT transfer, if this bit is '1'b, then the transmitting NT transmits to a multicast alias group consisting of the NC and the receiving NT, allowing the NC to monitor the data transmission by the transmitting NT. On a fabric topology or a fabric with public loop(s), this entails the use of a multicast server and an alias multicast group. On a private loop, this involves the use of selective replicate.

The establishment of multicast groups may be done either implicitly or explicitly. If they are formed explicitly, the generic services defined for the Class 3 multicast server shall be used.

This bit shall be '0'b for all Exchange formats other than NT-to-NT transfers.

4.4.4.1.19 MULTICAST

The MULTICAST bit shall be mapped to bit 0 of word 6 of the FC-AE Command Sequence (see Table 7). If this bit is '0'b, this indicates that the Destination_ID field specifies the address for a single Port_ID. If this bit is '1'b, this indicates that the Destination_ID field specifies a multicast (alias group) address. On a fabric topology or a fabric with public loop(s), this entails the use of a multicast server and an alias multicast group. On a private loop, this involves the use of selective replicate. For a broadcast Exchange, the value of D_ID shall be 'FF FF FF', and the value of MULTICAST shall be '0'b.

The establishment of multicast groups may be done either implicitly or explicitly. If they are formed explicitly, the generic services defined for the Class 3 multicast server shall be used.

4.4.4.1.20 Subaddress/Mode

Subaddress/Mode is mapped to FC-AE-1553 Command Sequence header word 7 in Table 7 which is normally the second word of Fibre Channel data payload. For the case of an NT-to-NT(s) transfer, this field denotes the subaddress for the transmitting NT. For the Command Sequence sent by the transmitting NT for an NT-to-NT transfer, this field denotes the subaddress for the receiving NT.

For non-mode code Exchanges, the Subaddress/Mode field may be used to identify a starting address for RDMA (remote direct memory access) operations. For NC-to-NT, NT-to-NT, NC-to-Multiple NTs, and NT-to-Multiple NTs transfer Exchanges, if the RECEIVE RDMA bit of the NC Command Sequence is '1'b, the receiving NT(s) shall interpret their subaddress field as the starting memory (byte) address for received data bytes. In this case, bytes to be received by the NT(s) shall be written to contiguous memory locations starting at this address. For all other Exchange formats, or if RECEIVE RDMA has a value of '0'b, the receiving NT(s) is not required to interpret the subaddress field as a starting memory address.

Similarly, for NT-to-NC, NT-to-NT, and NT-to-Multiple NTs transfer Exchanges, if the TRANSMIT RDMA bit of the NC Command Sequence is '1'b, the transmitting NT shall interpret the Subaddress field as the starting memory (byte) address for transmitted data bytes. In this case, bytes to be transmitted by the NT shall be read from contiguous memory locations starting at this address. For all other Exchange formats, or if TRANSMIT RDMA has a value of '0'b, the transmitting NT is not required to interpret the subaddress field as a starting memory address.

To enable communication with MIL-STD-1553 RTs, an FC-AE-1553 NT (N_Port or NL_Port) may connect to one or more Fibre-Channel-to-MIL-STD-1553 bridges. There is a MIL-STD-1553 Bus Controller embedded in each bridge. If an NT connects to such a bridge(s), then bits (31 to 10) of the FC-AE-1553 Subaddress field shall be used to identify a particular bridge. In this case, these 22 bits shall be used to specify the 'bus number' for a particular MIL-STD-1553 bus (bridge) associated with a given NT. To prevent conflicts with FC-AE-1553 mode code Exchanges, the values of all zeros or all ones for the upper 22 Subaddress bits of the subaddress field shall not be used to as the identifier for a bridge device.

For bridged Exchanges, the 5-bit MIL-STD-1553 RT Address maps directly to bits (9 to 5) of the Command Sequence Subaddress field, while the 5-bit MIL-STD-1553 Subaddress field maps directly to bits (4 to 0) of the Command Sequence Subaddress field.

For Command Sequences sent from the transmitting NT to the receiving NT for NT-to-NT or NT-to-Multiple NTs transfers, the Subaddress field shall be copied from the Other Subaddress field from the Command Sequence transmitted by the originating NC to the transmitting NT.

For a particular NT, for Exchanges not involving bridging to a MIL-STD-1553 RT or for broadcast mode code Exchanges involving a D_ID value of 'FF FF FF' (which, by definition, are addressed to any and all bridge RTs), a subaddress value of hex '00 00 00 00' or 'FF FF FF FF' indicates that the FC-AE-1553 Data Word Count/Mode Code field is to be interpreted as an FC-AE-1553 mode code, rather than a data word count. For Exchanges not involving bridging to a MIL-STD-1553 RT, a subaddress value between '00 00 00 01' and 'FF FF FF FE' shall be interpreted by the NT as a non-mode code subaddress, and possibly an RDMA address. In this case, the Data Byte Count/Mode Code field shall specify the number of data bytes to be transmitted or received.

For a particular NT receiving command Exchanges to D_IDs other than the broadcast address 'FF FF FF', for values of the FC-AE-1553 Subaddress field indicating a bridged Exchange, if the value of bits (4 to 0) of the FC-AE-1553 Subaddress field are '00000'b or '11111'b, this

indicates that the lower 5 bits of the Data Byte Count/Mode Code field are to be interpreted as a MIL-STD-1553 mode code, rather than the lower 5 bits of a data byte count. For values of Subaddress bits (31 to 10) indicating a bridged Exchange, a value of the lower 5 bits of the subaddress field between '00001'b and '11110'b indicates a non-mode code subaddress, and the lower 7 bits of the Data Byte Count/Mode Code field are to be interpreted as a word count field, as described in 4.4.4.1.21.

4.4.4.1.21 Data Byte Count/Mode Code

The MIL-STD-1553 Data Word Count/Mode Code field is mapped to FC-AE-1553 Command Sequence word 8 in Table 7, which is normally the third word of the Fibre Channel payload. MIL-STD-1553 specifies 5 bits for this function, allowing a maximum of 32 16-bit words (64 bytes) to be transmitted or received by an RT. FC-AE-1553 allocates 32 bits for this function, enabling data transfers of up to 4.3 GB for a single Exchange.

The content of this field is controlled by the Subaddress/Mode field. There are two scenarios under which the Data Byte count/Mode Code field contains a mode code, as defined in 4.4.4.2:

- the value of the Subaddress/Mode field is hex '00 00 00 00' or hex 'FF FF FF FF'; or
- the value of the upper 22 bits of the FC-AE-1553 Subaddress field is not all zeros or all ones and, for the particular NT, indicates that an Exchange is addressed to a Fibre-Channel-to-MIL-STD-1553 bridge, and the lower 5 bits of the subaddress field are '00000b' or '11111b'.

For all other Exchanges, the Data Byte count/Mode Code field is an unsigned integer value which indicates the number of data bytes to be transmitted or received. That is, a byte count field of hex '00 00 00 01' specifies one data byte, hex '00 00 00 02' specifies two data bytes, hex 'FF FF FF FF' specifies 232 – 1 data bytes, and a byte count field of hex '00 00 00 00' specifies 232 data bytes.

For communicating through bridges to MIL-STD-1553 RTs, the MIL-STD-1553 word count/mode code field maps to the lower seven bits of the FC-AE-1553 byte count/mode code field. For such applications, the maximum value of the FC-AE-1553 byte count field shall be hex '00 00 00 40', which specifies 64 data bytes = 32 16-bit data words; this latter value translates to a value of hex '00000' for the word count field transmitted in the MIL-STD-1553 command word by the bridge's bus controller.

For non-mode code Exchanges involving bridges to MIL-STD-1553 RTs, the bits (31 to 7) of the FC-AE-1553 byte count/mode code field shall all have values of '0'b. For mode code Exchanges involving bridges to MIL-STD-1553 RTs, the upper 27 bits of the FC-AE-1553 byte count/mode code field shall all have values of '0'b. For an Exchange to be bridged to a MIL-STD-1553 bus or RT with a MIL-STD-1553 word count less than 32, the value of the FC-AE-1553 byte count field shall be formulated by means of a one bit left-shift of the MIL-STD-1553 word count, and the LSB of the byte count shall be assigned a value of '0'b. If the MIL-STD-1553 word count is an odd number, a value of 2 (10b) shall be assigned to the Fill Bytes bits in the F_CTL field. If the MIL-STD-1553 word count is an even number, a value of 0 (00b) shall be assigned to the Fill Bytes bits in the F_CTL field.

For "native" FC-AE-1553 applications, the full 32-bit byte count field shall be used.

For all mode code Exchanges involving the mode codes defined by 4.4.4.2.1 through 4.4.4.2.17, the upper 27 bits of the FC-AE-1553 Byte Count/Mode Code field shall have values of '0'b. For these mode code Exchanges, the values of the lower five bits shall be equal to those for the respective FC-AE-1553B mode code, as detailed in 4.4.4.2.2 through 4.4.4.2.18. For any vendor-specific or user-specific mode codes created that are not defined by these subclauses, the full 32-bit mode code field may be used.

NOTE For all mode codes except for Transmit RT Address and Transmit NT_C-D/S_BURST_TOV, the lower 5 bits designating the FC-AE-1553 mode code are the same as the 5 bits which designate the respective MIL-STD-1553B mode code.

4.4.4.1.22 Transmitting NT status word for NT-to-NT Transfers

For the responding sub-Exchange for NT-to-NT transfers, the status bits for the transmitting NT map to FC-AE-1553 Command Sequence header word 9, which is normally the fourth word of the Fibre Channel payload. The descriptions of the FC-AE-1553 status bits are provided in 4.4.4.3.

