



CLDP-STD-1170
Baseline

Commercial Low-Earth Orbit (LEO) Development Program (CLDP)

Common Communications for Commercial Destinations in Low-Earth Orbit (C3DL) Radio Frequency (RF) Interface Standard

Baseline

July 2025

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PREFACE

**COMMERCIAL LOW-EARTH ORBIT DEVELOPMENT PROGRAM
COMMON COMMUNICATIONS FOR COMMERCIAL DESTINATIONS IN LEO (C3DL) RADIO
FREQUENCY (RF) INTERFACE STANDARD**

The contents of this document are intended to be consistent with the tasks and products to be prepared by the Commercial LEO Development Program (CLDP).

This document is under the control of a Joint Program Control Board (JPCB) with CLDP and Commercial Crew Program (CCP). The JPCB is the authority for baselining and approving changes. This document was developed and is maintained by the CLDP Systems Engineering and Integration (SE&I) Office.

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COMMERCIAL LOW-EARTH ORBIT DEVELOPMENT PROGRAM (CLDP)
COMMON COMMUNICATIONS FOR COMMERCIAL DESTINATIONS IN LEO (C3DL)
RADIO FREQUENCY (RF) INTERFACE STANDARD

CONCURRENCE

JULY 2025

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1.0 INTRODUCTION

1.1 PURPOSE

The National Aeronautics and Space Administration (NASA) Commercial Low-Earth Orbit (LEO) Development Program (CLDP) plans to purchase an End-To-End (ETE) commercial service, from a Commercial LEO Destination System (CLDS) Provider, including complete accommodations on a Commercial LEO Destination (CLD) required to support NASA crew and utilization and associated transportation to and from the Destination for crew and cargo. This program will support NASA's objectives for continued research, use of microgravity, and continuous United States (U.S.) presence in LEO.

This Radio Frequency (RF) Interface Standard establishes and controls the Common Communication for Commercial Destinations in Low-Earth Orbit (LEO) (C3DL) interface between the on-orbit Comm LEO Destinations (CLD) and the Visiting Vehicles (VVs). The systems encompassed within this document will include the on-orbit Destination(s) and the VVs, which include both crew and cargo vehicles.

This interface consists of:

- A. The C3DL forward link from the DESTINATION to the VV.
- B. The C3DL return link from the VV to the CLD.

1.2 SCOPE

Figure 1.2-1, C3DL Interface, shows the C3DL interface plane between the DESTINATION and the VV.

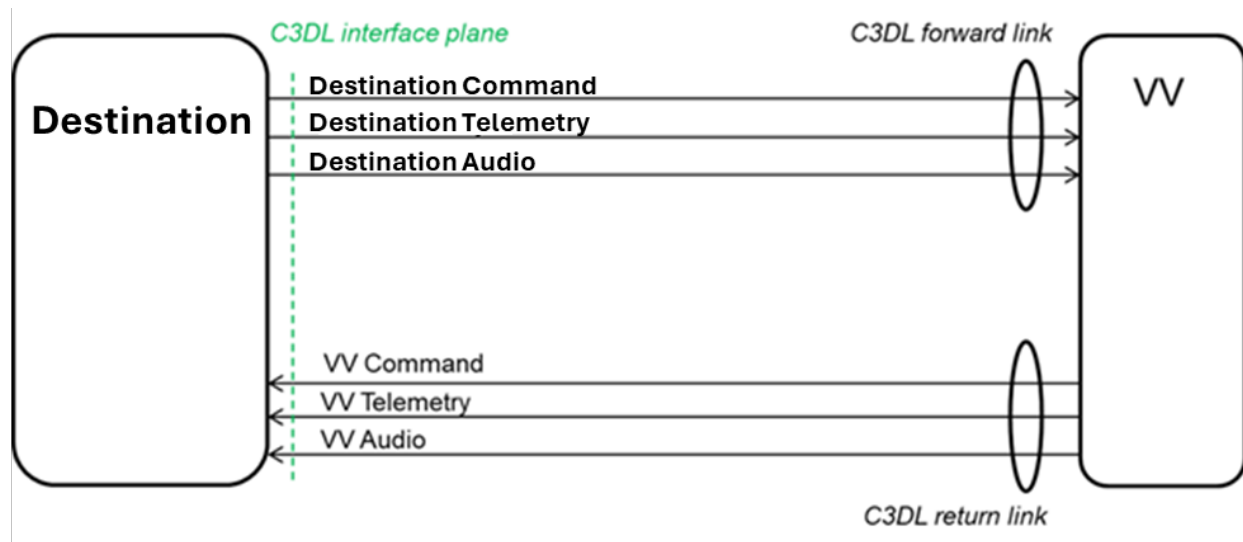


FIGURE 1.2-1 C3DL INTERFACE

CLDP-STD-1170

Baseline

The DESTINATION side of the interface is performed by the on-orbit Destination, referred to as "DESTINATION." The VV side of the interface is performed by the VV, referred to as "VV."

This RF Interface Standard establishes the C3DL interface plane as an RF interface plane that consists of a physical layer and data link layer (network layer and data content out of scope for C3DL except audio format will be defined in this RF Interface Standard) that is between the CLDs and the VVs.

This RF Interface Standard also includes a number of system requirements. These requirements appear in Section 3.2 as general requirements.

Because the different VVs have different data requirements (for example, cargo VV will not require audio), not all of the VV requirements are applicable to all VVs. The detailed C3DL design implementation for each VV will be controlled in the specific DESTINATION to specific VV Interface Control Document (ICD).

1.3 PRECEDENCE

In the event of conflict between CLDP-REQ-1130, Requirements and Standards for the Commercial Low Earth Orbit Development Program, and this RF Interface Standard, CLDP-REQ-1130 takes precedence.

1.4 CONVENTION AND NOTATION

The convention used in this document for requirements is as follows: Shall -- Used to indicate a requirement which must be implemented and its implementation verified; Should -- Used to indicate a goal which must be addressed by the design but is not formally verified; Will -- Used to indicate a statement of fact and is not verified.

In some cases, the values of quantities included in these requirements have not been determined and are designated as "To Be Resolved" (TBR), "To Be Resolved by Vendor" (TBR-V), "To Be Determined" (TBD), "To Be Determined by Vendor" (TBD-V), or "To Be Supplied" (TBS). Where approximate values of such quantities are known and provide useful guides for development, these are annotated with the TBR notation. When approximate values of such quantities are known but the final value will be determined by the vendor, these are shown along with the TBR-V notation. Where no value is yet known, a TBD is included. Where no value is yet known and the value will be determined by the vendor, a TBD-V is included. Where a value is known but has not been supplied to the Interface Standard Book Manager, a TBS is included.

1.5 CHANGE AUTHORITY

This document was jointly prepared by and managed by the Commercial LEO Development Program (CLDP) and the Commercial Crew Program (CCP). A Joint Program Control Board (JPCB) with CLDP and CCP is the authority for baselining and approving changes to this document. This document will be maintained in accordance with Configuration Management (CM) process standards for the CLDP documentation.

CLDP-STD-1170**Baseline**

The CLDP and CCP are jointly responsible for assuring the definition, control, implementation, and verification of the requirements identified in this document.

The appropriate NASA Office of Primary Responsibility (OPR) identified for this document is the CLDP SE&I Office.

2.0 DOCUMENTS

2.1 APPLICABLE DOCUMENTS

The following documents of the exact issue shown below, including any DESTINATION outstanding approved changes, form a part of this document to the extent specified herein.

Document Number	Title
CCSDS 131.0-B-5 September 2023	Telemetry (TM) Synchronization and Channel Coding
CCSDS 133.0-B-2 June 2020	Space Packet Protocol
CCSDS 355.0-B-2 July 2022	Space Data Link Security Protocol, Recommended Standard
CCSDS 732.0-B-4 October 2021	Advanced Orbiting Systems (AOS) Space Data Link Protocol
FIPS PUB 197 November 2001	Specification for the Advanced Encryption Standard (AES)
IETF RFC 3550	RTP: A Transport Protocol for Real-Time Applications
IETF RFC 3551	RTP Profile for Audio and Video Conferences with Minimal Control
ISO 14496-3	Information Technology - Very Low Bitrate Audio-Video Coding, Part 3: Audio (Advanced Audio Coding – AAC)
ITU-T G.729	Series G: Transmission Systems and Media Digital Systems and Networks. Coding of speech at 8 Kbit/s using Conjugate-Structure Algebraic-Code-Excited Linear Prediction (CS-ACELP)
NIST SP800-38D	Recommendation for Block Cipher Modes of Operation: Galois/Counter Mode (GCM) and GMAC

2.2 REFERENCE DOCUMENTS

The following documents are referenced in this RF Interface Standard for context and user convenience.

