Range Commanders Council

TELEMETRY GROUP

IRIG STANDARD 106-01
PART II

TELEMETRY NETWORKS

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IRIG STANDARD 106-01
PART II

TELEMETRY NETWORKS

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FOREWORD

The IRIG 106, *Telemetry Standards*, documents have taken on a new look effective with this release. The IRIG-106 is now published in two parts. Part I contains the more familiar information and standards that have evolved over the years. Part II is a totally new entity that is devoted to the standards associated with the present technological evolution/revolution in the telemetry networks area.

The Telemetry Group (TG) of the Range Commanders Council (RCC) has prepared this document to foster the compatibility of telemetry transmitting, receiving, and signal processing equipment at the member ranges under the cognizance of the RCC. The Range Commanders highly recommend that telemetry equipment operated by the ranges and telemetry equipment used in programs that require range support conform to these standards.

These standards do not necessarily define the existing capability of any test range, but constitute a guide for the orderly implementation of telemetry systems for both ranges and range users. The scope of capabilities attainable with the utilization of these standards requires the careful consideration of tradeoffs. Guidance concerning these tradeoffs is provided in the text. The standards provide the necessary criteria on which to base equipment design and modification. The ultimate purpose is to ensure efficient spectrum utilization, interference-free operation, interoperability between ranges, and compatibility of range user equipment with the ranges.

This standard, published in two parts, is complemented by a companion series, RCC document 118, *Test Methods for Telemetry Systems and Subsystems*, and RCC document 119, *Telemetry Applications Handbook*.

The policy of the Telemetry Group is to update the telemetry standards and test methods documents as required to be consistent with advances in the state of the art. To determine the current revision status, contact the RCC Secretariat at White Sands Missile Range, New Mexico at (505) 678-1107 or DSN 258-1107 (rcc@wsmr.army.mil).

CHAPTER 1

INTRODUCTION

1.1 General

Part II of the IRIG 106 Telemetry Standards addresses the standards specifically devoted to the area of Telemetry Networks. This part does not stand-alone and must be used in conjunction with Part I of the 106 Telemetry Standards to define and implement a telemetry system.

1.2 Scope

The concept of Telemetry (TM) Networks is currently evolutionary. Initial releases of this part of the standard, while incomplete, reflect those areas of the technology mature enough to define methods, techniques, and/or specifications needed to ensure interoperability among and across the ranges. The Range Commanders Council (RCC) Telemetry Group (TG) plan is to systematically expand the standards and information in this part to the point users are able to totally implement a telemetry network from the acquisition of data through the transmission and/or recording process.

1.2.1 Rapidly changing technology and acquisition reform have led the Department of Defense to rely more heavily on commercial-off-the-shelf (COTS) hardware and software. Consequently, existing and near horizon commercial communications standards are implemented or tailored to the maximum extent possible. In general, the body of any adopted or adapted standard is not repeated in this document, but is cited in the list of reference documentation associated with each chapter. The source to obtain such documentation is cited in those cases where the publications are not universally available.

1.2.2 The TM Networks standards addressed here will describe systems that use packetized data, protocols, and architectures similar to traditional computer networks.

CHAPTER 2

MESSAGE STRUCTURES

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CHAPTER 3

INTERVEHICULAR TRANSPORT PROFILE

3.1 Introduction

3.1.1 Background. Traditional instrumentation systems consist of a PCM switch with many transducer interfaces. These systems were very centralized with wire bundles running from the switch throughout the test article. Trouble-shooting and replacing such a system was time consuming yet straightforward. Distributed data systems split the centralized functions into multiple units around the test article. The data acquisition units (DAUs) communicated via a unique and often proprietary data link. This factor increased the complexity of the data system, but decreased the effort to install and modify the system. The transducer wiring was routed only to the nearest DAU – not all the way back to a central location.

As distributed systems became more prevalent, there was a desire to mix and match capabilities found in various systems. The non-standard data link used between units precluded such activity. The T&E community has standardized on a common interconnect bus. This bus makes interchanging units between systems possible. To gain even greater benefit, this profile targets a widespread commercial standard that can be applied to test vehicle instrumentation.

3.1.2 Purpose. This Intravehicular Transport Profile is intended to provide a starting point for interoperability of Fibber Channel end-items in a test-vehicle instrumentation environment. It is envisioned this profile will be one of a family of interoperability chapters in IRIG 106. When taken as a whole, interoperability between compliant nodes will be assured. Since this document is focused at the system level, the target audience is both the end-item designers concerned about interoperability and the instrumentation engineer concerned with understanding the capabilities and tradeoffs of such a system.

3.1.3 Scope. Some profiles provide a boundary limit to contain the capabilities of the compliant devices. This profile, which takes a slightly different approach, specifies a minimum set required to achieve interoperability between multiple-vendor end-items on a Fibre Channel instrumentation bus. Therefore, this profile is not intended to limit the capabilities of a unit or system. It does require whatever capability the unit has and it shall include the capabilities in this profile as a minimum. This document only addresses the ability to move the data. The format of the data is beyond the scope of this document.

3.1.4 Precedence. The order of precedence for instrumentation interoperability shall be this document, the FC-AE profile, and the Fibre Channel suite of standards.

3.1.5 Responsibility. This chapter is a result of a joint effort between the Office of the Secretary of Defense (OSD) Central Test & Evaluation Program (CTEIP) Office and the Range Commanders Council Telemetry Group. The authority of this chapter remains with the RCC Telemetry Group. The Fibre Channel documents referenced throughout this chapter are the responsibility of the T11 Technical Committee (TC) under Accredited Standards Committee (ASC) National Committee for Information Technology Standardization (NCITS). In turn, NCITS operates under the procedures of the American National Standards Institute (ANSI).

3.1.6 References.

ANSI X3.230-1994	Information Technology - Fibre Channel Physical and Signaling Interface (FC-PH), 1994
ANSI X3.297-1997	Information Technology - Fibre Channel Physical and Signaling Interface - 2 (FC-PH-2), 1997
ANSI X3.303-1998	Information Technology - Fibre Channel Physical and Signaling Interface - 3 (FC-PH-3), 1998
ANSI X3.272-1996	Information Technology - Fibre Channel Arbitrated Loop (FC-AL), 1996
ANSI X3.nnn-200x	Information Technology - Fibre Channel Arbitrated Loop (FC-AL-2), 200x
ANSI X3.nnn-200x	Fibre Channel Avionics Environment Technical Report
ANSI X3.nnn-200x	Information Technology – Fibre Channel – Physical Interfaces (FC-PI)
ANSI X3.nnn-200x	Information Technology – Fibre Channel – Framing and Signaling (FC-FS)

3.2 Fibre Channel Deviations and Clarifications

The following section identifies the mandatory changes to the indicated standards or reports. The majority of the changes are concerned with making optional capabilities mandatory or prohibited in order to increase the likelihood of interoperability. Table 3-1, which appears later in this chapter, is not meant to restrict the ability of the end item. Rather, it is intended to define a minimum operating set. Once the requirements are met, additional features may be included provided they do not interfere with interoperable operation (for example, supporting speeds in addition to 1063 Mbaud).

3.2.1 Physical.

3.2.1.1 Signaling Rate. All compliant systems shall be capable of operating at a signaling rate of 1,062.5 Mb/s. Additional signaling rates are allowed.

3.2.2 Transmission Protocol. No further clarifications of the Fibre Channel standard have been defined.

3.2.3 Signaling Protocol.

3.2.3.1 Port Type. To preclude the requirement of any particular topology, NL_PORTs will be required. This will allow any unit to be connected in a point-to-point, loop, or switched fabric topology.

3.2.3.2 Login. Fibre Channel calls out two methods to log in to the network: explicit and implicit. Explicit logins require an exchange of parameters between two units, or the unit and the network, to arrive at a set of parameters acceptable to both. While this exchange may be desirable and should not be discouraged, a more practical approach is the implicit login. Implicit logins allow the user to load the unit with the proper commands, protocols, etc. that the network is using. Implicit logins shall be supported for compliant systems.

3.2.3.3 Class of Service. Each unit shall be capable of operating with class 3 service. Other classes of services may be utilized as required.