NOTE Status word bits 14 and 13 are included for use only by FC-AE-1553-to-MIL-STD-1553 bridges, in order to provide indications of 'No Response' and 'Format Error' conditions from MIL-STD-1553 RTs attached to a bridge. For non-bridged Exchanges, these two bits shall have values of '0'b. For all Command Sequences transmitted by NCs, including the transmit command for an NT-to-NT transfer, this field is reserved and shall be assigned a value of hex '00 00 00 00'.

4.4.4.1.23 Multicast address or other Port_ID

The Multicast Address or Other Port_ID field is mapped to FC-AE-1553 Command Sequence header word 10, which is normally the fifth word of the Fibre Channel payload.

The use of this field, which is defined in Table 8 below, varies as a function of the lower four control bits of Command Sequence word 6 in Table 7: NT-to-NT Transfer (bit 3), T/R* (bit 2), NC Monitor for NT-to-NT Transfer (bit 1), and Multicast (bit 0).

Table 8 – Multicast address or other Port_ID Field

NT-to-NT(s) Transfer	T/R*	NC monitor for NT-to-NT transfer	Multicast	Bits 23-0 description
0	0	X	X	Reserved. Shall be '00 00 00', see NOTE.
0	1	X	X	Reserved. Shall be '00 00 00'.
1	1	0 or 1 (see description)	0 or 1 (see description)	Port_ID of receiving NT for NT-to-NT or NT-to-NTs transfer. This combination of the NT-to-NT Transfer and T/R* control bits denotes the Command Sequence sent by the originating NC to the transmitting NT. If NC Monitor for NT-to-NT Transfer and/or Multicast = '1'b, then this Port_ID shall be an alias address. If NC Monitor for an NT-to-NT Transfer = '1'b, the alias group shall include the originating NC.
1	0	0 or 1 (see description)	0 or 1 (see description)	Port_ID of originating NC. For NT-to-NT or NT-to-NTs transfers, the combination of the NT-to-NT Transfer and T/R* control bits, along with this Port_ID denotes the Command Sequence sent by the transmitting NT to the receiving NT or NTs. For this Sequence, the values of the Data Byte Count field, along with the Receive RDMA, NC Monitor for NT-to-NT Transfer, and Multicast control bits are repeated from the Command Sequence from the originating NC.
NOTE For this case, if Multicast = '1'b, this denotes that the Port_ID in the Destination_ID field is an alias address.				

4.4.4.1.24 Other subaddress

The Other Subaddress field is mapped to FC-AE-1553 Command Sequence word 11 in Table 7, which is normally the sixth word of the Fibre Channel payload. For Command Sequences from the originating NC to the transmitting NT for NT-to-NT or NT-to-NTs transfers, this field shall specify the 32-bit subaddress for the receiving NT(s). For Command Sequences from the transmitting NT to the receiving NT for NT-to-NT or NT-to-NTs transfers, this field shall specify the 32-bit subaddress for the transmitting NT. In the latter case, this address is provided for advisory purposes only, and is not required to be checked by the receiving NT.

For Command Sequences for an NC-to-NT transfer in which the Transmit RDMA bit is ‘1’b, this field shall represent the starting byte memory address within the NC’s local memory space from where the NC will read from for data to be transmitted to the NT. For Command Sequences for an NT-to-NC transfer in which the Receive RDMA bit is ‘1’b, this field shall represent the starting byte memory address in the NC’s local memory space where the NC will store data to be received from the NT. In both of these cases, this address is provided for advisory purposes only, and is not required to be checked by the NT.

For Command Sequences from the originating NC for NC-to-NT transfers with Tx RDMA = 0, NT-to-NC transfers with Rx RDMA = 0, or Exchanges other than NT-to-NT, NT-to-NTs, NC-to-NT, or NT-to-NC transfers, this field is reserved and shall be assigned a value of hex ’00 00 00 00’.

4.4.4.2 FC-AE-1553 mode codes

4.4.4.2.1 General

FC-AE-1553 provides for the equivalent network control functions that are available using MIL-STD-1553 mode codes. There are also two additional mode codes which are specific to FC-AE-1553. FC-AE-1553 mode codes provide network management capability. The determination of whether the Command Sequence contains a mode code command is accomplished by decoding the Subaddress/Mode field. If the value of this field is hex ’00 00 00 00’ or hex ’FF FF FF FF’, this indicates that the Exchange is a mode code. In addition, for command Exchanges in which Subaddress/Mode field bits (31 to 10) indicate an Exchange bridged to a MIL-STD-1553 bus or MIL-STD-1553 RT(s) and the value of bits (4 to 0) of the Subaddress/Mode field are ‘00000b’ or ‘11111b’, then this also indicates that the Exchange is a mode code. In either case, the Byte Count/Mode Code field contains the mode code type.

Mode codes are designated by the value of the T/R* bit, along with bits (4 to 0) of the Byte Count/Mode Code field. The defined FC-AE-1553 mode codes are described in the following sub-clauses. FC-AE-1553 implementers may create vendor-specific or system-specific mode functions for code values not defined in the subclauses below.

4.4.4.2.2 Dynamic network control hex ‘00 00 00 00’ (T/R* = ‘1’b)

FC-AE-1553 Dynamic Network Control replaces the MIL-STD-1553B Dynamic Bus Control function. The NC shall issue a transmit command to an NT capable of performing the FC-AE-1553 network (loop and/or fabric) control function. This NT shall respond with a Status Sequence. The Network Control functions being performed by the specific NC initiating the Exchange passes to the accepting NT upon completion of the transmission of the Status Sequence by the NT indicating acceptance of the Network Control function. If the NT rejects taking control of the network, the offering NC retains control of the network.

4.4.4.2.3 Synchronize (without data word) hex ‘00 00 00 01’ (T/R* = ‘1’b)

This mode code command shall cause the NT to synchronize (e.g., to reset an internal timer). The NT shall complete the Exchange by transmitting its Status Sequence.

4.4.4.2.4 Transmit status sequence hex ‘00 00 00 02’ (T/R* = ‘1’b)

This mode code command shall cause the NT to transmit the Status Sequence associated with the last valid Command Sequence other than a Transmit Status or Transmit Last Command mode code preceding this command that was received from the respective NC. This mode code command shall not alter the NTs Status Sequence.

4.4.4.2.5 Initiate self-test hex ‘00 00 00 03’ (T/R* = ‘1’b)

This mode code command shall be used to initiate self-test within the receiving NT. The NT shall transmit a Status Sequence following reception of this command.

4.4.4.2.6 Transmitter shutdown hex '00 00 00 04' (T/R* = '1'b)

This mode code command may be used with dual redundant systems, and shall cause the NT to disable FC-AE-1553 transmissions for the alternate redundant port. The NT shall respond with a Status Sequence on the port where the command was received prior to shutdown. While shutdown, the NT shall not respond to Command Sequences on the effected port. This mode code command may be used to completely disable a redundant port for purposes of power management. Systems that make use of triple, quad, or higher redundancy levels shall use the Selected transmitter shutdown and override mode code commands to shutdown and re-enable redundant channels.

4.4.4.2.7 Override transmitter shutdown hex '00 00 00 05' (T/R* = '1'b)

This mode code command, which may be used with dual redundant systems, shall cause the NT to re-enable transmissions on the NT's alternate port which was previously shutdown by means of a Transmitter shutdown mode code command. The NT shall transmit a Status Sequence in response to this command.

4.4.4.2.8 Inhibit Terminal Flag (T/F) hex '00 00 00 06' (T/R* = '1'b)

This mode code command shall force the NT to cause the Terminal flag bit in its Status Sequence to a value of '0'b until an Override inhibit terminal flag mode command has been received. The NT shall transmit a Status Sequence in response to this command.

4.4.4.2.9 Override inhibit Terminal Flag hex '00 00 00 07' (T/R* = '1'b)

This mode code command shall cause the NT to override the inhibit Terminal flag bit in the Status Sequence. This will re-enable the NT's Terminal flag Status Sequence bit to become set to '1'b following a failure of its internal self-test. The NT shall respond with a Status Sequence.

4.4.4.2.10 Reset Network Terminal hex '00 00 00 08' (T/R* = '1'b)

This mode code command shall be used to reset an NT to a power-up initialized state. In this state, all Status Sequence bits shall be reset to '0'b, the Terminal flag bit will not be inhibited, and none of the NT's transmitters shall be in a shutdown state. The NT shall transmit a Status Sequence in response to this command and then reset. This mode code is not a network initialization command.

4.4.4.2.11 Transmit Vector Word hex '00 00 00 10' (T/R* = '1'b)

This mode code command shall cause the NT to transmit a Status Sequence that includes a 16-bit data word containing service request information.

4.4.4.2.12 Synchronize (with data word) hex '00 00 00 11' (T/R* = '0'b)

This mode code command shall cause the NT to receive the 16-bit synchronization word in the Command Sequence. The data word shall contain synchronization information for the NT. After receiving the command and data, the NT shall transmit the Status Sequence.

4.4.4.2.13 Transmit last command sequence hex '00 00 00 12' (T/R* = '1'b)

This mode code command shall cause the NT to transmit its Status Sequence comprised of the normal Status Sequence (see Table 9) concatenated with words 0 through 11 (see Table 7) of the most recently received Command Sequence other than a Transmit Status Sequence or Transmit Last Command Sequence mode command. This mode command shall not alter the state of the NT's Status Sequence.

In the case of a Transmit last Command Sequence mode code Exchange that is bridged through an FC-AE-1553 NT to a MIL-STD-1553 BC, the "last Command Sequence"

transmitted back to the NC shall be for the last Exchange except for a Transmit status or Transmit last Command Sequence mode code Exchange that was relayed through the bridge to the addressed MIL-STD-1553 RT.