CLDP-STD-1170
Baseline - DRAFT

Document Number	Title
CLDP-REQ-1130	Requirements and Standards for the Commercial Low Earth Orbit Development Program
NIST SP800-175B, Rev. 1	Guideline for Using Cryptographic Standards in the Federal Government: Cryptographic Mechanisms
RFC 1242	Benchmarking Terminology for Network Interconnection Devices

3.0 REQUIREMENTS

3.1 INTERFACE DEFINITION

The C3DL interface covered by this RF Interface Standard includes data link layer and physical layer for both the C3DL forward link and the C3DL return link. The data content formatting (telemetry and command information) inside the network layer (space packets) is outside the scope of this RF Interface Standard, although audio data formatting with a Real-Time Transport Protocol (RTP) header is defined within the scope of this document. Therefore, the C3DL demarcation is the input and output of network layer space packets. Figure 3.1-1, C3DL Interface for Data Content, shows the C3DL interface for the data content for both the C3DL forward link and the C3DL return link. The C3DL forward link carries three different data types: DESTINATION command, DESTINATION telemetry, and DESTINATION audio. The C3DL return link carries three different data types: VV command, VV telemetry, and VV audio. In the lower layers (data link and physical) covered by this document, the C3DL processes each of these types of data into its own virtual channel; the resulting virtual channels are multiplexed together, and the resulting data stream is transmitted across the RF link to the other vehicle.

In the network layer prior to the C3DL, each type of data except for audio is packaged into a Consultative Committee for Space Data Systems (CCSDS) data structure space packet. Table 3.1-1, C3DL Forward Link Data Content and Network Layer Packaging, and Table 3.1-2, C3DL Return Link Data Content and Network Layer Packaging, show how the C3DL forward and return link data is packaged. Each type of data is the data content for a different virtual channel.

Because the different VVs will have different data requirements, not all of the VV requirements are applicable to all the VVs. The detailed C3DL design implementation for each VV will be controlled in the specific DESTINATION to specific VV ICD.

TABLE 3.1-1 C3DL FORWARD LINK DATA CONTENT AND NETWORK LAYER PACKAGING

Data Content	Network Layer Packaging
DESTINATION Command	CCSDS Space Packets
DESTINATION Telemetry	CCSDS Space Packets
DESTINATION Audio	Real-Time Transport Protocol (RTP) encapsulated G.729 Audio Frames (put in Virtual Channel Access Service Data Units (VCA_SDUs))

TABLE 3.1-2 C3DL RETURN LINK DATA CONTENT AND NETWORK LAYER PACKAGING

Data Content	Network Layer Packaging
VV Command	CCSDS Space Packets
VV Telemetry	CCSDS Space Packets

VV Audio	RTP encapsulated G.729 Audio Frames (put in VCA_SDU)
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The C3DL interface handles two different types of packets: CCSDS space packets (command and telemetry) and RTP encapsulated G.729 audio frames (audio frames are part of Network layer that station provider can tailor). In the data link layer, each packet type (space packet or RTP audio packet) is processed differently to generate Virtual Channel Data Units (VCDUs) before they are transmitted as shown in Figure 3.1-2, Transmit Packet Processing; and after they are received, the VCDUs are processed into the different packet types as shown in Figure 3.1-3, Receive Packet Processing. The C3DL links can be configured to encrypt/decrypt any virtual channel or bypass the encryption/decryption on any virtual channel. Each virtual channel is identified by a Virtual Channel ID (VCID) that is specified in requirements in later sections of this document by references to the appropriate CCSDS document.

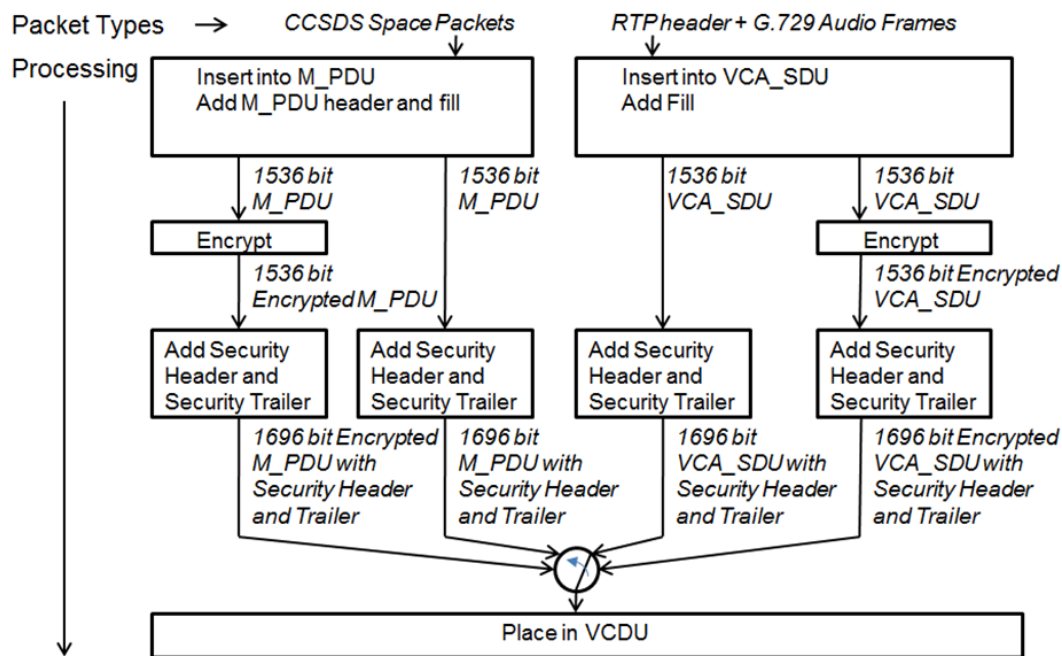


FIGURE 3.1-1 TRANSMIT PACKET PROCESSING

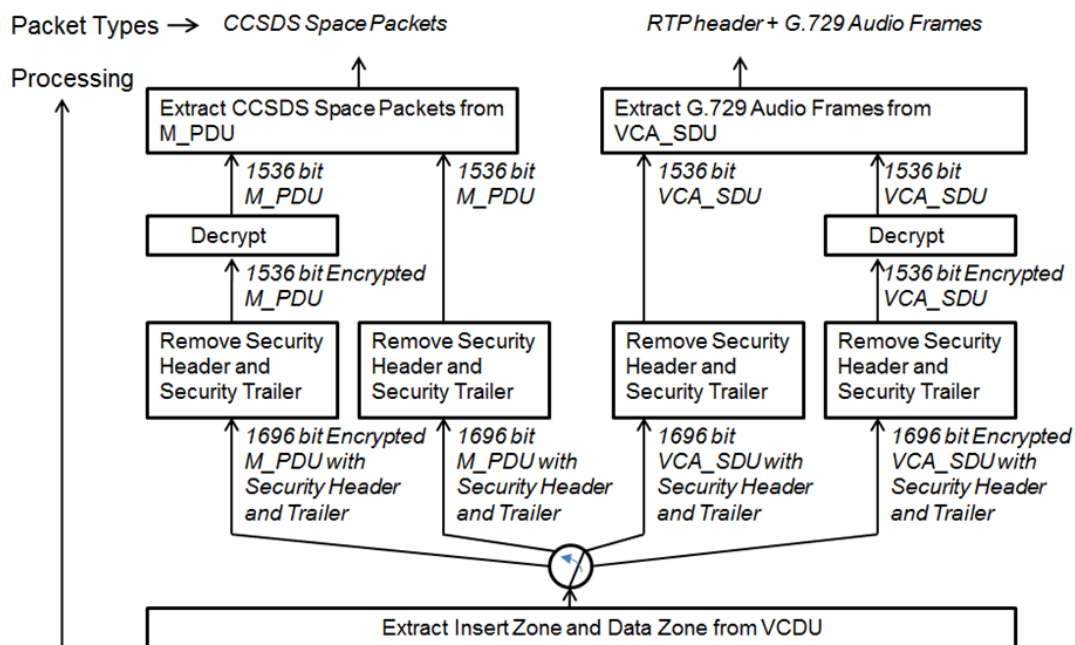


FIGURE 3.1-2 RECEIVE PACKET PROCESSING

Figure 3.1-4, Processing of CCSDS Space Packets into VCDUs – Showing Short Packets and Gaps – Unencrypted, Figure 3.1-5, Processing of CCSDS Space Packets into VCDUs – Showing Long Packet – Unencrypted, and Figure 3.1-6, Processing of CCSDS Space Packets into VCDUs – Showing Long Packet – Encrypted, show how the CCSDS space packets are packaged into VCDUs. Figure 3.1-4 shows how the VCDU is constructed when the packets are shorter than the Multiplexing Protocol Data Unit (M_PDU) packet zone and what happens when there is a gap in the CCSDS packets. Figure 3.1-5 shows how the VCDU is constructed when the packets are longer than the M_PDU packet zone. Figure 3.1-6 shows how the VCDU is constructed for an encrypted virtual channel. For all cases, the VCDU insert zones contain the C3DL DESTINATION Frame Count. On the C3DL forward link, the VCDU insert zone also contains the Return Link Status Bits. The C3DL DESTINATION Frame Count is transmitted by the CLDs and then re-transmitted back by the VVs to the CLDs to assess the status of the communication link. The Return Link Status Bits are generated by the CLDs and transmitted to the VVs to provide insight about the DESTINATION return link to the VV.

The RTP encapsulated G.729 audio frames are handled using the CCSDS Virtual Channel Access (VCA) service (The formatting of G.176 audio frames are within the scope of this RF Interface Standard). Figure 3.1-7, Processing of RTP Encapsulated G.729 Audio Frames into VCDUs – Unencrypted, shows how the VCDU is constructed for the VCA service when the audio is not encrypted. Figure 3.1-8, Processing of RTP Encapsulated G.729 Audio Frames into VCDUs – Encrypted, shows how the VCDU is

constructed for the VCA service when the audio is encrypted. For all cases, the VCDU insert zones contain the C3DL DESTINATION Frame Count. On the C3DL forward link, the VCDU insert zone also contains the Return Link Status Bits.