3.2.3.4 Clock Synchronization. A clock synchronization service is described in clause 32 of FC-FS. Its use requires Fabric Clock Synchronization (FCS) ports to minimize delays through a Fabric. This method also requires that all NL_Ports on a loop be FCS capable ports. An FCS port is a new concept and may not be readily available in the field in the near future. As a result, neither the Fabric nor client n-bit counters are required. Since time synchronization within an instrumentation network is crucial, an alternate method will be required.

Each node or client of the clock synchronization server shall be capable of storing a time propagation delay value. If enabled, the delay value will be added to the time value received prior to synchronizing the node's internal clock. In order to accommodate the maximum delay from a timeserver on a loop, a data field able to count to 48,900 ns is suggested. The method of formatting and sending the clock synchronization words is defined in clause 32 of FC-FS for extended link services (ELS).

NOTE

1. When calculating the delay value, the congestion of the network should be taken into account. 2. A minor drawback of this approach requires a-priori knowledge of the network (e.g., individual node and propagation delays). With the static nature of a test instrumentation network, this factor should not pose a problem. In the event that FCS ports do gain wide availability, the delay register can still be used to compensate for cable propagation delays for greater accuracy.

3.2.4 Common Services. No further definitions of the Fibre Channel standard have been developed.

3.2.5 Upper Layer Protocol Mapping. Each unit shall be capable of utilizing the Internet Protocol (IP). Additional protocols may be used as the situation warrants.

3.3 Summary

Table 3-1, which follows, summarizes the requirements in section 3.2. In the case of conflict, section 3.2 shall take precedence.

TABLE 3-1. SUMMARY OF INTRAVEHICULAR TRANSPORT REQUIREMENTS				
Feature	**Status**	**Change**	**FC Std**	**106**
R – Required I – Invocable A – Allowed P – Prohibited (see below for explanation) **PH : FC-PH, FC-PH-2, FC-PH-3 AL: FC-AL FS: FC-FS PI: FC-PI**				
FC-0 Physical				0
Data rate				0
1063 Mbaud	**I**		PH-5.1	
Data rate of 133, 266, 531, 2125, 4250 Mbaud	**A**		PH-5.1	
FC-1 Transmission Protocol				0
FC-2 Signaling Protocol				0
NL_Port	**R**			0
Login			PH-23	0
Implicit N_Port login	**I**		PH-23, 23.4	
Explicit N_Port login	**A**		PH-23.4.2	
Class of Service				0
Class 1	**A**		PH-22.1	
Class 2	**A**		PH-22.2	
Class 3	**I**		PH-22.3	
Class 3 multicast	**A**		PH-31	
Class 4	**A**		PH-22.5, 34	
Class 6	**A**		PH-22.6	
Clock Synchronization				0
ELS method	**I**		***FS-32.2***	
Primitive method	**A**		***FS-32.3***	
Client delay value	**I**		***New***	
Fabric n-bit counter	**A**		***FS-32.2.2.3***	
Client n-bit counter	**A**		***FS-32.2.2.4*** ***FS-32.2.3.3***	
FC-3 Common Services				0
FC-4 Upper Layer Protocol Mapping				0
Protocols				
IP	**I**			
SCSI	**A**			
SCPS-NP	**A**			
Others	**A**			

NOTES ON THE TABLE

Required: That feature shall be used between compliant units. The hardware is required to implement the feature. The application is required to use the feature.
Invocable: The hardware is required to implement the feature. However the user may choose whether to use the feature. This provides a common set of requirements that are implemented in the unit and available to the user for interoperability issues.
Allowed: That feature may be used between compliant units. The hardware is not required to implement the feature. The application may use the feature if it is available.
Prohibited: The feature 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.

	Implementation	Application
Required	Shall	Shall
Invocable	Shall	May
Allowed	May	May
Prohibited	May	Shall Not

The Fibre Channel Standard Column (FC Std) indicates where the indicated item can be found. Currently the Fibre Channel Standard Physical and Signaling Interface set (FC-PH, FC-PH-2, and FC-PH-3) is being rewritten, combined, and then split into two volumes: Fibre Channel Physical Interface (FC-PI) and Fibre Channel Framing and Signaling (FC-FS). Once these new documents are published, this section will be updated to reflect the reference changes. It is not expected to change the table any further except where noted

CHAPTER 4

EXTRAVEHICULAR TRANSPORT (WIRELESS)

4.1 Introduction

4.1.1 Background. This Range Commanders Council standard defines the recommended methodology for packet telemetry (wireless) radio frequency transmissions using the Consultative Committee for Space Data Systems (CCSDS) data multiplex format. "The CCSDS is an international organization of space agencies interested in mutually developing standard data handling techniques to support space research conducted exclusively for peaceful purposes." (Quoted from their web site: http://www.ccsds.org.) To this end, CCSDS has developed an extensive list of documents, including "Recommendations" (or standards), that have potential applicability to the RCC ranges. A related standard, IRIG 107, *Digital Data Acquisition and Onboard Recording Standard*, defines the format for on-board data recording. IRIG Standard 107 makes extensive use of the CCSDS packet telemetry standard (see Chapter 5 of 106 Part II, Recording).

The concept of packetized digital communications is not new and has been in use for a number of years. The protocols used in computer networks, such as TCP/IP, are packet systems. Its utilization in the RF arena for aircraft and missile telemetry and for satellite communications and telemetry purposes is a more recent application of the concept.

4.1.2 Purpose. This standard for RCC recommended packet telemetry references the CCSDS Recommendation and places the "tailored" requirements which are unique to the RCC telemetry applications within the body of IRIG Standard 106. The advantage of this approach is two fold. First, it eliminates the need to revise the 106 document every time the CCSDS Recommendation changes, thereby reducing the chances of errors and additional paper work. Second, the CCSDS Recommendation has a number of parameters that can vary with the application. In the interest of range interoperability, those parameters will be defined in the 106 document. In this manner, constrained flexibility can be achieved.

4.1.3 Scope. This standard provides the tester with a high degree of flexibility in the data transmitted to the ground, including in-flight changes to the telemetry formatting. Packet telemetry has the benefits of enabling the application of modern network techniques and facilitating multi-source additions and/or deletions to the test environments. This standard can also employ techniques for error detection and correction, as per the CCSDS recommended techniques.

4.1.4 Precedence. The CCSDS recommendation for packetized telemetry began in the mid-1980's as a baseline concept for spacecraft-to-ground data communication, and for missions that were cross-supported between space agencies of the CCSDS. This packet telemetry recommendation established a common framework and provided a common basis for the data structures of spacecraft telemetry streams. It has allowed each agency to proceed coherently with the development of compatible derived standards for the flight and ground systems that are within their cognizance (i.e., allowed the tailoring of the Recommendation into a local standard). A derived (or tailored) standard can utilize a subset of the optional features allowed by the Recommendation and may incorporate features not addressed by the Recommendation.

4.1.5 Responsibility. It is the responsibility of the user of this standard to notify the support command or range in sufficient time to ensure compliance with this standard. This standard will be treated in the same manner as a Class II PCM and, therefore, it will not be automatic that each command/agency/range have the capability of processing this format. Providing the supporting range sufficient time to establish the ground processing part of this format will be in the best interests of participating organizations. Compliance with this RCC standard for packet telemetry should provide the customer another opportunity for cost savings.

4.1.6 References.

4.1.6.1 Referenced Standards.

1) CCSDS 102.0-B-4 Packet Telemetry, Blue Book, November 1995.
2) CCSDS 713.0-B-1 Space Communications Protocol Specification (SCPS) – Network Protocol (SCPS-NP), Blue Book, May 1999

4.1.6.2 Additional Information.

3) CCSDS 101.0-B-3 Telemetry Channel Coding, Blue Book, May 1992.
4) CCSDS 100.0-G-1 Telemetry Summary of Concept and Rationale, Green Book, December 1987
5) CCSDS 103.0-B-1 Packet Telemetry Services, Blue Book, May 1996.
6) CCSDS 120.0-G-1 Lossless Data Compression: Summary of Concept and Rationale, Green Book, May 1997.
7) CCSDS 121.0-B-1 Lossless Data Compression, Blue Book, May 1997.
8) CCSDS 301.0-B-2 Time Code Formats, Blue Book, April 1990.
9) CCSDS 320.0-B-1 CCSDS Global Spacecraft Identification Field Code Assignment Control Procedures, Blue Book, October 1993.
10) CCSDS 320.0-B-1 Cor. 1 Technical Corrigendum 1 to CCSDS 320.0-B-1, November 1996.
11) CCSDS 401.0-B Radio Frequency and Modulation Systems—Part 1: Earth Stations and Spacecraft, Blue Book, November 1994.
12) CCSDS 411.0-G-3 Radio Frequency and Modulation—Part 1: Earth Stations, Green Book, May 1997.