NOTE In general, the last Exchange which was routed through the bridge to the addressed MIL-STD-1553 RT will **not** be the last Exchange received by the NT, since this most recent Exchange may have been non-bridged or an Exchange which was routed to a different bridged MIL-STD-1553 RT. Therefore, in order to implement the Transmit Last Command Sequence mode code for exchanges which are bridged to MIL-STD-1553 RTs, it is necessary for the bridge to maintain copies of the most recent 12-word Command Sequence headers which were used for generating MIL-STD-1553 messages to each of the RTs connected to the bridge.

4.4.4.2.14 Transmit built in test (BIT) Word hex '00 00 00 13' (T/R* = '1'b)

This mode code command shall cause the NT to transmit its Status Sequence followed by a single 16-bit data word containing the NT BIT data. This function is intended to supplement the available bits in the Status Sequence when the NT hardware is sufficiently complex to warrant its use. The data word, containing the NT BIT data, shall not be altered by reception of a transmit last command or a transmit Status Sequence mode code. This function shall not be used to convey BIT data from the associated subsystem(s).

4.4.4.2.15 Selected transmitter shutdown hex '00 00 00 14' (T/R* = '0'b)

This mode code command may be used with multi-redundant systems, and shall cause the NT to disable FC-AE-1553 Sequence transmissions for a specified redundant port. The NT shall respond with a Status Sequence after this command prior to the shutdown of the effected port. While shutdown, the specified port shall not respond to Command Sequences. This mode code command may be used to completely disable a redundant channel for power management purposes.

4.4.4.2.16 Override selected transmitter shutdown hex '00 00 00 15' (T/R* = '0'b)

This mode code command shall cause the NT to re-enable the transmitter on a specified redundant port that had previously been shutdown by means of a Selected transmitter shutdown mode code command. The transmitter that is to be enabled shall be identified in the 16-bit data word following the command. The NT shall respond with a Status Sequence.

4.4.4.2.17 Transmit RT address hex '00 00 00 16' (T/R* = '1'b)

This mode code command shall cause the NT to respond with status, followed by a single 16-bit data word containing the NT's hardwired MIL-STD-1553 and/or MIL-STD-1760 RT address. If the NT has a hardwired RT address, then bits (15 to 6) shall have a value of '0'b, bit 5 shall contain the value of the hardwired RT address parity bit, and bits (4 to 0) shall contain the values of the hardwired RT address bits. If the NT does not have a hardwired NT address, then this word shall have a value of hex 'FFFF'.

This mode code is not applicable to Exchanges transmitted through bridges to MIL-STD-1553B RTs.

4.4.4.2.18 Transmit NT_C-D/S_BURST_TOV hex '00 00 00 17' (T/R* = '1'b)

This mode code command shall cause the NT to respond with status, followed by a single 16-bit data word containing the NT's NT_C-D/S_BURST_TOV timeout value. This timer indicates the NT's maximum time between reception of an NC's Command Sequence or Data Sequence, and the beginning of the NT's Status Sequence response with the Burst Size Acknowledge bit set, indicating the number of payload bytes that the NT is able to receive in the next Data Sequence.

The 16-bit data word consists of two fields, BURST_TOV_Mantissa (bits 15-4) and BURST_TOV_Exponent (bits 3-0). The values of bits 15, 3, and 2 must be '0'b. This word indicates the value of the NT's NT_C-D/S_BURST_TOV timer such that:

NT_C-D/S_BURST_TOV = (BURST_TOV_Mantissa) * (16(BURST_TOV_Exponent)), with a resolution of 1 µS/LSB. This provides a timeout range from 1 µS to 8.38 s.

For example, if BURST_TOV_Mantissa = '0111 1010 0001'b and BURST_TOV_Exponent = '0010'b, then NT_C-D/S_BURST_TOV = 499.97 mS.

This mode code is not applicable to Exchanges transmitted through bridges to MIL-STD-1553B RTs.

4.4.4.3 MIL-STD-1553B status word mapping to FC-AE-1553

4.4.4.3.1 General

Table 9 shows the mapping of MIL-STD-1553 status word to word 6 of the FC-AE-1553 Status Sequence header. The FC-AE-1553 Status Sequence header includes a 2-word device header beyond the standard Fibre Channel header. If transmitted, the Status Sequence is always the first Sequence sent by an NT, and may include data bytes. The Status Sequence bits map directly to the lower 15 bits (bits 14 to 0) of status header word 6 as shown in Table 9.

Bits 14 and 13 are included for use only by FC-AE-1553-to-MIL-STD-1553 bridges, in order to provide indications of 'No Response' and Format Error' conditions from MIL-STD-1553 RTs attached to a bridge. For N_Ports and NL_Ports which are not attached to bridges, these two bits are not used and shall be transmitted with values of '0'b. Bit 12 is provided to allow receiving NTs to pace Sequence transmission from a transmitting NC or NT. The function of bit 11 is to notify an NC that two NTs need to perform explicit Port Login in order to complete an NT-to-NT transfer. The upper 17 bits are reserved, and shall be transmitted with values of '0'b.

In response to Command Sequences or Data Sequences (except for the final Data Sequence of the Exchange) in which NT Burst Size Request or Delayed NT Burst Size Request is set to '1'b, Status Sequence word 7 conveys the value of the maximum number of bytes that the NT is able to receive in the next transmitted Data Sequence.

The other function of Status Sequence word 7 is to enable the transmitting NT for an NT-to-NT transfer to respond to an NC with the receiving NT's status bits, along with its own status bits. For FC-AE-1553 Exchange formats other than NT-to-NT transfers, word 7 is reserved and not used; that is, the NT shall respond with a value of hex '00 00 00 00' for this word.

Table 9 – FC-AE-1553 status sequence header

Word	Bits			
	31 to 24	23 to 16	15 to 8	7 to 0
0	R_CTL	Destination ID (NC or NT address)		
1	CS_CTL	Source ID (Local NT address)		
2	TYPE	F_CTL		
3	SEQ_ID	DF_CTL	SEQ_CNT	
4	OX_ID		RX_ID	
5	Parameter			
6	NT Status (for Status Sequence sent by transmitting NT to originating NC for NT-to-NT transfers, this is the transmitting NT's status):			
	Reserved (17)	14: No by MIL-STD-1553 Response 1553 RT 13: MIL-STD-1553 Format Error 12: Burst Size Acknowledge 11: Port Login Required 10: Message Error 9: Instrumentation 8: Service Request 7:5: Reserved (3 bits) 4: Broadcast Cmd. Received 3: Busy 2: Subsystem Flag 1: Dynamic Network control 0: Terminal Flag		
7	In response to a Command Sequence and/or Data Sequence with Busy = '0'b and Burst Size Acknowledge = '1'b, this word represents the maximum Sequence size, in bytes, that the NT is able to receive in the next Data Sequence. For all Exchange types except as described above, or for the transmitting NT's Status Sequence to the originating NC for NT-to-NT transfers (see below), this word shall be reserved, and transmitted with a value of hex '00 00 00 00'. For the transmitting NT's Status Sequence to the originating NC for NT-to-NT transfers, this word shall represent the Status Sequence that the transmitting NT received from the receiving NT, as follows:			
	Reserved (17)	14: No Response by MIL-STD-1553 RT 13: MIL-STD-1553 Format Error 12. Burst Size Acknowledge 11: Port Login Required 10: Message Error 9: Instrumentation 8: Service Request 7:5: Reserved (3 bits) 4: Broadcast Cmd. Received 3: Busy 2: Subsystem Flag 1: Dynamic Network control 0: Terminal Flag		

4.4.4.3.2 No response by MIL-STD-1553 RT, bit 14

For an NT connected to a MIL-STD-1553 RT by means of a 1553-to-Fibre Channel bridge, this bit shall be '1'b if the RT does not respond within the time specified by MIL-STD-1553B. That is, the 1553 BC in the bridge shall wait a minimum of 14 µs to determine that an RT has not responded. If this bit is '1'b, the NT shall not transmit any data bytes. If the 1553 RT responded in time, this bit shall have a value of '0'b. For all Exchanges not involving a 1553-to-Fibre Channel bridge and a 1553 RT, the value of this bit shall be '0'b.

4.4.4.3.3 MIL-STD-1553 RT format error, bit 13

For an NT connected to a MIL-STD-1553 RT by means of a 1553-to-Fibre Channel bridge, this bit shall be '1'b if the RT responds within the required time, but its response does not meet the validity criteria specified by MIL-STD-1553B (i.e., correct RT address, byte count, validity of all words, etc.). If this bit is '1'b, the NT shall not transmit any data bytes. If the 1553 RT response is valid or the RT does not respond in time, this bit shall have a value of '0'b. For all Exchanges not involving a 1553-to-Fibre Channel bridge and a 1553 RT, the value of this bit shall be '0'b.

4.4.4.3.4 Burst size acknowledge, bit 12

This bit may be set by the receiving NT for an NC-to-NT transfer, or by the receiving NT for an NT-to-NT transfer. This bit shall be set in response to an NC's (or transmitting NT) Command Sequence which includes a value of '1'b for the NT Burst Size Request bit. If Burst Size Acknowledge is '1'b, this indicates that word 7 of the Status Sequence represents the maximum number of bytes that the NT can receive in the next Sequence. If this number is less than the value of the Byte Count field in the Command Sequence, then the NC will need to segment its total payload into multiple Data Sequences. In this case, following reception of the first data Sequence or a subsequent data Sequence, the NT shall respond with a second (or third, etc.) Status Sequence with Burst Size Acknowledge = '1'b.