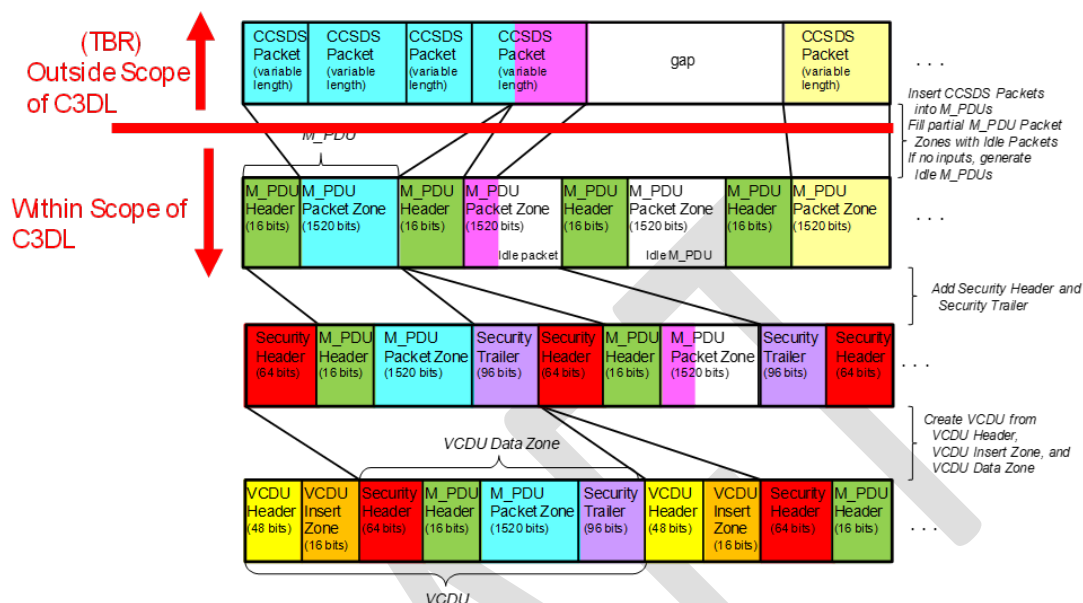


FIGURE 3.1-3 PROCESSING OF CCSDS SPACE PACKETS INTO VCDUS – SHOWING SHORT PACKETS AND GAPS - UNENCRYPTED

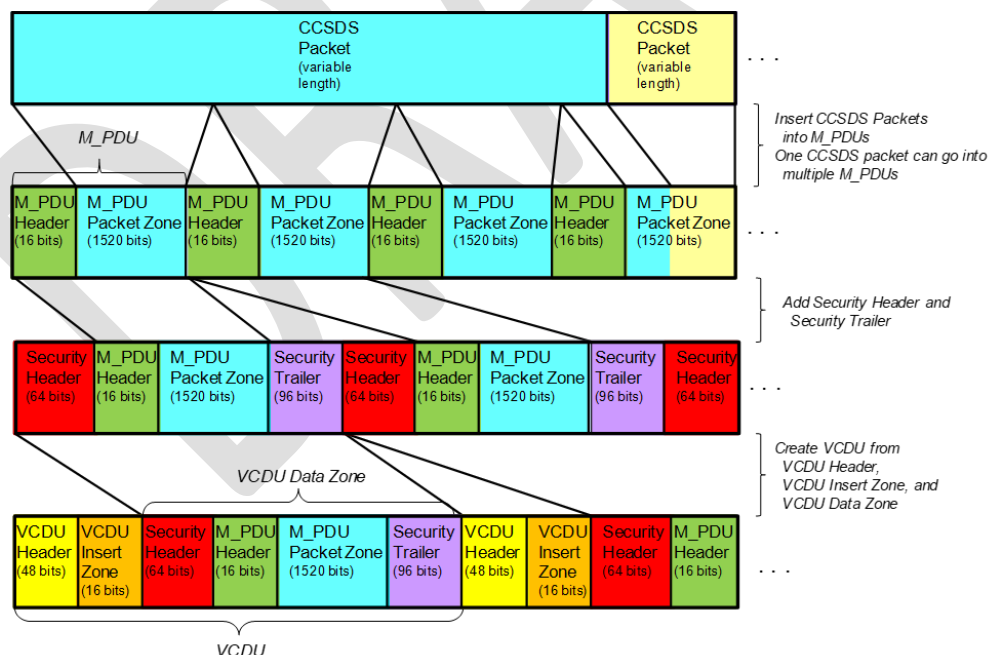


FIGURE 3.1-4 PROCESSING OF CCSDS SPACE PACKETS INTO VCDUS – SHOWING LONG PACKET - UNENCRYPTED

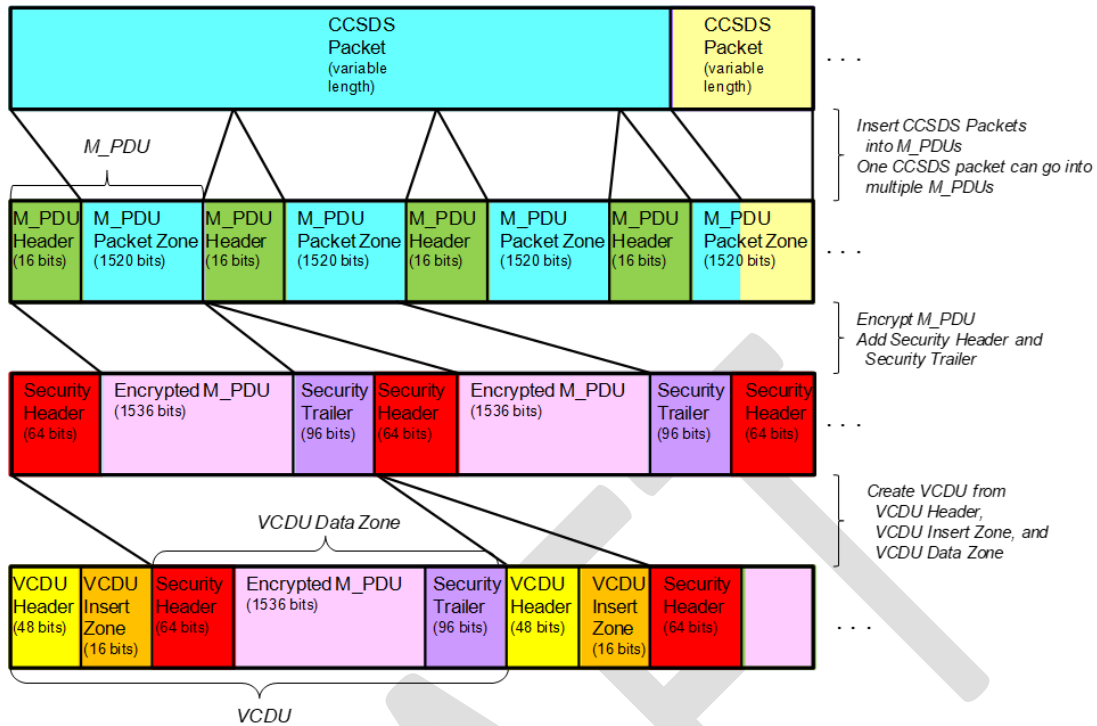


FIGURE 3.1-5 PROCESSING OF CCSDS SPACE PACKETS INTO VCDUS – SHOWING LONG PACKET - ENCRYPTED

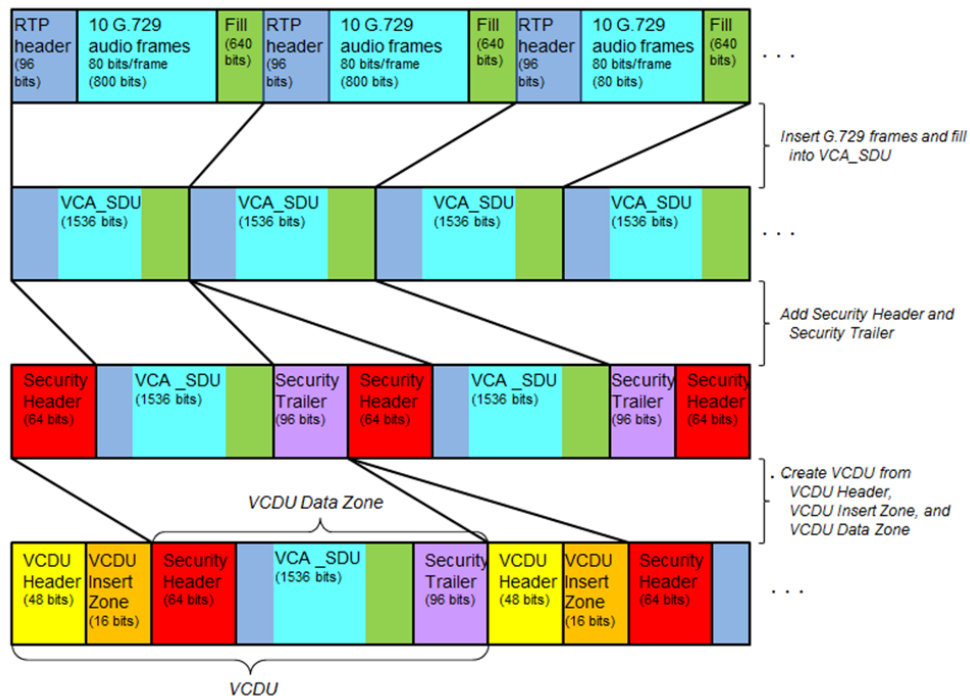


FIGURE 3.1-6 PROCESSING OF RTP ENCAPSULATED G.729 AUDIO FRAMES INTO VCDUS - UNENCRYPTED

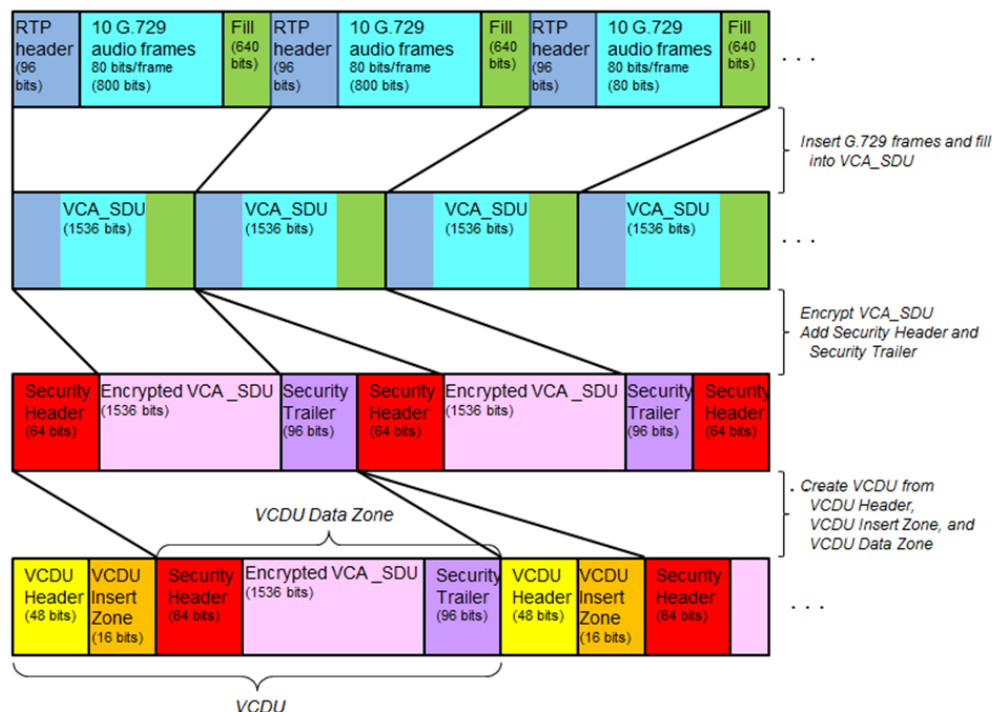


FIGURE 3.1-7 PROCESSING OF RTP ENCAPSULATED G.729 AUDIO FRAMES INTO VCDUS - ENCRYPTED

The virtual channels generated by the data processing are multiplexed together, and the resulting VCDUs are Reed Solomon (RS) encoded, randomized, marked with an Attached Sync Marker (ASM), and convolutionally encoded before being modulated and transmitted across the RF channel to the other vehicle. The other vehicle demodulates and syncs the signal, convolutionally decodes it, and uses the ASM to frame sync and perform data polarity correction. It then derandomizes and Reed Solomon decodes it and demultiplexes the VCDUs. Figure 3.1-9, CADU Structure for Coded CADUs, shows the Channel Access Data Unit (CADU) structure.

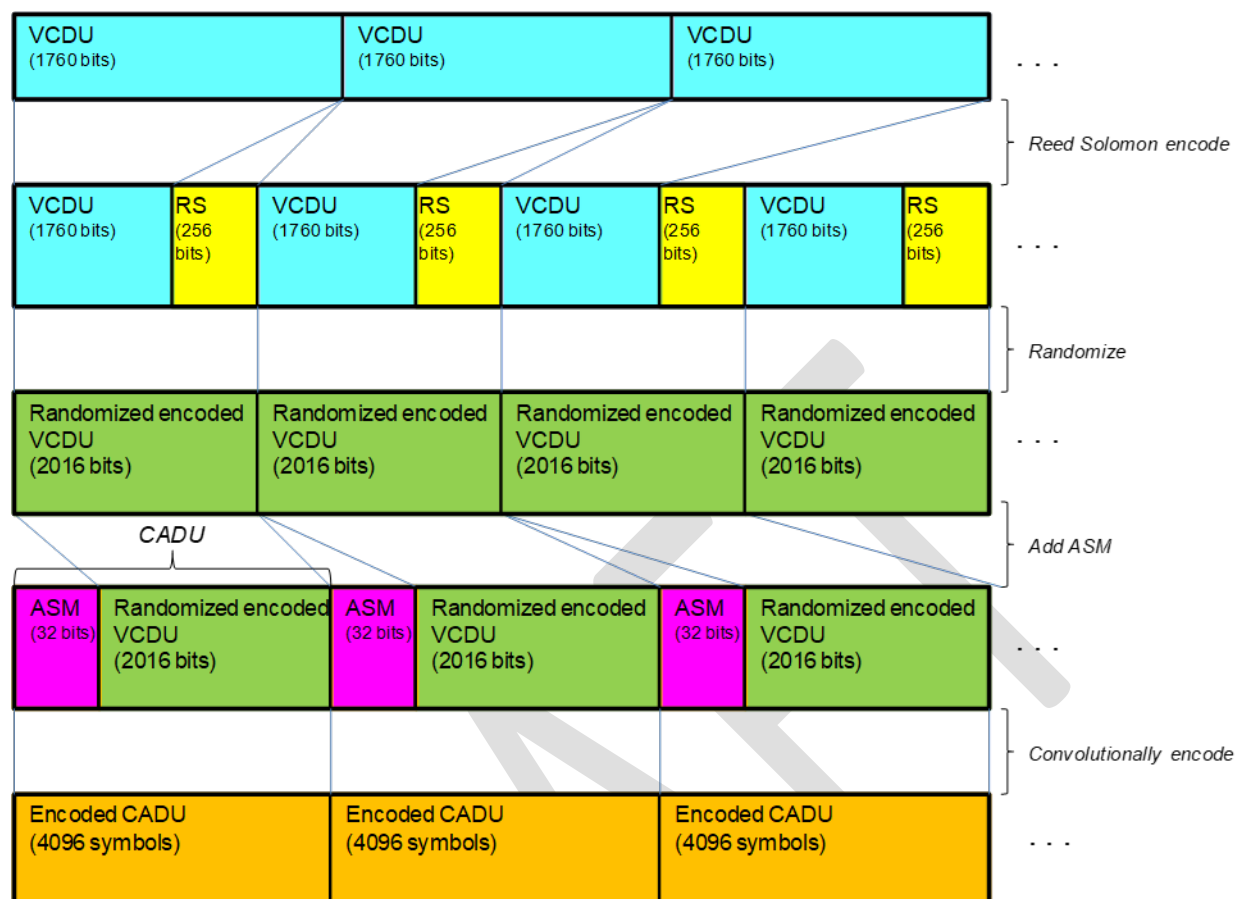


FIGURE 3.1-8 CADU STRUCTURE FOR CODED CADUS

The C3DL forward link and C3DL return link can use Offset Quadrature Phase Shift Keying (OQPSK) modulation. Appendix D <TBR D-1> shows conceptual block diagrams that show the data flow from the DESTINATION data exchange interface to the RF interface.

3.2 GENERAL REQUIREMENTS

3.2.1 CONCURRENT C3DL FORWARD LINK AND C3DL RETURN LINK

The requirements in this section are applicable to the CLDs and to all VV users of the C3DL System.

- A. The DESTINATION shall receive the C3DL return link and transmit the C3DL forward link concurrently.