13)	CCSDS 412.0-G-1	Radio Frequency and Modulation Systems—Spacecraft-Earth Station Compatibility Test Procedures, Green Book, May 1992.
14)	CCSDS 501.0-B-1	Radio Metric and Orbit Data, Blue Book, January 1987.
15)	CCSDS A12.0-G-1	CCSDS-Related Implementations, Green Book, November 1996.
16)	CCSDS A30.0-G-3	CCSDS Glossary, Green Book, July 1997.

NOTE

CCSDS Color Code	**Document Type**	**RCC Equivalent**
Blue Book	Recommendation	RCC Standard
Red Book/Pink Sheets	Draft Recommendation	Draft Standard or "Pink Sheets"
Green Book	Report	

4.2 Packet Telemetry

4.2.1 General. Packet telemetry provides an alternative to traditional time-division-multiplexing "PCM" methods which are predominantly based on repeated sampling. Packet telemetry methods provide a means for many sources to transmit data to many destinations via a single link in a packet switching environment. This is often done as a "common carrier" service without knowledge of the contents.

NOTE

This section does not define word boundaries or means to decode data down to the measurement, sample, or word level comparable to the preceding sections of IRIG Standard 106-01, Part I, Chapter 4. Future, more detailed, standardization may be required for specific application areas.

4.2.2 Scope of Application. The most widely used international approach to packet telemetry was developed by the CCSDS through "Packet Telemetry," Recommendation CCSDS 102.0-B-4, November 1995 (Ref. #1). Packet telemetry described herein is an application of that Recommendation. Only limited portions of that document are shown in this section; however, the full Recommendation is included by reference. Also included by reference is the SCPS-NP packet definition in CCSDS 713.0-B-1, May 1999 (Ref.#2).

4.2.3 Benefits. Packet telemetry provides the benefits of enabling the application of modern network techniques and facilitating multi-source to multi-user test environments but incurs an inherent added latency and overhead which may or may not be suitable for some Range users.

4.2.4 Concept. The CCSDS Packet Telemetry Recommendation (Ref.#1) contains the essence of the packet telemetry concept, which permits multiple application processes onboard a test article to create data that is best suited to the data source (whether an instrument or a sub-system) and to format the information for transmission to the ground system for recovery and dissemination to multiple users. Citing from Ref. #1: "To accomplish these functions, the Recommendation defines two data structures – SOURCE PACKETs and TRANSFER FRAMEs – and a multiplexing process to interleave SOURCE PACKETs from various APPLICATION PROCESSES into TRANSFER FRAMES."

4.2.5 Summary. Packet TM using CCSDS Recommendations consists of source packets multiplexed into transfer frames of virtual channels that are then multiplexed into a Master Channel. If a user does not invoke "Virtual Channel" concepts for serving many user groupings, the transfer frames are simply multiplexed into a Master Channel. See Fig. 4-1 for clarification of these terms. For a complete definition of this process consult Ref. #1.