Similarly, after reception of a Command Sequence with the Delayed NT Burst Size Request bit set and an immediately subsequent Data Sequence, if the number of payload bytes received is less than the total Byte Count specified by the Command Sequence, the receiving NT shall respond with a Status Sequence with the Burst Size Acknowledge bit set, and word 7 of the Status Sequence represent the maximum number of bytes that the NT can receive in the next Data Sequence.

In either case, the NT's transmission of its Status Sequence with the Busy bit set to '0'b and the Burst Size Acknowledge bit set to '1'b is followed by the NC's (or transmitting NT's) transmission of the next Data Sequence. This process is repeated until the NC or transmitting NT has transmitted the total number of data bytes specified in its Command Sequence.

If at any time the receiving NT cannot receive any additional data bytes, it shall respond with a value of '1'b for the Busy bit and a value of '0'b for Burst Size Acknowledge, thereby terminating the Exchange. Following valid reception of the last Data Sequence, if the Command Sequence Suppress Status bit was '0'b, the receiving NT shall respond with its final Status Sequence. In this Status Sequence, Burst Size Acknowledge shall have a value of '0'b.

In response to all Exchanges where the NT Burst Size Request and Delayed NT Burst Size Request Command Sequence bits are both '0'b, the value of the Burst Size Acknowledge bit in the NT's Status Sequence shall be '0'b.

4.4.4.3.5 Port login required, bit 11

The purpose of this bit is to handle a situation where the transmitting NT for an NT-to-NT transfer receives a command Sequence from an originating NC to transmit to an NT for which it must login with explicitly (PLOGI). In this scenario, the transmitting NT shall respond with a value of '1'b for this bit. If the originating NC retries the same command Sequence before the

transmitting NT has completed its explicit login with the receiving NT, then the transmitting NT shall continue to respond with a value of '1'b for this bit. The transmitting NT shall not attempt to complete the NT-to-NT transfer until the originating NC retries the command Sequence at a time following completion of the login procedure.

If explicit login with the receiving NT is not required or has already been completed, this bit shall be '0'b and the transmitting NT shall proceed with transmitting to the receiving NT. For Status responses to command Sequences other than transmit commands for NT-to-NT transfers, the value of this bit shall be '0'b.

4.4.4.3.6 Message error bit, bit 10

If the Message Error bit is a '1'b, this indicates that either:

a) the combination of IU type, NT Burst Size Request, Delayed NT Burst Size Request, Receive RDMA, Transmit RDMA, NT-to-NT Transfer, T/R* bit, Multicast, Subaddress, and Byte Count/Mode Code fields for the current Exchange has been illegalized (i.e., not implemented) by the NT. Note that for purposes of determining the value of Message Error, the value of Receive RDMA is "don't care" for a transmitting NT (T/R* = '1'b), including the command from the originating NC for an NT-to-NT transfer. In addition, for purposes of deterring the value of Message Error, the value of Transmit RDMA is "don't care" for a receiving NT (T/R* = '0'b), including for the receiving NT for an NT-to-NT transfer; or

b) for the response to a Transmit status or Transmit last command mode code Exchange (but no other Exchange types), that the previous Exchange was illegal or that there was an error in the data portion (but not in the command portion) of the most recent previous Exchange received from the respective NC.

In all other circumstances, the value of this bit shall be '0'b.

4.4.4.3.7 Instrumentation bit, bit 9

The value of this bit shall always be '0'b.

4.4.4.3.8 Service Request bit, bit 8

The use and implementation of the Service Request Bit is optional. A Service Request Bit that is set to a value of '1'b, shall indicate the need for the Network Controller to take specific predefined actions relative to either the NT or the associated subsystem. A Service Request Bit that is set to a '0'b, shall indicate that either that the feature is not implemented by the NT, or the absence of a service request.

4.4.4.3.9 Broadcast command received bit, bit 4

This bit shall be '0'b in all Status Sequences except for Transmit status mode code or Transmit last command mode code Status Sequences. When the Broadcast Command Received bit is set to a '1'b, this indicates that the most recently received valid command received (other than these two mode codes) from the current Exchange's BC was a broadcast Exchange. For Transmit status or Transmit last command mode codes, when this bit is '0'b, this indicates that the most recently received valid command received from the respective BC was not a broadcast Exchange.

4.4.4.3.10 Busy bit, bit 3

The use and implementation of the Busy Bit is optional. When the Busy Bit is set to a '1'b this indicates that the NT or subsystem was unable to move data to or from the subsystem in compliance with the controller Command Sequence. If not implemented, this bit shall always be '0'b.

4.4.4.3.11 Subsystem flag bit, bit 2

The use and implementation of the Subsystem Flag Bit is optional and may be used to indicate a subsystem fault condition. A '1'b indicates a fault and a '0'b indicates no fault. If the Subsystem Flag Bit is not implemented, it shall be a '0'b.

4.4.4.3.12 Dynamic network control acceptance bit, bit 1

The use and implementation of the Dynamic Network Control Acceptance Bit is optional and is used to indicate the acceptance or rejection of an offer to take control of the FC-AE-1553 network. This bit shall only be set to a '1'b to indicate that the NT has accepted the Network Controller function in response to a Dynamic Network Control mode command. For all other Status Sequences, or if Dynamic Network Control is not implemented, this bit shall be set to a '0'b.

4.4.4.3.13 Terminal flag bit, bit 0

The use and implementation of the Terminal Flag Bit is optional. The Terminal Flag Bit may be used to indicate the presence of an NT fault condition. A '1'b shall indicate a fault condition. If not used, this bit shall be a '0'b.

4.4.4.4 FC-AE-1553 ULP timers

4.4.4.4.1 General

FC-AE-1553 defines six ULP-specific timers: NT_C/S_TOV, NT_C-D/S_BURST_TOV, NC_C/S_TOV, NC_C-D/S_BURST_TOV, C-S/D_TX_TOV, and C-S/D_RX_TOV. For a given network, the values for these six timers shall be defined implicitly or explicitly by means of Process Login (PRLI). These six timers are illustrated by Figure 17.

4.4.4.4.2 NT_C/S_TOV

The NT_C/S_TOV timeout value defines the maximum time between an NT's reception of an NC's Command Sequence, Command Sequence followed by a Data Sequence, or final Data Sequence and the NT's start of transmission of its final Status Sequence response.

4.4.4.4.3 NT_C-D/S_BURST_TOV

The NT_C-D/S_BURST_TOV timeout value defines the maximum time between an NT's reception of a Command Sequence or Data Sequence from an NC or transmitting NT for an NT-to-NT transfer, and the beginning of the NT's Status Sequence response with the Burst Size Acknowledge bit set, indicating the maximum number of payload bytes that the NT is able to receive in the next Data Sequence.

4.4.4.4.4 NC_CS _TOV

The NC_C/S_TOV timeout value defines the minimum time that an NC shall wait for an NT's final status response before determining that a no response condition has occurred. It shall be the time from the end of the NC's transmission of its Command Sequence, Command Sequence plus Data Sequence, or final Data Sequence until the beginning of reception of the NT's final Status Sequence response. The value of NC_C/S_TOV shall be greater than the value of NT_C/S_TOV.

4.4.4.4.5 NC_C-D/S_BURST_TOV

The NC_C-D/S_BURST_TOV timeout value defines the minimum time that an NC shall wait for an NT's status response with its Burst Size Acknowledge bit set, before determining that a no response condition has occurred. This shall be the time from the end of the NC's transmission of its Command Sequence, Command Sequence plus Data Sequence, or Data Sequence, until the beginning of reception of the NT's Status Sequence with the Burst Size Acknowledge bit set, indicating the number of payload bytes that the NT is able to receive in

the next Sequence. The value of NC_C-D/S_BURST_TOV shall be greater than the value of NT_C-D/S_BURST_TOV.

4.4.4.4.6 C-S/D_RX _TOV

For an NC transmitting a Data Sequence, the C-S/D_TX _TOV timeout value defines the maximum time between the end of its Command Sequence and the start of its transmitted Data Sequence, or the time between the end of one Data Sequence and the start of the next Data Sequence. For an NT transmitting a Data Sequence, the C-S/D_TX _TOV timeout value defines the maximum time between the end of its Status Sequence and the start of its transmitted Data Sequence.

4.4.4.4.7 C-S/D _RX _TOV

For an NT receiving a Command Sequence followed by a Data Sequence from an NC, the C-S/D_RX _TOV timeout value defines the minimum time that the NT shall wait between receiving the end of an NC's Command Sequence and the beginning of reception of the NC's Data Sequence, or the time between the end of one Data Sequence and the start of the next Data Sequence, before determining that a C-S/D_RX _TOV timeout condition has occurred. For an NC receiving a Status Sequence followed by a Data Sequence from an NT, the C-S/D_RX _TOV timeout value defines the minimum time that the NC shall wait between receiving the end of an NT's Status Sequence and the beginning of reception of the NT's Data Sequence, or the time between the end of one Data Sequence and the start of the next Data Sequence, before determining that a C-S/D_RX _TOV timeout condition has occurred. The value of C-S/D_RX _TOV shall be greater than the value of C-S/D_TX _TOV.