- B. The VV shall receive the C3DL forward link and transmit the C3DL return link concurrently.

Rationale: CLDP-REQ-1130 (R.CLDS.535 and R.CLDS.092) requires the CLDs to have the capability for bidirectional communication during free flight. This Interface Standard defines design requirement values for a communications link that will operate when the distance between the CVV and DESTINATION is ≤ 10 km.

3.2.2 MAXIMUM POWER

The requirement in this section is applicable to the CLDs and to all VV users of the C3DL System.

- A. The VV shall produce an RF signal with no greater than -50 dBW received power at an isotropic antenna at the DESTINATION antenna locations when the VV is 5 or more meters away from the DESTINATION antennas.

Rationale: The C3DL return link must operate with a significant variation in range and DESTINATION antenna gain. The VV must limit the power incident on the DESTINATION antennas to limit the dynamic range required of the DESTINATION receiver.

3.2.3 SECURITY

The requirements in this section are applicable to the CLDs. The VV encryption requirements are applicable to VV users that transmit encrypted data, and the VV decryption requirements are applicable to VV users that receive encrypted data.

- A. The DESTINATION shall use the Advanced Encryption Standard (AES) -256 per Federal Information Processing Standard (FIPS) Publication (PUB) 197, Specification for the Advanced Encryption Standard (AES), using the Galois/Counter Mode (GCM) mode as stated in National Institute of Standards and Technology (NIST) Special Publication 800-38D, Recommendation for Block Cipher Modes of Operation: Galois/Counter Mode (GCM) and GCM Message Authentication Code (GMAC), for encryption and decryption of the C3DL forward link data and the C3DL return link data, respectively.
- B. The VV shall use the AES -256 per FIPS PUB 197 using GCM mode as stated in NIST Special Publication 800-38D for decryption and encryption of the C3DL forward link data and the C3DL return link data, respectively.