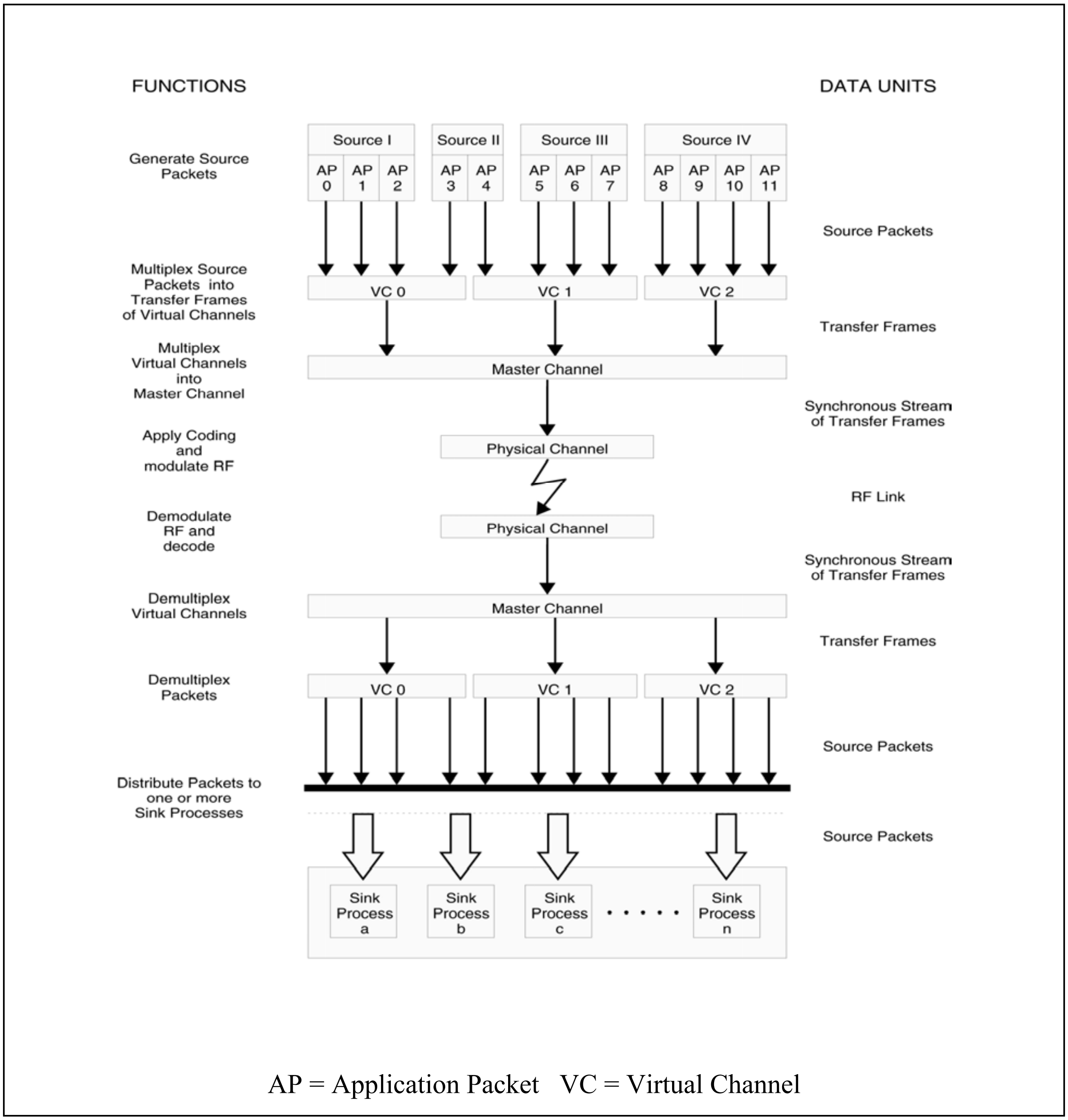


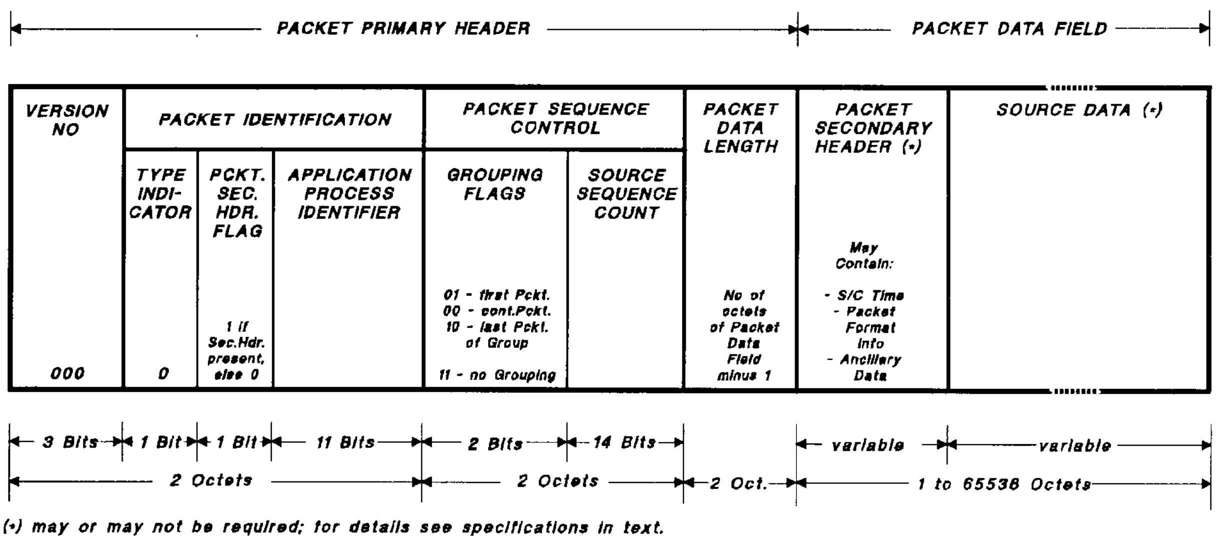
Figure 4-1. Packet Telemetry Data Flow

4.3 Source Packet

4.3.1 Structure and Content. The source packet is the fundamental data structure generated by an on-board application process. It contains a packet header and the data that is under control of the application process. The normal CCSDS packet structure is replicated in Fig. 4-2 as an example. Another example is the SCPS-NP packet defined in Ref. #2. Source information content is optional and depends on user implementation. Any type of packet used shall contain Packet Length and Version Number in accordance with the protocol in use. Concurrence from the range involved should be acquired to ensure compatibility.

> **NOTE**
>
> For noisy channels where bit errors and bit slips are likely, it is recommended that the packet sizes be restricted to Class I or Class II subframe maximum lengths (see Ch.4, IRIG 106, Part I, Fig. 4-2) to minimize the loss of data. See additional recommendations in Ref. #1.

4.3.2 Format.



Header Descriptor	Bits	Header Descriptor	Bits
Version No.	Set to "000"	Grouping Flags	Set to "11" – no grouping
Type Indicator	Set to "0" for telemetry		
Packet Sec Hdr Flag	"0" if Sec. Hdr. is not present "1" if Sec. Hdr. Is present	Source Seq Count	Sequential binary count of each packet with the same Application Process ID
Application Process ID	Different for each Process on Same Master Channel	Packet Data Length	Binary number of the number octets minus one in

Figure 4-2. Source Packet Format (Ref. #1)

4.4 Transfer Frame

The transfer frame provides the structure for transmission over a noisy RF channel from the test article to the receiver. It shall be of constant length during the mission and is limited to 8920 bits, not including the Attached Synchronization Marker (ASM) that precedes the transfer frame. The ASM is analogous to the minor frame synchronization word of the PCM (see paragraph 4.3.2.1.3 of IRIG 106 Part I), but is fixed in length at 32 bits. The recommended synchronization pattern of 32 bits is given in table C-1, appendix C (IRIG 106 Part I). The transfer frame structure is shown in figure 4-3. The fields within the transfer frame are defined as follows (for additional details see Ref. #1):

Header Descriptor	Bits
Transfer Frame Version Number	Set to "00"
Test Article (Spacecraft ID)	The test article identifier shall be negotiated with the Test Range. For spacecraft operating under the CCSDS see Ref. #1 par. 5.1.2.1c
Virtual Channel Identifier	Identifies the virtual channel being transmitted (1 of 8)
Operational Control Field Flag	"1" if operational control field is present, "0" if operational control field is not present
Master Channel Frame Count Field	A running count or sequence identifier of each transfer frame transmitted within the Master Channel
Virtual Channel Frame Counter Field	A running count or sequence identifier for each transfer frame transmitted through a specific virtual channel of a master channel
Transfer Frame Secondary Header Flag	"1" if the transfer frame secondary header is present, "0" if the secondary header is not present
Synchronization Flag	"0" if octet-synchronized and forward-ordered source packets or idle data are inserted, "1" if privately defined data are inserted
Packet Order Flag	Not used/undefined. Set to "0"
Segment Length Identifier	Not used/undefined. Set to "0"
First Header Pointer	If the Sync Flag is "0", the first header pointer identifies the position of the first source packet within the transfer frame data field. The pointer

	contains a binary representation of the location of the first octet of the first packet primary header. Numbering with the first octet being “0” If no packet primary header starts in the transfer frame, the first header pointer is set to “11111111111”. If idle data is contained in the transfer frame data field, the pointer is set to “11111111110”. If sync flag is “1”, the header is undefined.
Transfer Frame Sec Hdr Ver No.	Set to “00”
Transfer Frame Secondary Header Length	Length of the secondary header in octets minus one, represented as a binary number.
Transfer Frame Secondary	Contains the secondary header data, up to 63 Octets.
Transfer Frame Data Field	Contains the data to be transmitted to the receiving site and shall consist of an integral number of octets. The data may consist of source packets, idle data, and privately defined data. To maintain synchronization with the receiving station, idle data is transmitted whenever insufficient data from other sources is not available.
Operational Control Field	This field is set to 0 (used only for telecommand). See Ref. # 1 for definition and applications.
Frame Error Control Field	This (*) field is optional only if the transfer frame is contained within the data space of a Reed-Solomon Code Block. It is mandatory if Reed-Solomon is not used. See Ref. #1 for more descriptive information.

NOTE

The Operational Control Field (used for Telecommand) is not present in IRIG 106 and the corresponding Operational Control Field Flag is set to zero. They are shown here in the Transfer Frame Format only for clarity and consistency with CCSDS standards.

4.4.1 Master Channel. In most instances the Master Channel is identical to the data organization in the physical channel used for transmission. In Ref. #1, however, the Master Channel is defined as: “All transfer frames with the same transfer frame version number and the same spacecraft identifier (read test article) on the same physical channel." In this standard, the physical channel is taken to be a transmitter-receiver radio link.

4.4.2 Virtual Channelization. Virtual Channel utilization enables independent users of the common RF link to view their data (and entire "formats" in traditional terms) as exclusive and separate. Virtual Channelization is also a mechanism for multiplexing data from a number of different sources so channel capacity and access can be assigned and allocated on a priority basis. In addition it provides for accumulating data by grouping, which can expedite the transfer of received data to the user. For additional information on virtual channels see "Telemetry Summary of Concept and Rationale," Report Concerning Space Data Systems Standards, CCSDS 100.0-G-1. Green Book. Issue 1. Washington, DC: CCSDS, December 1987.