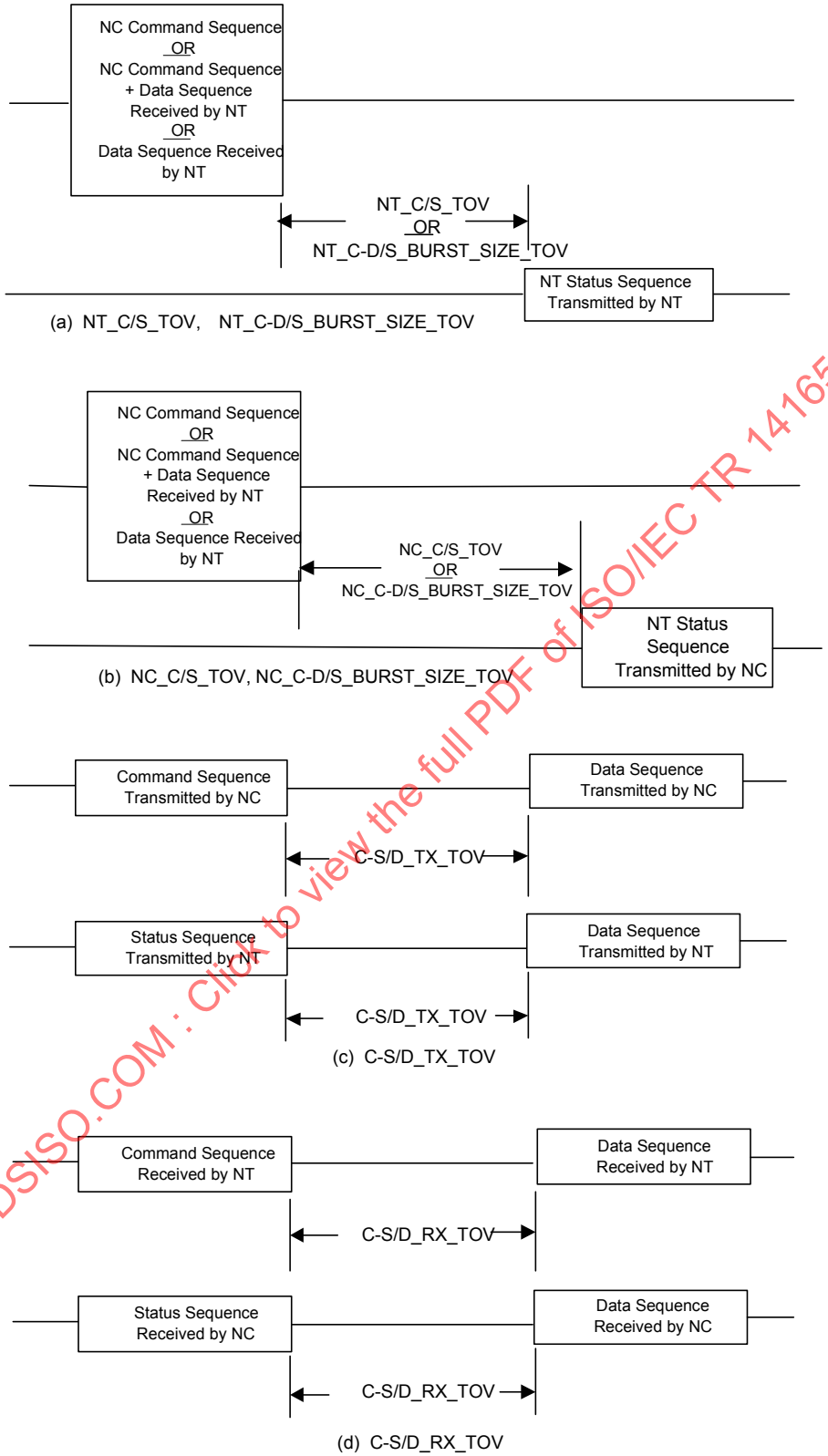

Figure 17 – FC-AE-1553 ULP timers: (a) NT_C/S_TOV and NT_C-D/S_BURST_TOV; (b) NC_C/S_TOV and NC_C-D/S_BURST_TOV; (c) C-S/D_TX_TOV (shown for NC and NT); (d) C-S/D_RX_TOV (shown for NC and NT)

4.4.4.5 NT Sequence(s) validation and response

An NT receiving a Sequence from an NC or another NT shall perform the following validity checks on all received frames, Sequences, and Exchanges:

a) For all received frames, valid SOF (Start_of_Frame): SOF_{i3} for the Command Sequence or first frame of a Data Sequence; or SOF_{n3} for all frames of Data Sequence following the first data frame.

b) For all received ordered sets and words, correct 8B/10B encoding and running disparity.

c) For all received frames, valid Fibre Channel header, as follows:

1) Valid D_ID: this may be either the NT's unique Port_ID, the broadcast D_ID (hex 'FF FF FF'), or a previously established alias Port_ID, or (on a loop) selective replicate Port_ID, or (on a loop) the AL_PA broadcast replicate address of hex 'FF'.

2) ROUTING bits of R_CTL field = 0000

3) Information Category = 6 for Command Sequence, or 1 for Data Sequence

4) For all Sequences, same Information Category for all frames of a Sequence.

5) Valid S_ID, per system specification

6) TYPE field = 48h.

7) Valid F_CTL field, including correct values per Exchange for First Sequence ('1'b for command, '0'b for data), Last_Sequence, End_Sequence, Sequence Initiative transferred, Relative Offset present, and Fill Bytes. Refer to Table 10 below for the correct values for these F_CTL field bits. All other F_CTL bits shall be '0'b.

8) Same SEQ_ID for all frames of a Data Sequence

9) Same OX_ID for Command Sequence and all frames of all Data Sequences, if any.

10) RX_ID = FFFF for all Command and Data frames.

11) DF_CTL = 00h.

12) SEQ_CNT is monotonically increasing.

13) Parameter field: for Data Sequences, the value of Relative Offset shall be monotonically increasing for all successive frames.

d) Valid FC-AE-1553 header extension for received Command Sequence, as follows:.

1) The upper 23 bits of the first word of the FC-AE-1553 header extension shall have values of all '0's.

2) For a non-mode code Exchange with T/R* = 1, then Suppress Status shall have a value of '0'b. For a mode code Exchange, or a non-mode code Exchange with T/R* = 0, then the NT shall observe the value of Suppress Status.

3) The values of the D_ID field (for broadcast); along with the values of the NT-to-NT Transfer, T/R*, Tx RDMA, and RDMA bits; and the Subaddress, Byte Count/Mode Code, and Other Subaddress fields shall be interpreted and verified In accordance with Table 11.

Table 10 – Correct values for F_CTL field bits

Type(s) of sequence	First sequence	Last sequence	End sequence	Sequence Initiative transferred (this bit is only valid for the last frame of each sequence)	Relative offset present	Fill bytes
- Command Sequence for NC-to-NT transfers; consists of FC-AE-1553 Command Sequence header extension plus up to 2 048 data bytes maximum. Not followed by NC Data sequence. - Command Sequence for transmitting NT for NT-to-NT transfer Exchanges; consists of FC-AE-1553 Command Sequence header extension plus up to 2 048 data bytes maximum. Not followed by a Data Sequence.	1	0 (if Suppress status = '0'b) 1 (if Suppress status = '1'b)	1	1 (if Suppress status = '0'b) 0 (if Suppress status = '1'b)	0	any value
- Command Sequence for NT-to-NC transfers. - Command Sequence for non-broadcast mode code exchanges (with or without data word).	1	0	1	1	0	00
- Command Sequence for NC-to-NT transfers; consists of FC-AE-1553 Command Sequence header extension plus up to 2 048 data bytes maximum, and is followed by an NC Data sequence. - Command Sequence sent by transmitting NT for NT-to-NT or NT-to-NTs transfer exchanges; consists of FC-AE-1553 Command Sequence header extension plus up to 2 048 data bytes maximum, and is followed by an NT Data Sequence.	1	0	1	1 (if Suppress status = '0'b) 0 (if Suppress status = '1'b)	0	If RX RDMA = '1'b: 00 If RX RDMA = '0'b: any value
- First frame(s), up to but not including the last frame of Data Sequence following the Command Sequence for the originating NC for NC-to-NT or NC-to-multiple NTs transfer exchanges. - First frame(s), up to but not includingthe last frame of Data Sequence following the Command Sequence for the transmitting NT for NT-to-NT or NT-to-NTs transfer Exchanges.	0	0 (if Suppress Status = '0'b) 1 (if Suppress Status = '1'b)	0	0	1	00
- Last frame of Data Sequence transmitted by originating NC for NC-to-NC or NC-to-multiple NTs transfer exchanges. - Last frame of Data Sequence transmitted by transmitting NT for NT-to-NT or NT-to-NTs transfer Exchanges.	0	0 (if Suppress Status = '0'b) 1 (if Suppress Status = '1'b)	1	1 (if Suppress Status = '0'b) 0 (if Suppress Status = '1'b)	1	If RX RDMA = '1'b: 00 If RX RDMA = '0'b: any value
- Command Sequence for NC-to-Multiple NTs transfers; consists of FC-AE-1553 Command Sequence header extension plus up to 2 048 data bytes maximum. Not followed by NC Data Sequence. - Mode Command Sequence (with or without data word) to multiple NTs exchanges.	1	0 (if Suppress Status = '0'b) 1 (if Suppress Status = '1'b)	1	1 (if Suppress Status = '0'b) 0 (if Suppress Status = '1'b)	0	For NC-to-multiple NTs: if RX RDMA = '1'b, then 00.; if RX RDMA = '0'b, then any value. For mode code Exchanges: 00 or 10

Table 11 – Values for D_ID field (for broadcast); NT-to-NT Transfer, T/R*, Tx RDMA, and RDMA bits; subaddress, byte Count/Mode bode, and other subaddress fields