Rationale: Federal Government systems are required to use approved algorithms for encryption; AES-256 as specified in FIPS PUB 197 is an approved algorithm and is the preferred algorithm for new products per NIST Special Publication SP800-21, Second Edition, "Guideline for Implementing Cryptography In the Federal Government". Conversations with NIST indicate the GCM to be the more secure and robust capability to ensure authentication and confidentiality. For space use and the future ramifications of supporting communications with crewed vehicles, NIST prefers to see NASA pursue AES-GCM usage.

- C. The DESTINATION shall be configurable by command to operate with or without link security enabled for each virtual channel on both the C3DL forward and return links.
- D. The VV shall be configurable by command to operate with or without link security enabled for each virtual channel on both the C3DL forward and return links.

Rationale: For the DESTINATION and the VV, the data requiring security will be configurable via command for both the C3DL forward link and the C3DL return link.

- E. The VV shall process the encrypted C3DL forward link DESTINATION command virtual channel.
- F. The DESTINATION shall process the encrypted C3DL return link VV command virtual channel.

Rationale: All VVs that receive an encrypted C3DL forward link DESTINATION command virtual channel is required to be able to process the encrypted C3DL forward link DESTINATION command virtual channel. Any VV may encrypt or decrypt other virtual channels, as negotiated with the DESTINATION Program. All CLDs that receive an encrypted C3DL return link VV command virtual channel are required to be able to process the encrypted C3DL return link VV command virtual channel. Any DESTINATION may encrypt or decrypt other virtual channels, as negotiated with the VV Program.

- G. The VV shall discard time-tagged commands that do not agree to the VV time within one minute.
- H. The DESTINATION shall discard time-tagged commands that do not agree to the DESTINATION time within one minute.

Rationale: Time authentication needs to be part of the communication security design.

- I. The DESTINATION shall comply with the security procedures in CCSDS 355.0-B-2, Section 4.2, excluding §4.2.4.3 g through j.
- J. The VV shall comply with the security procedures in CCSDS 355.0-B-2, Section 4.2, excluding §4.2.4.3 g through j.

Rationale: CCSDS 355.0-B-2, Section 4.2 specifies the security protocols to be used for CCSDS data link layer security. CCSDS 355.0-B-2, §4.2.4.3 g through j is excluded because anti-replay protection is provided via time authentication of all command links.

- K. The DESTINATION shall perform cryptographic operations using devices that meet FIPS Pub 140-3, Security Requirements for Cryptographic Modules, Level 2 certification.
- L. The VV shall perform cryptographic operations using devices that meet FIPS Pub 140-3, Security Requirements for Cryptographic Modules, Level 2 certification.

Rationale: The Advanced Encryption Standard (AES) Galois/Counter Mode (GCM) algorithm is publicly known and accessible, making the security of the cryptographic keys of the utmost importance, including their generation, distribution, and loading. The Key Management Plan and Key Production Specification will be strictly followed for the generation, distribution and loading of all cryptographic keys. Cryptographic key generation and establishment will follow the FIPS 140-3 Implementation Guidance to ensure valid and approved methods of using keys.

3.3 DESTINATION TO VV C3DL FORWARD LINK REQUIREMENTS

3.3.1 SPECTRUM REQUIREMENTS

The requirements in this section are applicable to the CLDs and to all VV users of the C3DL System. Each DESTINATION will be assigned a C3DL forward and return link frequency pair and so will have one applicable frequency. The frequencies applicable to a VV are those for the CLDs with which it performs Rendezvous, Proximity Operations, and Docking (RPOD) and Undocking (RPODU).

3.3.1.1 FREQUENCY

- A. The DESTINATION shall transmit the C3DL forward link at an assigned center frequency in the 410 Mega Hertz (MHz) to 415 MHz band +/- 3 parts per million (ppm).
- B. The VV shall receive the forward link at the assigned center frequency +/- 3 ppm.

Rationale: The return C3DL Ultra High Frequency (UHF) Return Link Frequencies have been chosen for the DESTINATION Program based on reasonable spectrum availability, cost, and risk in the 410 MHz to 420 MHz band using the Frequencies.

3.3.1.2 BANDWIDTH

- A. The DESTINATION shall transmit the C3DL forward link signal for the 72 ksps symbol rate with a bandwidth less than or equal to 46 kilo Hertz (kHz) **<TBR 3-2>** edge to edge.
- B. The DESTINATION shall transmit the C3DL forward link signal for the 144 ksps symbol rate with a bandwidth less than or equal to 92 kHz **<TBR 3-3>** edge to edge.

Rationale: The signal bandwidth is defined as the width of a frequency band that contains 99 percent of the total mean power of a given emission.

3.3.2 RADIO FREQUENCY REQUIREMENTS

3.3.2.1 SYMBOL RATE

The C3DL provides selectable symbol rates; the VVs may select which symbol rate(s) to utilize and verify, as indicated in the specific DESTINATION to specific VV ICD. All requirements in this section are applicable to the CLDs.

- A. The DESTINATION shall transmit the C3DL forward link symbol rates listed in Table 3.3.2.1-1, C3DL Forward Link Symbol Rates.
- B. The VV shall receive the C3DL forward link symbol rates listed in Table 3.3.2.1-1.

TABLE 3.3.2.1-1 C3DL FORWARD LINK SYMBOL RATES

Link	Rate
Low Data Rate (LDR)	72 kilo symbols per second (ksps) +/- 0.1%
Medium Data Rate (MDR)	144 ksps +/- 0.1%

Rationale: The C3DL interface can be moded to support different symbol rates at different ranges. For clarity and verification purposes, the rates are defined as symbol rates at the input to the modulator as shown in Figure 3.3.2.1-1, C3DL Forward Link Symbol Definition.

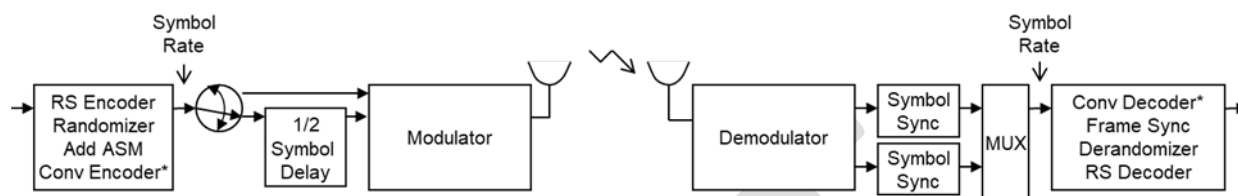


FIGURE 3.3.2.1-1 C3DL FORWARD LINK SYMBOL DEFINITION

The CLDs will be capable of transmitting and the VVs will be capable of receiving the data types listed Table 3.3.2.1-2, C3DL Forward Link Data Types by Symbol Rates, when using the corresponding symbol rates.

TABLE 3.3.2.1-2 C3DL FORWARD LINK DATA TYPES BY SYMBOL RATES

Link	Data Types
Low Symbol Rate	DESTINATION Commands DESTINATION Telemetry
Medium Symbol Rate	DESTINATION Commands DESTINATION Telemetry DESTINATION Audio

3.3.2.2 MODULATION

All requirements in this section are applicable to the CLDs and to all VV users of the C3DL System.

- A. The DESTINATION shall transmit the C3DL forward link using Filtered Offset Quadrature Phase Shift Keying (OQPSK) modulation with the characteristics listed in Table 3.3.2.2-1, C3DL Forward Link Filtered OQPSK Parameters.
- B. The VV shall receive the Filtered OQPSK modulated C3DL forward link with the characteristics listed in Table 3.3.2.2-1.

TABLE 3.3.2.2-1 C3DL FORWARD LINK FILTERED OQPSK PARAMETERS

Parameter	Value	Tolerance
QPSK Symbol Mapping	See Figure 2.4.10-2 Constellation Mapping on Page 2.4.10-2 of CCSDS 401-0-B-30	
Q sinusoid phase relative to I sinusoid phase	90-degree delay (at RF, e.g., after the last upconverter and before the first downconverter)	+/- 3 degrees

Q data delay relative to I data (Offset QPSK)	½ symbol	+/- 3%
I:Q power ratio	1:1	+/-0.4dB
Filter Type	SRRC Filter ($\alpha = 0.5$)	

Rationale: Space systems typically use OQPSK modulation because it is more spectrally efficient than Binary Phase Shift Key (BPSK) without costing additional power. Filtered OQPSK is more spectrally efficient than OQPSK in order to meet the approved spectrum filing.

3.3.2.3 POLARIZATION

The requirements in this Section are applicable to the CLDs and to all VV users of the C3DL system.

- A. The DESTINATION shall transmit the C3DL forward link using Right Hand Circular Polarization (RHCP).
- B. The VV shall receive the C3DL forward link using RHCP.

Rationale: Space systems typically use circular polarization to avoid the large mismatches possible with linear polarization.

3.3.2.4 MINIMUM POWER AT VV

The DESTINATION shall produce an RF signal with a received power at an isotropic antenna at the VV antenna locations no less than the values in Table 3.3.2.4-1, DESTINATION Signal Prec at VV, for the C3DL forward link.