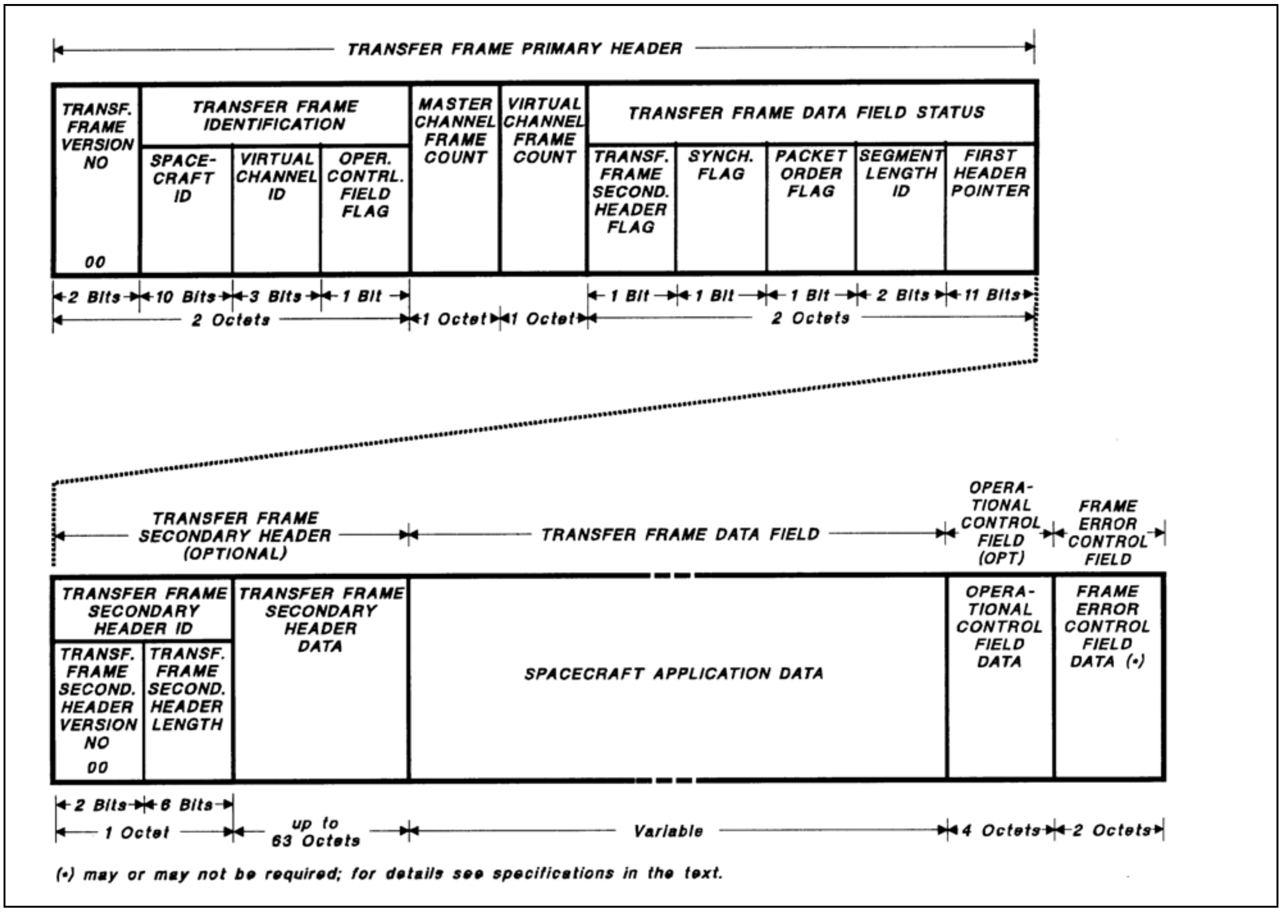


Figure 4-3. Transfer Frame Format

CHAPTER 5

RECORDING

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APPENDIX A

COMMON ABBREVIATIONS & DEFINITIONS

Arbitrated Loop - A Fibre Channel topology where nodes are linked together in a closed loop. Traffic is managed with a token-acquisition protocol, and only one connection can be maintained in the loop at a time.

Class 1 - Dedicated connection allocating full bandwidth between a pair of ports. Class 1 provides confirmation of delivery or notification of non-delivery between the source and destination ports.

Class 2 - Connectionless class of service with confirmation of delivery or notification of non-deliverability of frames. No bandwidth is allocated or guaranteed.

Class 3 - Connectionless class of service providing a datagram-like delivery service with no confirmation of delivery, or notification of non-delivery.

Class 4 - Connection oriented class of service which provides a virtual circuit between a pair of ports with guaranteed fractional bandwidth and latency with confirmation of delivery and notification of non-delivery.

Class 6 - A derivative of class 1 that provides a reliable one-to-many multicast service with confirmation of delivery and notification of non-delivery.

classes of service - Different types of services provided by the Fabric and used by the communicating N_Ports.

command-response architecture - A network containing a device which controls the access of the other nodes to the network.

counter-rotating ring - An arrangement whereby two signal paths, the directions of which are opposite, exist in a physical ring or loop topology.

F_Port - Fabric Port - A Fibre Channel term referring to the port residing on the Fabric (Switch) side of the link. It attaches to a Node Port (N_Port) at the connected device, across a link.

FL_Port – An F_Port that contains Arbitrated Loop functions associated with Arbitrated Loop topology.

fabric - denotes the interconnect of ports without regard to topology

Fabric - A transport medium that provides switched interconnects between ports. Fabric specifies a topology distinct from Point-to-Point and Arbitrated Loop.

Fibre Channel – An ANSI communication standard that can utilize either copper or fiber optic cable plants.

informative - Information provided for completeness. Not required for standard compliance.

interoperability - The capability to communicate or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units.

Internet Protocol (IP) - Part of the TCP/IP family of protocols describing software that tracks the Internet address of nodes, routes outgoing messages, and recognizes incoming messages.

N_Port - Node Port. A Fibre Channel term, referring to the link control facility which connects across a link to the Fabric Port (F_Port) at the Fabric (switch).

NL_Port - An N_Port that contains Arbitrated Loop functions associated with Arbitrated Loop topologies.

node - A point of connection into a network. In Fibre Channel, a collection of one or more N_Ports.

node synchronization – The ability to time synchronize two or more nodes to a common time base.

OEM - Original Equipment Manufacturer

open systems - Everyone would comply with a set of hardware and software standards.

peer-to-peer architecture - A network that contains equivalent nodes with respect to their capability of control or operation.

Point-to-Point - Fibre Channel topology in which communication between two N_Ports occurs without the use of Fabric.

port - Network access point for data entry or exit. In Fibre Channel, a generic reference to an N_Port or F_Port.

protocol - A procedure for adding order to the exchange of data. A specific set of rules, procedures, or conventions relating to format and timing of data transmission between two devices.

simultaneous sampling - Acquiring multiple data samples within a given time period.

time correlation - The ability to correlate two or more data samples with respect to the time they were sampled.

time synchronization - The ability to synchronize two or more sources.

APPENDX B

INSTRUMENTATION SYSTEM ISSUES (INFORMATIVE)

INSTRUMENTATION SYSTEM ISSUES (INFORMATIVE)

This section provides insight to ideas that may affect a Fibre Channel instrumentation system. It is based on the bus requirements identified early in the NexGenBus project. Requirements are not to be construed from this section.

B.1 Architecture

B.1.1 Controller Based Architecture. The Fibre Channel by itself does not imply the type of architecture an instrumentation system must utilize. There are two basic architectures that can be employed in the design of the system. The nodes may or may not support both architectures. In the traditional system, a controller or master is used to command the nodes and receive the responses. The controller is programmed with the knowledge of the overall format and directs each node to acquire data and respond (reference Figure B-1). The controller typically becomes the aggregator of the data as it formats the output(s) for recording, transmitting, or processing. This architecture keeps the nodes simple. Traffic on the bus is very orderly based on what the controller requests. This is also known as a command-response architecture. Multiple formats can be stored in the controller and changed via a cockpit switch or sophisticated uplink. Controllers can vary from small inexpensive units that are inflexible to large expensive units that can do everything.