D_ID = ' FF FF FF' or Multicast = '1'b	Subaddress 31 to 0	Subaddress 31 to 10	NT-to-NT transfer	T/R*	Rx RDMA	Tx RDMA	Subaddress field (SA 31 to 0)	Byte Count/Mode Code 31 to 0	"Other subaddress" field
Yes	> '00 00 00 00' and < '11 11 11 11'	X	X	1	X	X	Invalid combination		
X	Bits 31 – 10 not all '0's and not all '1's; and Bits 9 – 5 = '11111b'; and Bits 4 – 0 > '00000b' and < '11111b"	A value designating a MIL-STD-1553 bridge address	X	1	X	X	Invalid combination		
X	= '00 00 00 00' or = '11 11 11 11'	X	1	X	X	X	Invalid combination		
X	Bits 31 – 10 not all '0's and not all '1's; and Bits 4 –0 = '00000b' or '11111b'	A value designating a MIL-STD-1553 bridge address	1	X	X	X	Invalid combination		
X	= '00 00 00 00' or = '11 11 11 11'	By definition, not a MIL-STD-1553 bridge address	0	X	Must = '0'b (else invalid)	Must = '0'b (else invalid)	Specifies an FC-AE-1553 mode code Exchange	Bits 31 – 5 must be all '0'bs (else invalid); Bits 4 – 0 designate specific FC-AE-1553 mode code command	All '0'bs (else invalid)
X	> '00 00 00 00' and < '11 11 11 11'	Not a MIL-STD-1553 bridge address	0	0	0	0	32-bit FC-AE-1553 Receive Subaddress	32-bit FC-AE-1553 byte count	All '0'bs (else invalid)
No	> '00 00 00 00' and < '11 11 11 11'	Not a MIL-STD-1553 bridge address	0	1	0	0	32-bit FC-AE-1553 Transmit Subaddress	32-bit FC-AE-1553 byte count	All '0'bs (else invalid)
X	> '00 00 00 00' and < '11 11 11 11'	Not a MIL-STD-1553 bridge address	0	0	0	1	32-bit FC-AE-1553 Receive Subaddress	32-bit FC-AE-1553 byte count	NC RDMA transmitting starting address (advisory)
No	> '00 00 00 00' and < '11 11 11 11'	Not a MIL-STD-1553 bridge address	0	1	0	1	NT RDMA transmit starting address	32-bit FC-AE-1553 byte count	Must be all '0's (else invalid)

D_ID = ‘ FF FF FF’ or Multicast = ‘1’b	Subaddress 31 to 0	Subaddress 31 to 10	NT-to-NT transfer	T/R*	Rx RDMA	Tx RDMA	Subaddress field (SA 31 to 0)	Byte Count/Mode Code 31 to 0	“Other subaddress” field
X	> ‘00 00 00 00’ and < ’11 11 11 11’	Not a MIL-STD-1553 bridge address	0	0	1	0	NT RDMA receive starting address	32-bit FC-AE-1553 byte count	Must be all ‘0’s (else invalid)
No	> ‘00 00 00 00’ and < ’11 11 11 11’	Not a MIL-STD-1553 bridge address	0	1	1	0	32-bit FC-AE-1553 Transmit Subaddress	32-bit FC-AE-1553 byte count	NC RDMA receiving starting address (advisory)
X	> ‘00 00 00 00’ and < ’11 11 11 11’	Not a MIL-STD-1553 bridge address	0	0	1	1	NT RDMA receive starting address	32-bit FC-AE-1553 byte count	NC RDMA transmitting starting address (advisory)
No	> ‘00 00 00 00’ and < ’11 11 11 11’	Not a MIL-STD-1553 bridge address	0	1	1	1	NT RDMA transmit starting address	32-bit FC-AE-1553 byte count	NC RDMA receiving starting address (advisory)
X	> ‘00 00 00 00’ and < ’11 11 11 11’	Not a MIL-STD-1553 bridge address	1	0	0	0	Rx NT 32-bit FC-AE-1553 Receive Subaddress	32-bit FC-AE-1553 byte count	Tx NT 32-bit FC-AE-1553 subaddress
No	> ‘00 00 00 00’ and < ’11 11 11 11’	Not a MIL-STD-1553 bridge address	1	1	0	0	Tx NT 32-bit FC-AE-1553 Transmit Subaddress	32-bit FC-AE-1553 byte count	Rx NT 32-bit FC-AE-1553 subaddress
X	> ‘00 00 00 00’ and < ’11 11 11 11’	Not a MIL-STD-1553 bridge address	1	0	0	1	Rx NT 32-bit FC-AE-1553 Receive Subaddress	32-bit FC-AE-1553 byte count	Tx NT RDMA starting address (advisory)
No	> ‘00 00 00 00’ and < ’11 11 11 11’	Not a MIL-STD-1553 bridge address	1	1	0	1	Tx NT RDMA starting address	32-bit FC-AE-1553 byte count	Rx NT 32-bit FC-AE-1553 subaddress
X	> ‘00 00 00 00’ and < ’11 11 11 11’	Not a MIL-STD-1553 bridge address	1	0	1	0	Rx NT RDMA starting address	32-bit FC-AE-1553 byte count	Tx NT 32-bit FC-AE-1553 subaddress
No	> ‘00 00 00 00’ and < ’11 11 11 11’	Not a MIL-STD-1553 bridge address	1	1	1	0	Tx NT 32-bit FC-AE-1553 Transmit Subaddress	32-bit FC-AE-1553 byte count	Rx NT RDMA starting address
X	> ‘00 00 00 00’ and < ’11 11 11 11’	Not a MIL-STD-1553 bridge address	1	0	1	1	Rx NT RDMA starting address (advisory)	32-bit FC-AE-1553 byte count	Tx NT RDMA starting address
No	> ‘00 00 00 00’ and < ’11 11 11 11’	Not a MIL-STD-1553 bridge address	1	1	1	1	Tx NT RDMA starting address	32-bit FC-AE-1553 byte count	Rx NT RDMA starting address

D_ID = ' FF FF FF' or Multicast = '1'b	Subaddress 31 to 0	Subaddress 31 to 10	NT-to-NT transfer	T/R*	Rx RDMA	Tx RDMA	Subaddress field (SA 31 to 0)	Byte Count/Mode Code 31 to 0	"Other subaddress" field
X	Bits 31 – 10 not all '0's and not all '1's	A value designating a MIL-STD-1553 bridge address	0	0	Must = '0'b (else invalid)	X	SA 31 - 10 = bridge address; SA 9 - 5 = MIL-STD-1553 RT Address; SA 4- 0 = MIL-STD-1553 Subaddress	If SA 9 – 5 = '00000b' or '11111b', then bits 31- 5 must = all '0's (else invalid) and bits 4 –0 = MIL-STD-1553 mode code. If SA 9 – 5 > '00000b' and > '11111b', then bits bits 31 – 6 = all '0's (else invalid) and bits 5 – 0 specify 2*(MIL-STD-1553 word count).	Must be all '0's (else invalid)
X	Bits 31 – 10 not all '0's and not all '1's	A value designating a MIL-STD-1553 bridge address	0	1	X	Must = '0'b (else invalid)	SA 31 - 10 = bridge address; SA 9 - 5 = MIL-STD-1553 RT Address; SA 4- 0 = MIL-STD-1553 Subaddress	If SA 9 – 5 = '00000b' or '11111b', then bits 31- 5 must = all '0's (else invalid) and bits 4 –0 = MIL-STD-1553 mode code. If SA 9 – 5 > '00000b' and < '11111b', then bits bits 31 – 6 = all '0's (else invalid) and bits 5 – 0 specify 2*(MIL-STD-1553 word count).	Must be all '0's (else invalid)
X	Bits 31 – 10 not all '0's and not all '1's	A value designating a MIL-STD-1553 bridge address	1	0	Must = '0' (else invalid)	0	SA 31 - 10 = bridge address; SA 9 - 5 = MIL-STD-1553 RT Address (receiving RT); SA 4- 0 = MIL-STD-1553 (receiving RT) Subaddress	If SA 9 – 5 = '00000b' or '11111b', then invalid If SA 9 – 5 > '00000b' and < '11111b', then bits bits 31 – 6 = all '0's (else invalid) and bits 5 – 0 specify 2*(MIL-STD-1553 word count).	Tx NT 32-bit FC-AE-1553 subaddress
X	Bits 31 – 10 not all '0's and not all '1's	A value designating a MIL-STD-1553 bridge address	1	0	Must = '0'b (else invalid)	1	SA 31 - 10 = bridge address; SA 9 - 5 = MIL-STD-1553 RT Address (receiving RT); SA 4- 0 = MIL-STD-1553 (receiving RT) Subaddress	If SA 9 – 5 = '00000b' or '11111b', then invalid If SA 9 – 5 > '00000b' and < '11111b', then bits bits 31 – 6 = all '0's (else invalid) and bits 5 – 0 specify 2*(MIL-STD-1553 word count).	Tx NT 32-bit RDMA starting address (advisory)

D_ID = ' FF FF FF' or Multicast = '1'b	Subaddress 31 to 0	Subaddress 31 to 10	NT-to-NT transfer	T/R*	Rx RDMA	Tx RDMA	Subaddress field (SA 31 to 0)	Byte Count/Mode Code 31 to 0	"Other subaddress" field
No	Bits 31 – 10 not all '0's and not all '1's	A value designating a MIL-STD-1553 bridge address	1	1	1	Must = '0'b (else invalid)	SA 31 - 10 = bridge address; SA 9 - 5 = MIL-STD-1553 RT Address (receiving RT); SA 4- 0 = MIL-STD-1553 (receiving RT) Subaddress	If SA 9 – 5 = '00000b' or '11111b', then invalid If SA 9 – 5 > '00000b' and < '11111b', then bits 31 – 6 = all '0's (else invalid) and bits 5 – 0 specify 2*(MIL-STD-1553 word count).	Rx NT 32-bit RDMA starting address
No	Bits 31 – 10 not all '0's and not all '1's	A value designating a MIL-STD-1553 bridge address	1	1	0	Must = '0'b (else invalid)	SA 31 - 10 = bridge address; SA 9 - 5 = MIL-STD-1553 RT Address (receiving RT); SA 4- 0 = MIL-STD-1553 (receiving RT) Subaddress	If SA 9 – 5 = '00000b' or '11111b', then invalid If SA 9 – 5 > '00000b' and < '11111b', then bits 31 – 6 = all '0's (else invalid) and bits 5 – 0 specify 2*(MIL-STD-1553 word count).	Rx NT 32-bit FC-AE-1553 subaddress

(1)

The bits of the fourth word of the FC-AE-1553 header extension shall have values as illustrated in Table 12 below.