Rationale: This requirement allows the CLDs to reduce their power as the range to a VV decreases. The C3DL link margin analysis shows that the specified received power is sufficient to provide the desired Code Word Error Rate (CWER) and margin for the applicable symbol rates at the desired ranges.

TABLE 3.3.2.4-1 DESTINATION SIGNAL PREC AT VV

Range/Symbol Rate	LDR	MDR
30 km $\geq$ range > 10 km <TBR 3-4 >	<TBD 3-1> dBWi	<TBD 3-2> dBWi
10 km <TBR 3-5> $\geq$ range	<TBD 3-3> dBWi	<TBD 3-4> dBWi

3.3.2.5 TRANSMIT SIGNAL PARAMETERS

The requirement in this Section is applicable to the CLDs. VV users of the C3DL System must function with distortion on the forward link from the CLD.

The DESTINATION shall transmit a signal with an Error Vector Magnitude (EVM) no greater than 10 percent.

Rationale: The EVM is a measure of the difference between the reference waveform and the measured waveform. This difference is called the error vector. In order to achieve the desired Symbol Error Rate (SER) and margin, the transmit signal must meet certain parameters so the receiver can process it.

3.3.2.6 CODE WORD ERROR RATE

The CLDs provide selectable symbol rates; the VVs may select which symbol rate(s) to utilize, and therefore, which parameter(s) are applicable, as indicated in the specific DESTINATION to specific VV ICD.

The VV shall provide a CWER no greater than 4×10^{-7} when DESTINATION meets its EVM and provides a received Prec power at a 0 dB gain (isotropic) VV antenna no less than the values in Table 3.3.2.6-1, VV Prec for VV CWER.

TABLE 3.3.2.6-1 VV PREC FOR VV CWER

Symbol Rate	Prec (dBW)
72 ksp/s	<TBD 3-5>
144 ksp/s	<TBD 3-6>

Rationale: The CWER is the rate that Reed Solomon codewords are discarded due to Reed Solomon decoder failures. The VV is only required to provide the specified CWER when the DESTINATION provides the specified Prec.

3.3.3 BASEBAND REQUIREMENTS

3.3.3.1 VIRTUAL CHANNEL DATA

3.3.3.1.1 DESTINATION COMMANDS

The requirements in this section are applicable to the CLDs and to VVs that receive DESTINATION Commands via the C3DL forward link.

- A. The DESTINATION shall insert the commands for the C3DL forward link into CCSDS Space Packets with the characteristics in Table 3.3.3.1.1-1, as specified in CCSDS 133.0-B-2, Space Packet Protocol.
- B. The VV shall extract the received commands from the C3DL forward link from CCSDS Space Packets with the characteristics in Table 3.3.3.1.1-1, C3DL CCSDS Space Packet Structure, as specified in CCSDS 133.0-B-2.

TABLE 3.3.3.1.1-1 C3DL CCSDS SPACE PACKET STRUCTURE

Structure	Length In Bits
Packet Primary Header	48
User Data Field	variable

Rationale: All of the C3DL data, except for audio, is placed into CCSDS space packets. CCSDS space packets are defined in CCSDS 133.0-B-2, and they consist of a packet primary header, a variable packet secondary header, and a variable user data field. The C3DL packets will not use a packet secondary header to minimize overhead.

The content of the DESTINATION commands will be controlled in the specific DESTINATION to specific VV ICD.

3.3.3.1.2 DESTINATION TELEMETRY

The requirements in this section are applicable to the CLDs and to VVs that receive DESTINATION Telemetry.

- A. The DESTINATION shall insert DESTINATION Telemetry on the C3DL forward link to the VV into CCSDS space packets with the characteristics in Table 3.3.3.1.1-1 as specified in CCSDS 133.0-B-2.
- B. The VV shall extract the received DESTINATION Telemetry from the C3DL forward link from CCSDS space packets with the characteristics in Table 3.3.3.1.1-1 as specified in CCSDS 133.0-B-2.

Rationale: All of the C3DL data, except for audio, is placed into CCSDS space packets. CCSDS space packets are defined in CCSDS 133.0-B-2, and they consist of a packet primary header, a variable packet secondary header, and a variable user data field. The C3DL packets will not use a packet secondary header to minimize overhead.

The content of the DESTINATION telemetry will be controlled in the specific DESTINATION to specific VV ICD.

3.3.3.1.3 DESTINATION AUDIO

The requirements in this section are applicable to the CLDs and to VVs that support a voice link to the CLDs via the C3DL System.

- A. The DESTINATION shall send DESTINATION audio consisting of a 96 bit RTP header in accordance with Internet Engineering Task Force (IETF) RFC 3550 and IETF RFC 3551 and ten 80-bit 10 millisecond (ms) G.729 audio frames in accordance with International Telecommunication Union (ITU)-T G.729, Series G: Transmission Systems and Media Digital Systems and Networks, Coding of Speech at 8 Kbit/s Using Conjugate-Structure Algebraic-Code-Excited Linear Prediction (CS-ACELP) on the C3DL forward link to the VV.
- B. The VV shall receive DESTINATION audio consisting of a 96-bit RTP header in accordance with IETF RFC 3550 and IETF RFC 3551 and ten 80-bit 10 ms G.729 audio frames in accordance with ITU-T G.729 on the C3DL forward link.

Rationale: ITU-T G.729, Sections 2, 3, and 4 define a standard for how audio is encoded and decoded. IETF RFC 3550 specifies a network transport function for real-time audio, and IETF 3551 specifies a profile for use of RTP for audio and video multiparticipant conferences with minimal control.

3.3.3.2 VIRTUAL CHANNEL PACKAGING

3.3.3.2.1 CCSDS SPACE PACKETS FOR UNENCRYPTED VIRTUAL CHANNELS

The requirements in this section are applicable to the CLDs and to VVs that receive any of the following data types from the CLDs: unencrypted DESTINATION Command and unencrypted DESTINATION Telemetry.

3.3.3.2.1.1 CCSDS SPACE PACKETS MULTIPLEXING PROTOCOL DATA UNITS FOR UNENCRYPTED VIRTUAL CHANNELS

- A. The DESTINATION shall insert the CCSDS Space Packets for unencrypted virtual channels on the C3DL forward link into M_PDUs with the characteristics in Table 3.3.3.2.1.1-1, C3DL Forward Link M_PDU Structure for Unencrypted Virtual Channels as specified in CCSDS 732.0-B-4, Advanced Orbiting Systems (AOS) Space Data Link Protocol.
- B. The VV shall extract the received CCSDS Space Packets from unencrypted virtual channels on the C3DL forward link from the M_PDUs with the characteristics in Table 3.3.3.2.1.1-1 as specified in CCSDS 732.0-B-4.
- C. The DESTINATION shall generate an Idle Space Packet as specified in CCSDS 732.0-B-4 and CCSDS 133.0-B-2 when insufficient CCSDS Space Packets are available to fill the M_PDU Packet Zone for unencrypted virtual channels on the C3DL forward link.
- D. The VV shall remove Idle Space Packets as specified in CCSDS 732.0-B-4 from the received M_PDUs for unencrypted virtual channels on the C3DL forward link.

TABLE 3.3.2.1.1-1 C3DL FORWARD LINK M_PDU STRUCTURE FOR UNENCRYPTED VIRTUAL CHANNELS

Structure	Length In Bits
M_PDU Header	16
M_PDU Packet Zone	1520

Rationale: Each C3DL virtual channel can be configured to be encrypted or not encrypted. When a C3DL forward link virtual channel containing CCSDS space packets is not encrypted, the requirements in this section apply. CCSDS 732.0-B-4 provides the M_PDU structure in Section 4.1.4.2. The M_PDU header is mandatory and must be 16-bits long, and the M_PDU Packet Zone is mandatory and must be an integer number of octets, where an octet is equal to eight-bits. Each M_PDU can only contain data for one Virtual Channel. The M_PDU goes into the Data Zone of the VCDUs.

When insufficient CCSDS Space Packets are available, the remaining space in the M_PDU Packet Zone can be filled with an Idle CCSDS Space Packet so that the CCSDS Space Packets that are available will not be delayed. CCSDS 732.0-B-4 4.2.2.5 says that the Packet Processing Function can generate an Idle Packet of

appropriate length to fill in the M_PDU. Idle CCSDS Space Packets are described in CCSDS 133.0-B-2, but the idle pattern is left for the project to specify.

When no user data is available, an Idle VCDU is sent as described in Section 3.3.3.5. Idle M_PDUs are not used on the C3DL forward link.

3.3.3.2.1.2 SECURITY HEADER

- A. The DESTINATION shall add a 64-bit security header to the M_PDUs for unencrypted virtual channels on the C3DL forward link with the fields listed in Table 3.3.3.2.1.2-1, Security Header for M_PDUs, as specified in CCSDS 355.0-B-2.
- B. The VV shall extract a 64-bit security header from before the M_PDUs for unencrypted virtual channels on the C3DL forward link with the fields listed in Table 3.3.3.2.1.2-1, as specified in CCSDS 355.0-B-2.

Rationale: CCSDS 355.0-B-2 specifies the security header to be used with the M_PDUs. The sequence number and pad length fields are not used for C3DL. The fields of the Security Header and their usage are defined in Annex A of this document. (Note: Distribution of Annex A is limited to those having a need to know.)