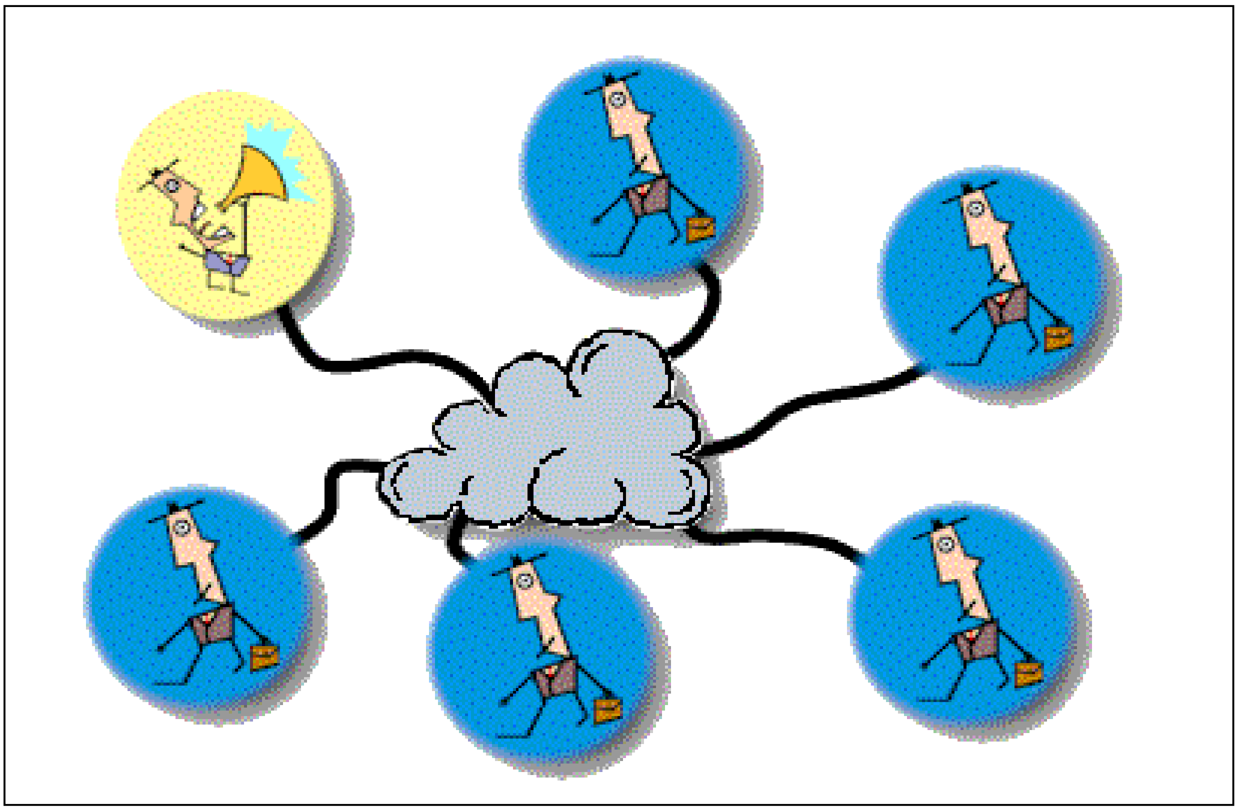

Figure B-1 Controller Based Architecture

B.1.2 Peer-to-Peer Architecture. Another architecture available to the instrumentation network is the peer-to-peer architecture, wherein each node is programmed with its own schedule. Individually the nodes determine when to acquire the data, how to packetize the data, whom to send it to, and how often to send it (reference Figure B-2). One of the advantages of an autonomous system is the ease at which new nodes may be added. Additional nodes just need to be physically connected to the bus and programmed. The other nodes are not affected (assuming there is plenty of bandwidth on the bus). One node could still receive all the data and format it into the proper outputs for recording and transmitting similar to the command response architecture.

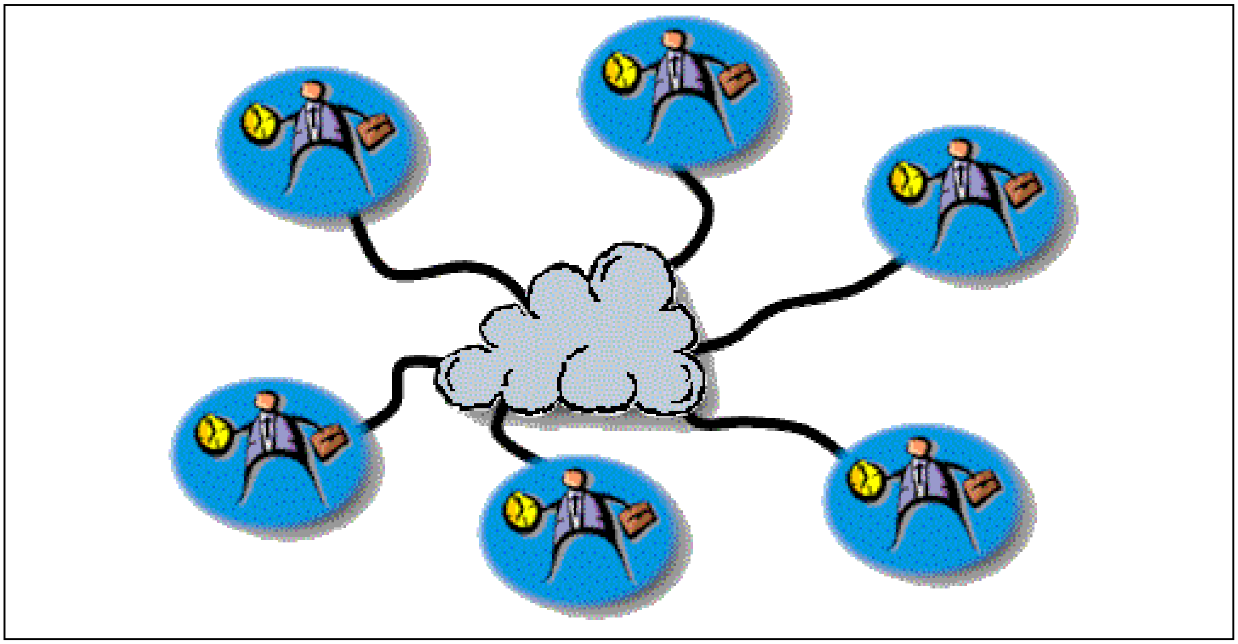

Figure B-2 Peer-to-Peer Architecture

B.2 Open System

In an open system, the specifications are generally in the public domain. Of particular importance, the specifications should be in wide use as well. This system allows ready access not only to the specifications but also to the chipsets, OEM boards, drivers, and test equipment.

B.3 Topology

Fibre Channel defines three major topologies: point-to-point, fabric, and arbitrated loop. Another topology available is hybrid topology.

B.3.1 Point-to Point Topology. The point-to-point topology is the simplest. It connects two ports with a bi-directional link consisting of a transmit cable and a receive cable (reference Figure B-3).

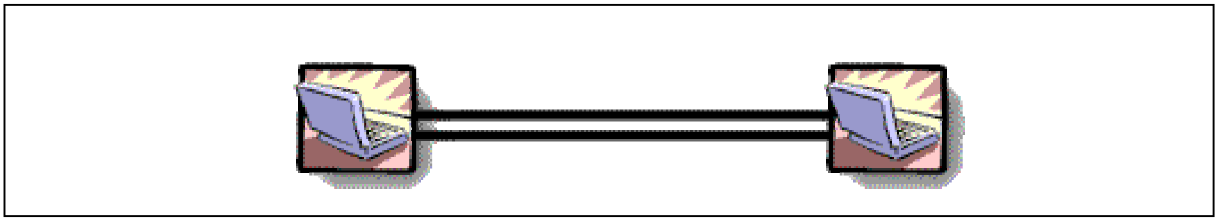

Figure B-3 Point-to-Point Topology

B.3.2 Fabric Topology. In the Fabric topology, each node is connected to a switch. Depending on the capabilities of the switch, any node may connect to any other node (reference Figure B-4). When denoting Fabric topologies, the Fabric is shown as a cloud. This represents the Fabric notion without showing any physical connections. One of the drawbacks of Fabric, is the requirement for one or more Fabric switches that physically take the place of the network cloud. These switches are not necessarily cheap - especially for a test environment. Because of the connectivity, adding additional nodes increases the total bandwidth available to the system. In reality, this is only true if there is a broad distribution of network traffic. If all nodes are trying to talk through one link to the recorder, then more nodes will only make it worse.