Table 12 – Correct values for fourth word of FC-AE-1553 header extension

NT-to-NT transfer	T/R*	Fourth word of FC-AE-1553 header extension	
		Bits 31 to 15, 9, 7, 6, and 5	Bits 14 to 10, 8, and 4 to 0
0	X	hex '00 00 00 00'	
1	0	All '0'bs	0 or 1
1	1	hex '00 00 00 00'	

The Multicast Address or Other Port_ID field shall have a value as illustrated in Table 13 below.

Table 13 – Correct Values for multicast address or other Port_ID field

NT-to-NT Transfer	T/R*	Multicast	Multicast address or other Port_ID field	
			Bits 31 to 24	Bits 23 to 0
0	0	X	hex '00'	hex '00 00 00'
0	1	0	hex '00'	hex '00 00 00'
0	1	X	hex '00'	hex '00 00 00'h
1	1	0	hex '00'	Valid unique Port_ID (of receiving NT), not equal to the NT's own Port_ID, per system specification; or broadcast address = hex 'FF FF FF'.
1	1	1	hex '00'	Previously established multicast Port_ID (of receiving NTs' alias group). This Port_ID cannot = broadcast address = hex 'FF FF FF'.
1	0	X	hex '00'	Valid unique Port_ID (of originating NC), not equal to the NT's own Port_ID.

For the Other Subaddress field:

- if NT-to-NT Transfer is '0'b, then this field must be '00 00 00 00';
- if NT-to-NT Transfer = '1'b then this word must contain a value other than '00 00 00 00' or 'FF FF FF FF.

a) For an Exchange involving the NC's transmission of one or more Data Sequences, the start of each Data Sequence shall be received within C-S/D_RX_TOV following the end of the NC's Command Sequence or the previous Data Sequence.

b) For an NC or NT transmitting a Data Sequence, the receiving NT shall verify that the time between frames is less than E_D_TOV.

c) Correct byte count for data payload, as follows:
   - For all non-mode code Exchanges, the total number of received data bytes in the Command Sequence, or combined number of data bytes in the Command Sequence and subsequent Data Sequences shall be equal to the number specified in the Command Sequence Byte Count/Mode Code field.
   - For the case of a mode code Exchange, the only correct payload byte counts are 0 if bit 4 of the Byte Count/Mode Code field is '0'b, and 2 if the bit 4 of the byte count/mode code field is '1'b.

d) For a non-mode Exchange with NT Burst Size Request = '1'b or Delayed NT Burst Size Request = '1'b, the receiving NT shall also verify that the byte count for a received Data Sequence is less than or equal to the maximum value that it is configured to receive. For

the case where NT Burst Size Request = '1'b and Delayed NT Burst Size Request = '0'b or for Data Sequences other than the initial one for the case where Delayed NT Burst Size Request = '1'b and NT Burst Size Request = '0'b, the maximum byte count value is specified in Word 7 of the most recent Status Sequence transmitted by the NT with the Burst Size Acknowledge bit = '1'b. For the case of the first Data Sequence of an Exchange where Delayed NT Burst Size Request = '1'b and Burst Size Request = '0'b, the value for this maximum byte count is specified by means of implicit or explicit FC-AE-1553 Process Login.

e) Correct CRC for all frames.

f) Valid EOF (End_of_Frame): EOF_n for all frames except for last frame of Sequences; EOF_t for last frames of Sequences.

With the exception of Exchanges with the Suppress Status bit having a value of '1'b, if the Command Sequence, or Command and Data Sequence(s) received from the NC or transmitting NT meets the above validation criteria, the NT shall respond with its Status Sequence within a maximum time of NT_C/S_TOV. If the NT's response includes one or more Data Sequences, the start of transmission of each Data Sequence shall occur within C-S/D_TX_TOV following the end of its Status Sequence or previous Data Sequence. If the NT receives an Exchange from an NC or transmitting NT that does not meet the above validation criteria, then the NT shall suppress the transmission of its Status Sequence (and Data Sequence, if any).

4.4.4.6 NC timeouts

For the case of NT Burst Size Request = Delayed NT Burst Size Request = '0'b, for all non-broadcast Exchange formats except for NT-to-NT transfers with the NC Monitor for NT-to-NT Transfer bit set to '0'b, or NC-to-NT transfers and mode code Exchanges with the Suppress Status bit having a value of '1'b, the NC, after completing transmission of a Sequence to an NT, shall monitor for the NT's response. The minimum time that an NC shall wait before determining that a response as specified has not occurred shall be NC_C/S_TOV.

For the case of NT Burst Size Request = '1'b or Delayed NT Burst Size Request = '1'b, for all non-broadcast Exchange formats except for NT-to-NT transfers with the NC Monitor for NT-to-NT Transfer bit set to '0'b, or NC-to-NT transfers and mode code Exchanges with the Suppress Status bit having a value of '1'b, the NC, after completing transmission of a Sequence to an NT, shall monitor for the NT's response. With the exception of the last transmitted Data Sequence of an Exchange, the minimum time that an NC shall wait before determining that a response as specified has not occurred shall be NC_C-D/S_BURST_TOV. For the case of the last transmitted Data Sequence of an Exchange, the minimum time that an NC shall wait before determining that a final status response as specified has not occurred shall be NC_C/S_TOV.

For Exchanges in which an NT responds with a Data Sequence following its Status Sequence, if the NC does not receive the start of the NT's Data Sequence within C-S/D_RX_TOV following the end of the NT's Status Sequence or previous Data Sequence, it shall determine that a timeout error has occurred.

For NC-to-NTs or mode code broadcast Exchanges, or NC-to-NT transfers and non-broadcast mode code Exchanges with the Suppress Status bit having a value of '1'b, the NC shall not anticipate any NT responses.

For the case of the originating Exchange for an NT-to-NT transfer, the timeout value shall be increased to account for the transmitting and receiving NTs' response times, and the time for the transmitting NT to send its Command Sequence and possible Data Sequence(s). In addition, for the case where NT Burst Size Request is set to '1'b or Delayed NT Burst Size Request is set to '1'b, this time needs to increase to account for the additional delays for the

receiving NT to respond with its Status Sequences indicating the maximum number of bytes it can receive in the next Data Sequence; that is, its NC_C-D/S_BURST_TOV timer.

This timeout value is considered for three different cases: (1) NT Burst Size Request = Delayed NT Burst Size Request = '0'b; (2) NT Burst Size Request = '1'b, with or Delayed NT Burst Size Request = '0'b; and (3) NT Burst Size Request = '0'b, with or Delayed NT Burst Size Request = '1'b. For the originating NC, the minimum timeout values for each of the respective cases is as follows:

(1) $NC\_NT\text{-}to\text{-}NT\_C/S\_TOV_{NO\_BURST\_SIZE\_REQUEST} = ((((10.3 * (Data\_Byte\_Count)) + 1\,040)) * t_{bit}) + (3 * NC\_C/S\_TOV) + ((N_{data\_seq} - 1) * C\text{-}S/D\_TX\_TOV) + C\text{-}S/D\_RX\_TOV$

(2) $NC\_NT\text{-}to\text{-}NT\_C/S\_TOV_{NT\_BURST\_SIZE\_REQUEST} = (((10.3 * (Data\_Byte\_Count)) + ((60 + ((N_{data\_seq} + 1) * 44)) * 10)) * t_{bit}) + (3 * NC\_C/S\_TOV) + (N_{data\_seq} * NC\_C\text{-}D/S\_BURST\_TOV)$

(3) $NC\_NT\text{-}to\text{-}NT\_C/S\_TOV_{NT\_DELAYED\_BURST\_SIZE\_REQUEST} = (((10.3 * (Data\_Byte\_Count)) + ((60 + ((N_{data\_seq}) * 44)) * 10)) * t_{bit}) + (3 * NC\_C/S\_TOV) + ((N_{data\_seq} - 1) * NC\_C\text{-}D/S\_BURST\_TOV)$

NOTE 1 The value t_{bit} specifies one transmission bit time. For example, for a 1.0625 Gbit/s bit rate, t_{bit} = 941 pS.

NOTE 2 N_{data_seq} = the number of Data Sequences in the Exchange.

NOTE 3 This model assumes contiguous frame transmission with 6 IDLEs between Data Frames, and all Data Frames containing 2 048 data bytes. Further, for the Burst Size Request and Delayed Burst Size Request modes, it is assumed that there is zero delay between the transmitting NT's reception of the receiving NT's Status Sequence indicating the maximum burst size it can receive and the start of the transmitting NT's next Data Sequence. If delays between the transmitting NT Status Sequence reception and start of Data Sequence transmission or between transmitted Data Frames are assumed, and/or the average number of data bytes per Data Frame is less than 2048, then the value of the constant "10.3" in the above equations should be increased accordingly.