TABLE 3.3.3.2.1.2-2 SECURITY HEADER FOR M_PDUs

Security Header Field	Length In Bits
Security Parameter Index	16
Initialization Vector	48

3.3.3.2.1.3 SECURITY TRAILER

- A. The DESTINATION shall add a 96-bit security trailer to the M_PDUs for unencrypted virtual channels on the C3DL forward link as specified in CCSDS 355.0-B-2.
- B. The VV shall extract a 96-bit security trailer from after the M_PDUs for unencrypted virtual channels on the C3DL forward link as specified in CCSDS 355.0-B-2.

Rationale: CCSDS 355.0-B-2 specifies the security trailer to be used with the M_PDUs. The fields of the Security Trailer and their usage are defined in Annex A of this document. (Note: Distribution of Annex A is limited to those having a need to know.)

3.3.3.2.2 CCSDS SPACE PACKETS FOR ENCRYPTED VIRTUAL CHANNELS

The requirements in this section are applicable to the CLDs and to VVs that receive any of the following data types from the CLDs: encrypted DESTINATION Command and encrypted DESTINATION Telemetry.

3.3.3.2.2.1 CCSDS SPACE PACKETS MULTIPLEXING PROTOCOL DATA UNITS FOR ENCRYPTED VIRTUAL CHANNELS

- A. The DESTINATION shall insert the CCSDS Space Packets for encrypted virtual channels on the C3DL forward link into M_PDUs with the characteristics in Table 3.3.3.2.2.1-1, C3DL Forward Link M_PDU Structure for Encrypted Virtual Channels as specified in CCSDS 732.0-B-4.
- B. The VV shall extract the received CCSDS Space packets from encrypted virtual channels on the C3DL forward link from the M_PDUs with the characteristics in Table 3.3.3.2.2.1 as specified in CCSDS 732.0-B-4.

TABLE 3.3.3.2.2.1-1 C3DL FORWARD LINK M_PDU STRUCTURE FOR ENCRYPTED VIRTUAL CHANNELS

Structure	Length in Bits
M_PDU Header	16
M_PDU Packet Zone	1520

- C. The DESTINATION shall generate an Idle Space Packet as specified in CCSDS 732.0-B-4 and CCSDS 133.0-B-2 when insufficient CCSDS Space Packets are available to fill the M_PDU Packet Zone for encrypted virtual channels on the C3DL forward link.
- D. The VV shall remove Idle Space Packets as specified in CCSDS 732.0-B-4 from the received M_PDUs for encrypted virtual channels on the C3DL forward link.

Rationale: Each C3DL virtual channel can be configured to be encrypted or not encrypted. When a C3DL forward link virtual channel containing CCSDS space packets is encrypted, the requirements in this section apply. CCSDS 732.0-B-4 provides the M_PDU structure in Section 4.1.4.2. The M_PDU header is mandatory and must be 16-bits long, and the M_PDU packet zone is mandatory and must be an integer number of octets, where an octet is eight-bits long. Each M_PDU can only contain data for one virtual channel. The M_PDU goes into the Data Zone of the Virtual Channel Data Units.

When insufficient CCSDS Space Packets are available, the remaining space in the M_PDU Packet Zone can be filled with an Idle CCSDS Space Packet so that the CCSDS Space Packets that are available will not be delayed. CCSDS 732.0-B-4 4.3.2.5 says that the Packet Extraction Function can discard Idle Packets. Idle CCSDS Space Packets are described in CCSDS 133.0-B-2, but the idle pattern is left for the project to specify.

When no user data is available, an Idle VCDU is sent as described in Section 3.3.3.5. Idle M_PDUs are not used on the C3DL forward link.

3.3.3.2.2.2 MULTIPLEXING PROTOCOL DATA UNIT ENCRYPTION

- A. The DESTINATION shall encrypt the Multiplexing Protocol Data Units for virtual channels configured to be encrypted on the C3DL forward link.

- B. The VV shall decrypt the Multiplexing Protocol Data Units for virtual channels configured to be encrypted on the C3DL forward link.

Rationale: Each C3DL virtual channel can be configured to be encrypted or not encrypted. CCSDS 355.0-B-2 specifies that data link layer encryption is performed on M_PDUs.

3.3.3.2.2.3 SECURITY HEADER

- A. The DESTINATION shall add a 64-bit security header to the encrypted M_PDUs for encrypted virtual channels on the C3DL forward link with the fields listed in Table 3.3.3.2.2.3-1, Security Header for Encrypted M_PDUs as specified in CCSDS 355.0-B-2.
- B. The VV shall extract a 64-bit security header from before the encrypted M_PDUs for encrypted virtual channels on the C3DL forward link with the fields listed in Table 3.3.3.2.2.3-1 as specified in CCSDS 355.0-B-2.

Rationale: CCSDS 355.0-B-2 specifies the security header to be used with the M_PDUs. The sequence number and pad length fields are not used for C3DL. The fields of the Security Header and their usage are defined in Annex A of this document. (Note: Distribution of Annex A is limited to those having a need to know.)

TABLE 3.3.3.2.2.3-1 SECURITY HEADER FOR ENCRYPTED M_PDUs

Security Header Field	Length In Bits
Security Parameter Index	16
Initialization Vector	48

3.3.3.2.2.4 SECURITY TRAILER

- A. The DESTINATION shall add a 96-bit security trailer to the encrypted M_PDUs for encrypted virtual channels on the C3DL forward link as specified in CCSDS 355.0-B-2.
- B. The VV shall extract a 96-bit security trailer from after the encrypted M_PDUs for encrypted virtual channels on the C3DL forward link as specified in CCSDS 355.0-B-2.

Rationale: CCSDS 355.0-B-2 specifies the security trailer to be used with the M_PDUs. The fields of the Security Trailer and their usage are defined in Annex A of this document. (Note: Distribution of Annex A is limited to those having a need to know.)

3.3.3.2.3 G.729 AUDIO FOR UNENCRYPTED VIRTUAL CHANNELS

The requirements in this section are applicable to the CLDs and to VVs who are using unencrypted audio.

3.3.3.2.3.1 DESTINATION AUDIO VCA_SDU FOR UNENCRYPTED VIRTUAL CHANNELS

- A. The DESTINATION shall insert DESTINATION Audio for unencrypted virtual channels on the C3DL forward link into a VCA_SDU with the characteristics in Table 3.3.3.2.3.1-1, C3DL Forward Link VCA_SDU Structure for Unencrypted Virtual Channels as specified in CCSDS 732.0-B-4.
- B. The VV shall extract the received DESTINATION Audio from unencrypted virtual channels on the C3DL forward link from VCA_SDUs with the characteristics in Table 3.3.3.2.3.1-1 as specified in CCSDS 732.0-B-4.

The DESTINATION adds 640-bits of fill data to the RTP header and audio frames to generate the VCA_SDU as shown in Figure 3.3.3.2.3.1-2. The fill data contains idle data that is all 0s. When the VV receives the VCA_SDU, it extracts the RTP header and audio by discarding the fill bits.

TABLE 3.3.3.2.3.1-1 C3DL FORWARD LINK VCA_SDU STRUCTURE FOR UNENCRYPTED VIRTUAL CHANNELS

Structure	Length In Bits
RTP Header	96
G.729 Audio Frames	800
Fill	640

RTP HEADER	TEN G.729 AUDIO FRAMES										FILL
	G.729 AUDIO FRAME #1	G.729 AUDIO FRAME #2	G.729 AUDIO FRAME #3	G.729 AUDIO FRAME #4	G.729 AUDIO FRAME #5	G.729 AUDIO FRAME #6	G.729 AUDIO FRAME #7	G.729 AUDIO FRAME #8	G.729 AUDIO FRAME #9	G.729 AUDIO FRAME #10	
96 bits	80 bits	80 bits	80 bits	80 bits	80 bits	80 bits	80 bits	80 bits	80 bits	80 bits	640 bits

FIGURE 3.3.3.2.3.1-1 VCA_SDU STRUCTURE FOR UNENCRYPTED AUDIO (FORWARD LINK)

Rationale: Each C3DL virtual channel can be configured to be encrypted or not encrypted. When a C3DL forward link virtual channel containing DESTINATION audio is not encrypted, the requirements in this Section apply. CCSDS 732.0-B-4 provides for a VCA service that uses privately formatted data of a fixed length. This service is used for the DESTINATION audio. The VCA_SDU length matches the length of the M_PDUs of the other data formats. The DESTINATION audio consists of a 96-bit RTP header and ten 80-bit long G.729 audio frames. In order to match the length of the M_PDUs, 640-bits of fill finish the VCA_SDU. The VCA_SDU goes into the Data Zone of the VCDUs.

3.3.3.2.3.2 SECURITY HEADER

- A. The DESTINATION shall add a 64-bit security header to the VCA_SDUs for unencrypted virtual channels on the C3DL forward link with the fields listed in

Table 3.3.3.2.3.2-1, Security Header for VCA_SDUs as specified in CCSDS 355.0-B-2.

- B. The VV shall extract a 64-bit security header from before the VCA_SDUs for unencrypted virtual channels on the C3DL forward link with the fields listed in Table 3.3.3.2.3.2-1 as specified in CCSDS 355.0-B-2.

Rationale: CCSDS 355.0-B-2 specifies the security header to be used with the VCA_SDUs. The sequence number and pad length fields are not used for C3DL. The fields of the Security Header and their usage are defined in Annex A of this document. (Note: Distribution of Annex A is limited to those having a need to know.)