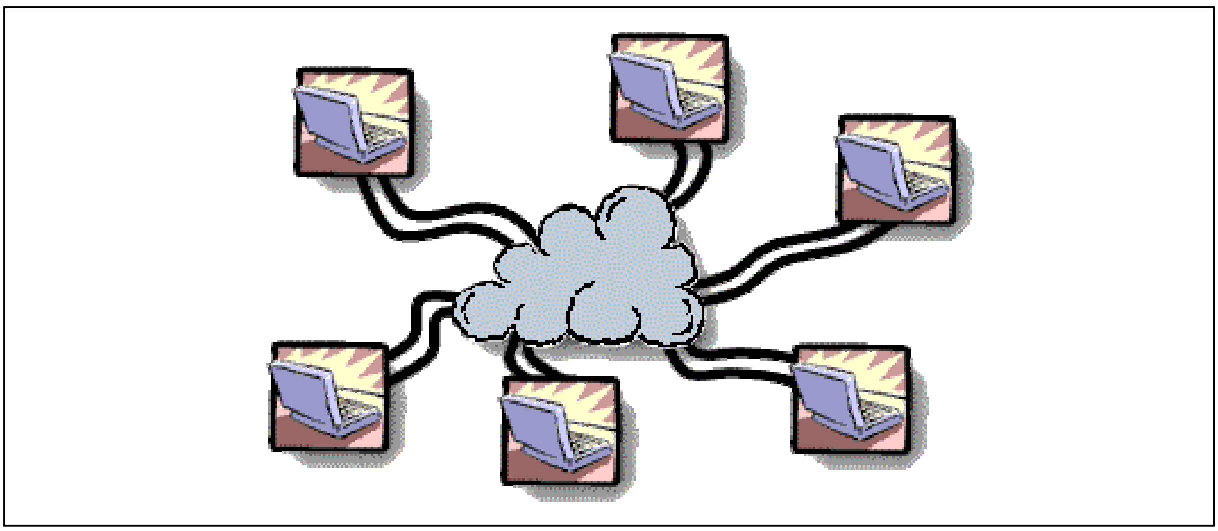

Figure B-4 Fabric Topology

B.3.3 Arbitrated Loop Topology The arbitrated loop topology is a simple concatenation from the transmitter of one node to the receiver of the next. This progresses through all nodes until the last transmitter is connected to the first receiver to form a loop (reference Figure B-5). Simplicity is one of the advantages of a loop. There is no additional network hardware required for connectivity. To add more nodes, the loop is broken with the additional nodes being inserted between the break. One of the drawbacks of a loop is the constant bandwidth. Regardless of the number of nodes, they all share the same bandwidth.

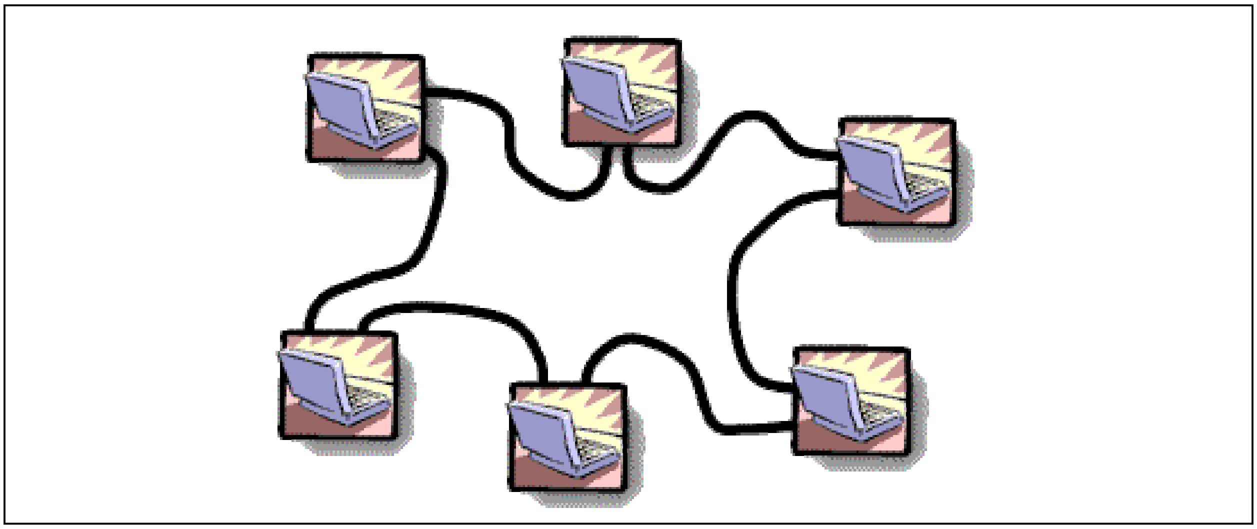

Figure B-5 Arbitrated Loop Topology

B.3.4 Hybrid Topology. The last type of topology available is the hybrid topology, which simply replaces one of the fabric nodes with a loop. Conversely, it replaces a loop node with a fabric (reference Figure B-6). Figure B-6 depicts one instance of a hybrid topology; there are many other variations. Understandably, the hybrid topology embodies the pros and cons of both the fabric and loop topologies.

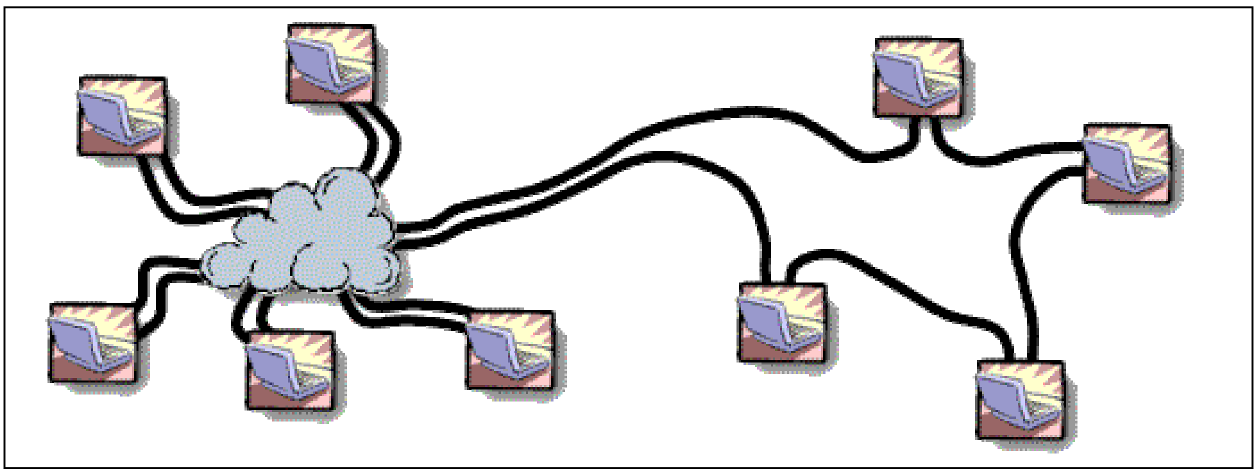

Figure B-6 Hybrid Topology

B.4 Fault Tolerance

In the systems most instrumentation engineers are familiar with, a single point failure has rarely brought a system to its knees. With traditional instrumentation systems, a faulty connection on a data acquisition unit simply meant no data would come from that unit. The rest of the system would continue to operate as is true for MIL-STD-1553 systems. With switched fabric systems, the switches become a single point failure. One single-point-failure mode does not seem like a big issue. Current systems have a single point failure in the system controller. When we consider arbitrated loop systems - each node on the loop is a single-point-failure source. There are several ways to make these systems more fault tolerant such as port bypass circuitry, hubs, and built in redundancy.

B.4.1 Port Bypass. One way to add fault tolerance to a loop topology is to add port bypass circuitry to each node. If something happens to the node (loss of power or other problem) the bypass kicks in and allows the loop to continue to operate. The node designer must add this circuitry to the unit prior to production. The port bypass circuit will not help a faulty connection to the port itself.

B.4.2 Hub. A hub allows a logical loop topology to be physically connected in a star fashion. The hub acts as a security guard monitoring the health of each of the ports. When it detects a failure on one of the ports or links, it bypasses the faulty link within the hub (reference Figure B-7). In this way, a port and its associated wiring can be completely removed and not affect the system. This works well, however, many of the drawbacks of the switched fabric topology have been reintroduced (e.g., the added expense (hardware and time) of routing the links back to a central location as well as the cost and maintenance of the hub).