4.4.4.7 Use of ABTS and RRQ

There is an FC-AE-1553 PRLI option to invoke ABTS protocol if an NC times out an Exchange waiting for NT Status or detects an error in status or data from a responding NT. Similarly, ABTS protocol shall be invoked for an NT-to-NT transfer if the transmitting NT times out waiting for Status or detects an error in Status from the receiving NT. In the latter case, the transmitting NT shall issue an ABTS to both the receiving NT, as well as to the originating NC. This has the effects of aborting both the originating and responding Exchanges.

ABTS protocol shall not be invoked for an error in the last Sequence of an Exchange.

In the ABTS request, Abort Exchange, bit 0 of the ABTS parameter field shall be assigned a value of '0'b. Following issuance of an ABTS request and following reception of a Basic Accept (BA_ACC), the ABTS Initiator shall wait for R_A_TOV before issuing an RRQ (Reinstate Recovery Qualifier) ELS request. This allows an NC and/or transmitting NT to retry a failed Exchange using the same OX_ID/SEQ_ID pair.

Annex A
(normative)

FC-AE-1553 process login

A.1 Overview of process login and process logout

Process Login allows for a process at one FC-AE-1553_Port to be related to a corresponding process at another FC-AE-1553_Port as an image pair. In addition, PRLI allows one or more FC-4 capabilities to be reported by the initiating FC-AE-1553_Port to the recipient FC-AE-1553_Port. The recipient FC-AE-1553_Port indicates its acceptance or rejection of the capabilities in its response to the PRLI request.

Since implicit login may be established by configuration conventions outside the scope of this standard, explicit Process Login is optional.

PRLI requests shall only be initiated by devices having the NC FC-AE-1553_Port capability. Devices having only NT FC-AE-1553_Port capability shall not perform a PRLI request.

An NC FC-AE-1553_Port shall have successfully completed Process Login with a NT FC-AE-1553_Port that establishes an image pair before any FC-AE-1553 IUs are Exchanged. An image pair may also be established by an implicit Process Login established by methods outside the scope of this standard. An image pair is removed by an implicit Process Logout or explicit PRLO. If an image pair is not established by an NC FC-AE-1553_Port to a NT FC-AE-1553_Port, the NC FC-AE-1553_Port and NT FC-AE-1553_Port shall not Exchange any FC-AE-1553 IUs. Any FC-AE-1553 IUs received by an NT FC-AE-1553_Port from an Nx_Port that does not have an image pair with that NT FC-AE-1553_Port shall be discarded. In addition, an NT FC-AE-1553_Port that receives an FC-AE-1553 Command Sequence from an Nx_Port that has successfully completed PLOGI, but does not have an image pair with that NT FC-AE-1553_Port, shall discard the FC-AE-1553 Command Sequence and respond with an explicit PRLO. Reasons why the Nx_Port does not have an image pair with the NT FC-AE-1553_Port include:

a) The Nx_Port has not established an image pair with that NT FC-AE-1553_Port;

b) The NT FC-AE-1553_Port performed an implicit Process Logout of the Nx_Port; or

c) The NT FC-AE-1553_Port processed a TPRLO that effected the Nx_Port.

Process_Associators shall not be used in NC FC-AE-1553_Ports and NT FC-AE-1553_Ports. If multiple images are required in an NC FC-AE-1553_Port, they shall be provided by transparent aliasing of the N_Port Identifier of the NC FC-AE-1553_Port.

The FC-4 Service Parameter pages for FC-AE-1553 are defined in A.2.5.

Process Login has two actions that may be performed, selected by the ESTABLISH IMAGE PAIR bit (see A.2.4):

a) informative action - service parameter information is Exchanged during the Process Login enabling subsequent negotiation for image pair establishment; or

b) binding action - service parameter information is Exchanged that establishes an image pair relationship between processes in the communicating N_Port or NL_Ports. The relationship does not allow any communication types or paths other than those established by FC-AE-1553 PRLI.

A.2 PRLI

A.2.1 Use of PRLI by FC-AE-1553

The PRLI request is transmitted from an Originator FC-AE-1553_Port to a Responder FC-AE-1553_Port to identify to the destination the capabilities that the Originator FC-AE-1553_Port expects to use with the Responder FC-AE-1553_Port and to determine the capabilities of the Responder (see FC-LS).

If the PRLI is requesting an informative action by setting the ESTABLISH IMAGE PAIR bit to zero, the PRLI accept reports the capabilities of the Responder to the Originator.

If the PRLI is requesting a binding action by setting the ESTABLISH IMAGE PAIR bit to one, the PRLI accept reports the capabilities of the responder to the Originator and establishes an image pair. An image pair shall be established only if the FC-AE-1553 devices have complementary NC FC-AE-1553_Port and NT FC-AE-1553_Port capabilities. If both FC-AE-1553 devices have both NC FC-AE-1553_Port and NT FC-AE-1553_Port capabilities, a single image pair allows both NC FC-AE-1553_Ports to access the complementary NT FC-AE-1553_Port capabilities of the other device in the pair. Some capabilities require support by both the Originator and Responder before they may be used (see A.2.6). The IMAGE PAIR ESTABLISHED bit in the PRLI accept indicates that an image pair was successfully established.

An accept response code indicating other than REQUEST EXECUTED (see A.2.5 and FC-LS) shall be provided if the FC-AE-1553 PRLI Service Parameter page is incorrect or if a requested image pair is not established.

The PRLI common service parameters and accept response codes are defined in FC-LS. FC-4 service parameters for mappings other than FC-AE-1553 are defined in other FC-4 standards.

A.2.2 Process_Associator requirements

Operation of the Process Login depends on the Originator's and Responder's requirements for Process_Associators as specified in FC-LS. Process_Associators are not used in FC-AE-1553 and shall not be used by FC-AE-1553 devices.

FC-AE-1553 assumes that the Originator has knowledge of the capabilities of the Responder. That information may be obtained by performing a PRLI requesting an informative action or by other mechanisms outside the scope of this standard.

A.2.3 New or repeated process login

After the completion of any new or repeated informative Process Login, the state of the Originator and Responder remains unchanged.

FC-AE-1553 devices may have default Process Login information provided in a manner outside the scope of this standard. Such devices do not require the processing of a PRLI to perform normal FC-AE-1553 operations. If default Process Login information is complete enough so that login (i.e., PLOGI) is sufficient to perform an implicit Process Login, then PLOGI shall perform the same clearing actions and establish the same Unit Attention condition that would normally be performed and established by Process Login.

A.2.4 PRLI payload page length and payload length fields

In the first word of the FC-AE-1553 PRLI payload field, the value of the Page Length field shall be 28h, while the value of the Payload Length field shall be 2Ch. This word is followed immediately by Words 0 through 9 of the FC-AE-1553 PRLI Service Parameter page, as described below.

A.2.5 PRLI request FC-AE-1553 service parameter page format

The FC-AE-1553 Service Parameter page for the PRLI request and is shown in Table A.1.

Table A.1 – FC-AE-1553 PRLI service parameter page, PRLI request and accept

FC-AE-1553 service parameter	Word	Bit
FC-AE-1553 TYPE CODE (48h)	0	31 to 24
RESERVED FOR TYPE CODE EXTENSION	0	23 to 16
ORIGINATOR PROCESS_ASSOCIATOR VALID	0	15
RESPONDER PROCESS_ASSOCIATOR VALID	0	14
ORIGINATOR: ESTABLISH IMAGE PAIR RESPONDER: IMAGE PAIR ESTABLISHED	0	13
RESERVED	0	12
ORIGINATOR: RESERVED RESPONDER: ACCEPT RESPONSE CODE	0	11 to 8
RESERVED	0	7 to 0
ORIGINATOR PROCESS_ASSOCIATOR	1	31 to 0
RESPONDER PROCESS_ASSOCIATOR	2	31 to 0
NC FUNCTION	3	31
NT FUNCTION	3	30
NC: NC-TO-NT TRANSFER (USING NT BURST SIZE REQUEST)	3	29
NC: NC-TO-NT TRANSFER (USING DELAYED NT BURST SIZE REQUEST)	3	28
NC: NT-TO-NT TRANSFER (USING NT BURST SIZE REQUEST)	3	27
NC: NT-TO-NT TRANSFER, WHERE THE NC IS THE RECEIVING NT (USING NT BURST SIZE REQUEST)	3	26
NC: NT-TO-NT TRANSFER (USING DELAYED NT BURST SIZE REQUEST)	3	25
NC: NT-TO-NT TRANSFER, WHERE THE NC IS THE RECEIVING NT (USING DELAYED NT BURST SIZE REQUEST)	3	24
NC: NC-TO-NT RDMA	3	23
NC: NT-TO-NC RDMA	3	22
NC: NT-TO-NT RDMA	3	21
NC: DYNAMIC NETWORK CONTROL MODE COMMAND – NON-BROADCAST	3	20
NC: TRANSMIT RT ADDRESS MODE COMMAND – NON-BROADCAST	3	19
NC: TRANSMIT NT_C-D/S_BURST_TOV MODE COMMAND – NON-BROADCAST	3	18
NC: USE OF ABTS BASIC LINK SERVICE AND RRQ EXTENDED LINK SERVICE TO ABORT ERRONEOUS EXCHANGES.	3	17
NC: NC MONITOR FOR NT-TO-NT TRANSFER	3	16
NC: MULTICAST	3	15
NC: TRANSMITTER SHUTDOWN – NON-BROADCAST	3	14
NC: TRANSMITTER SHUTDOWN – BROADCAST	3	13
NC: OVERRIDE TRANSMITTER SHUTDOWN – NON-BROADCAST	3	12
NC: OVERRIDE TRANSMITTER SHUTDOWN – BROADCAST	3	11
NC: SELECTED TRANSMITTER SHUTDOWN – NON-BROADCAST	3	10
NC: SELECTED TRANSMITTER SHUTDOWN – BROADCAST	3	9