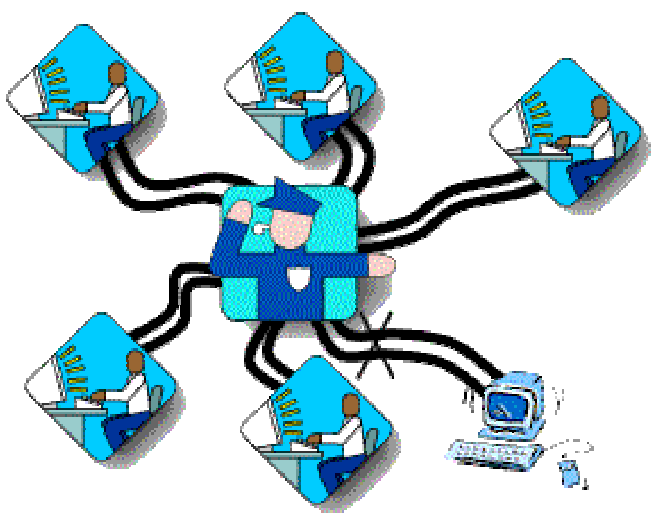

Figure B-7 Arbitrated Loop with Hub

B.4.3 Redundancy. Another solution, which must be designed into the port, is a redundant bus. For fabrics, it means multiple ports on each node. Each port is connected to the fabric and receives its own port address. The node is responsible for merging data from among its ports. To the rest of the fabric, it looks like there are more ports. For the data rates expected in initial instrumentation systems, wholesale redundant busses for fabrics do not seem to gain much. However, the concept of multiple ports for high bandwidth data sinks like recorders seems to have merit. For loops, an additional connection between nodes in the opposite direction may be installed. This creates a counter-rotating ring. If there is a connection failure, data can still traverse the ring.

B.4.3.1 Avionics Busses. Avionics Busses used to control the test vehicles have typically had redundancy built into the system. Given the criticality of a failure for operational systems, it is essential. Redundancy in instrumentation systems has been the exception rather than the rule. A Fibre Channel system built to the ANSI standards has a lower bit error rate than anything used previously. The system designer must decide if redundancy is required for a given implementation. Possible choices include counter rotating rings and dual ported nodes.

B.4.3.2 Addressing. When a port logs into the fabric, or when the loop is initialized, the port addresses are assigned. Fibre Channel allows a port to request a previously assigned address. It allows the ports to request an address on a cold start. The primary concern is for systems where new nodes may be coming online at random or under some other control. Since the test vehicle is a private system where the instrumentation engineer has the knowledge of what nodes are in the system, static addresses should not be a problem. The ability to preset an address is an advantage for many reasons, not the least of which is trouble-shooting.

B.5 Timing

Timing is one of the most critical issues facing instrumentation networks. There are three major timing issues: time correlation of data, simultaneous sampling, and the reconstruction of data sources. Synchronizing the nodes to a common time source, if done accurately enough, could solve all three issues. The question of what accuracy is required is still open to debate. It may be overridden by what is achievable. The issues surrounding the ability to synchronize differ with each topology selected.

B.5.1 Data Correlation. Time correlation of data requires knowledge of when a sample occurred in relation to other samples. If both samples occur within the same node, the issue is trivial. When they occur across different nodes, the time relationship between the nodes needs to be known.

B.5.2 Simultaneous Sampling. In some instances, knowing when different samples occurred is not good enough. The samples need to be acquired at the same moment in time for data processing issues to be reduced to a manageable level.

B.5.3 Data Source Reconstruction. Data source reconstruction is similar to data correlation, but a bit more specific. For some data sources, like MIL-STD-1553 data busses, the user wants to recreate the bus exactly for use with simulators or trouble-shooting equipment. In a packet-based environment, each packet will be stamped with the time of arrival. The fidelity of the time stamps will vary with the requirement for reconstruction.

B.6 Interoperability

This section will explain some of the rationale by which certain values are selected.

B.6.1 Cables and Connectors. The Fibre Channel standards were written with benign environments in mind. Because of space constraints within test vehicles, signal wires are sometimes tied in the same bundles as power lines and antenna cabling. The proximity of radars, avionics, and power distribution units creates an environment most cable/connector sets cannot tolerate. Because of this harsh environment, the physical component was expected to deviate from the standard. Changing the physical level should not affect the ability to leverage the commercial industry.

B.6.2 Port Type. Since this is an interoperability document, it was decided not to arbitrarily choose a topology. Because there are pros and cons to both port types, the system designer should decide what is best for the application. The selection of the NL_Port allows any of the topologies to be used.

B.6.3 Signaling Rate. For two nodes to communicate, they must operate at the same signaling rate. Full speed is by far the most prevalent rate and the one most vendors will design into their units. This preference does not preclude the use of additional rates like quarter speed or double speed, but will ensure that all units have a common rate with which to communicate.

B.6.4 Login. Since the instrumentation network is a private network, the system designer knows what nodes are going to be put on the network and how they need to operate. Therefore, the login parameters can be preloaded and stored internally. Explicit login appears more like an "auto-negotiate" routine, which adds a level of complication. Probably the greater concern is to ensure the variety of login parameters allows interoperability. For example, do we need to define default common service parameters for FLOGI and/or PLOGI?

B.6.5 Class of Service. Much the same as signaling rate, Fibre Channel allows several choices. However, class three seems to be the most prevalent class of service. Again, this does not preclude the use of other classes.

B.6.6 Protocol. Since NexGenBus did not study the upper layer protocols (ULP), selecting the most capable protocol is out of the question. The most prevalent ULP seems to be the only choice. The ULP used frequently on Fibre Channel is the SCSI protocol. This protocol has been used for years for read/write commands between a host (PC) and a target (tape drive). Because of Fibre Channel's robust architecture and low latency to send and receive SCSI commands, the use of SCSI in a Storage Area Network (SAN) has become almost universal. Recently the use of TCP/IP drivers on Fibre Channel has become popular. The use of TCP provides the ability to interoperate with many different devices. The penalty is that TCP uses a connection oriented protocol in which acknowledgments are received for each packet. This characteristic creates additional traffic on the network, which in turn reduces throughput and increases latency. An alternative to TCP is UDP, which uses the same size packet, etc., but does not acknowledge packets received. This characteristic increases throughput and decreases latency. Although not strictly an upper layer protocol, the Internet Protocol (IP) is the most pervasive protocol in use today. It provides a connectionless method of connecting, but has a rich set of tools developed for the Internet. The IP Protocol is used with either TCP or UDP. Many vendors are providing IP drivers along with their SCSI drivers.

APPENDIX C

INTRAVECHICULAR PHYSICAL CONSIDERATIONS (INFORMATIVE)

C.1 Physical Interface

The physical interface is the first test of interoperability. If the units cannot be physically connected together via an electrical or fiber optic cable, interoperability is squashed right off the bat. The cable and connector are usually selected together since selecting one will limit the choices for the other. The original "Fibre Channel Physical and Signaling Interface" (FC-PH) standards called out allowable cables and connectors in chapters 7 and 9. The new rewrite of the FC-PH three volume set into one "Fibre Channel Physical Interfaces" (FC-PI) standard is currently in draft. The new approach does not call out cable specifications or lengths. Instead, they provide specs to which the implementer must adhere. A portion of section 10.2 from the FC-PI draft standard states:

> Part of FC-PI draft v7.3, section 10.2 Cable Interoperability
> All styles of balanced cables are interoperable; i.e., electrically compatible with minor impact on TxRx Connection-length capability when intermixed. The unbalanced (coaxial) cables are also interoperable. Interoperability implies that the transmitter and receiver level and timing specifications are preserved, with the trade-off being distance capability in an intermixed system. Any electrically compatible, interoperable unbalanced or balanced cables may be used to achieve goals of longer distance, higher data rate, or lower cost as desired in the system implementation, if they are connector, impedance, and propagation mode compatible.
>
> When cable types are mixed, it is the responsibility or the implementer to validate that the lengths of cable used do not distort the signal beyond the received signal specifications referenced in clause 9.9 "Receiver characteristics."

C.2 Cable Connector Pairs

Because of the direction the Fibre Channel standards group is taking on identifying cables, this appendix will follow their lead. The following sections identify a couple of cable/connector pairs that have been tested using a very small sample size. The intent was to show they could be used – not they would work up to n feet and under x conditions. The unit designer should use cables and connectors appropriate for the application. Consideration should be given to the user application environment. Industry common balanced and unbalanced connectors help the user in minimizing test cables in labs, stockpiling of connector types, and using existing wiring in test articles. For more information regarding the tests performed on these cables, see document number NGB-00-DOC-7 (http://nexgenbus.nawcad.navy.mil).

C.2.1 Balanced. The Gore Quad Cable using MIL-C-38999 style connectors with impedance matching inserts as found to be acceptable for inter-enclosure use.

C.2.2 Unbalanced. The RG-302 Cable (military grade of RG-59) using BNC type connectors was found to be acceptable for intra-enclosure use.