TABLE 3.3.3.2.3.2-1 SECURITY HEADER FOR VCA_SDUs

Security Header Field	Length In Bits
Security Parameter Index	16
Initialization Vector	48

3.3.3.2.3.3 SECURITY TRAILER

- A. The DESTINATION shall add a 96-bit security trailer to the VCA_SDUs for unencrypted virtual channels on the C3DL forward link as specified in CCSDS 355.0-B-2.
- B. The VV shall extract a 96-bit security trailer from after the VCA_SDUs for unencrypted virtual channels on the C3DL forward link as specified in CCSDS 355.0-B-2.

Rationale: CCSDS 355.0-B-2 specifies the security trailer to be used with the VCA_SDUs. The fields of the Security Trailer and their usage are defined in Annex A of this document. (Note: Distribution of Annex A is limited to those having a need to know.)

3.3.3.2.4 G.729 AUDIO FOR ENCRYPTED VIRTUAL CHANNELS

The requirements in this section are applicable to the CLDs and to VVs who are using encrypted audio.

3.3.3.2.4.1 DESTINATION AUDIO VCA_SDU FOR ENCRYPTED VIRTUAL CHANNELS

- A. The DESTINATION shall insert the DESTINATION audio for encrypted virtual channels on the C3DL forward link into a VCA_SDU with the characteristics in Table 3.3.3.2.4.1-1, C3DL Forward Link VCA_SDU Structure for Encrypted Virtual Channels as specified in CCSDS 732.0-B-4.
- B. The VV shall extract the received DESTINATION audio from encrypted virtual channels on the C3DL forward link from VCA_SDUs with the characteristics in Table 3.3.3.2.4.1-1 as specified in CCSDS 732.0-B-4.

The DESTINATION adds 640-bits of fill data to the RTP header and audio frames to generate the VCA_SDU as shown in Figure 3.3.3.2.4.1-2. The fill data contains idle

data that is all 0s. When the VV receives the VCA_SDU, it extracts the RTP header and audio by discarding the fill bits.

TABLE 3.3.3.2.4.1-1 C3DL FORWARD LINK VCA_SDU STRUCTURE FOR ENCRYPTED VIRTUAL CHANNELS

Structure	Length In Bits
RTP Header	96
G.729 Audio Frames	800
Fill	640

RTP HEADER	TEN G.729 AUDIO FRAMES										FILL
	G.729 AUDIO FRAME #1	G.729 AUDIO FRAME #2	G.729 AUDIO FRAME #3	G.729 AUDIO FRAME #4	G.729 AUDIO FRAME #5	G.729 AUDIO FRAME #6	G.729 AUDIO FRAME #7	G.729 AUDIO FRAME #8	G.729 AUDIO FRAME #9	G.729 AUDIO FRAME #10	
96 bits	80 bits	80 bits	80 bits	80 bits	80 bits	80 bits	80 bits	80 bits	80 bits	80 bits	640 bits

FIGURE 3.3.3.2.4.1-1 VCA_SDU STRUCTURE FOR ENCRYPTED AUDIO (FORWARD LINK)

Rationale: Each C3DL virtual channel can be configured to be encrypted or not encrypted. When a C3DL forward link virtual channel containing DESTINATION audio is encrypted, the requirements in this section apply. CCSDS 732.0-B-4 provides for a VCA service that uses privately formatted data of a fixed length. This service is used for the DESTINATION audio. The VCA_SDU length matches the length of the M_PDUs of the other data formats. The DESTINATION audio consists of a 96-bit RTP header and ten 80-bit long G.729 audio frames. In order to match the length of the M_PDUs, 640-bits of fill finish the VCA_SDU. The VCA_SDU goes into the Data Zone of the VCDUs.

3.3.3.2.4.2 VCA_SDU ENCRYPTION

- A. The DESTINATION shall encrypt the VCA_SDUs for virtual channels configured to be encrypted on the C3DL forward link.
- B. The VV shall decrypt the VCA_SDUs for virtual channels configured to be encrypted on the C3DL forward link.

Rationale: Each C3DL virtual channel can be configured to be encrypted or not encrypted. CCSDS 355.0-B-2 specifies that data link layer encryption is performed on VCA_SDUs.

3.3.3.2.4.3 SECURITY HEADER

- A. The DESTINATION shall add a security header to the encrypted VCA SDUs for encrypted virtual channels on the C3DL forward link with the fields listed in Table 3.3.3.2.4.3-1, Security Header for Encrypted VCA_SDUs as specified in CCSDS 355.0-B-2.

- B. The VV shall extract a security header from before the encrypted VCA_SDUs for encrypted virtual channels on the C3DL forward link with the fields listed in Table 3.3.3.2.4.3-1 as specified in CCSDS 355.0-B-2.

Rationale: CCSDS 355.0-B-2 specifies the security header to be used with the VCA_SDUs. The sequence number and pad length fields are not used for C3DL. The fields of the Security Header and their usage are defined in Annex A of this document. (Note: Distribution of Annex A is limited to those having a need to know.)

TABLE 3.3.3.2.4.3-1 SECURITY HEADER FOR ENCRYPTED VCA_SDUs

Security Header Field	Length In Bits
Security Parameter Index	16
Initialization Vector	48

3.3.3.2.4.4 SECURITY TRAILER

- A. The DESTINATION shall add a 96-bit security trailer to the encrypted VCA_SDUs for encrypted virtual channels on the C3DL forward link as specified in CCSDS 355.0-B-2.
- B. The VV shall extract a 96-bit security trailer from after the encrypted VCA_SDUs for encrypted virtual channels on the C3DL forward link as specified in CCSDS 355.0-B-2.

Rationale: CCSDS 355.0-B-2 specifies the security trailer to be used with the VCA_SDUs. The fields of the Security Trailer and their usage are defined in Annex A of this document. (Note: Distribution of Annex A is limited to those having a need to know.)

3.3.3.3 VIRTUAL CHANNEL DATA UNIT INSERT ZONE

- A. The DESTINATION shall place a Frame Count and Return Link Status Bits in the VCDU 16-bit Insert Zone for the VCDUs on the C3DL forward link as shown in Table 3.3.3.3-1, C3DL Forward Link Insert Zone.
- B. The VV shall remove the Frame Count and Return Link Status Bits from the VCDU 16-bit Insert Zone for the received VCDUs on the C3DL forward link as shown in Table 3.3.3.3-1.

Rationale: In order to provide insight into the status of the C3DL link, the DESTINATION will transmit a Frame Count and Return Link Status Bits to the VV. The VV will return the Frame Count in the C3DL return link so the DESTINATION can assess the status of the forward link. The DESTINATION can compare the received frame count with its current frame count to determine whether the VV is receiving its forward link because if the forward link is not received, the VV will transit its “stale” (old) last received frame count. The frame count needs to be long enough and update often enough that the DESTINATION can determine that the frame count it receives from the VV is stale in a reasonable amount of time. The VV can use the Return Link Status Bits to assess the

status of the return link. The Insert Zone Service allows for data to be sent in each VCDU, so it is an ideal place to put the Frame Count and Return Link Status Bits. The bit positions in the table are based on the CCSDS bit numbering convention, where bit 0 is the first bit to be transmitted and the Most Significant Bit (MSB) for a field containing a binary value, such as a counter.

TABLE 3.3.3.3-1 C3DL FORWARD LINK INSERT ZONE

Field	Value	Length	Position	Notes
C2V2 Comm Unit VV Heartbeat Status	Variable	1-bit	0	'0': stale or no return link heartbeat '1': good return link heartbeat
C2V2 Comm Unit Return Link Frame Sync Status	Variable	1-bit	1	'0': no return link frame sync '1': good return link frame sync
C2V2 Frame Counter	Variable	14-bits	2-15	

3.3.3.4 VIRTUAL CHANNEL DATA UNITS

The requirements in this Section are applicable to the CLDs and to all VV users of the C3DL System.

- A. The DESTINATION shall place the VCDU Data Zones and Insert Zones for the C3DL forward link in 1760-bit VCDUs with the characteristics in Table 3.3.3.4-1, C3DL Forward Link VCDU Structure, with the VCDU Header shown in Figure 3.3.3.4-1 and Table 3.3.3.4-2 -as specified in CCSDS 732.0-B-4.
- B. The VV shall extract the received VCDU Data Zones and Insert Zones from the C3DL forward link from the 1760-bit VCDUs with the VCDU Header shown in Figure 3.3.3.4-1 and Table 3.3.3.4-2 with the characteristics in Table 3.3.3.4-1 as specified in CCSDS 732.0-B-4.

TABLE 3.3.3.4-1 C3DL FORWARD LINK VCDU STRUCTURE

Structure	Length In Bits
VCDU Header	48
VCDU Insert Zone	16
VCDU Data Zone (M_PDU or VCA_SDU)	1696

MASTER CHANNEL ID		VIRTUAL CHANNEL ID	VIRTUAL CHANNEL FRAME COUNT	SIGNALING FIELD			
TRANSFER FRAME VERSION NUMBER	SPACECRAFT ID			REPLAY FLAG	VC FRAME COUNT USAGE FLAG	RSVD SPARE	VC FRAME COUNT CYCLE
2 bits	8 bits	6 bits	24 bits	1 bit	1 bit	2 bits	4 bits
2 octets			3 octets	1 octet			

FIGURE 3.3.3.4-1 VCDU HEADER (FORWARD LINK)

TABLE 3.3.3.4-2 VCDU HEADER FIELDS (FORWARD LINK)

Field	Value	Length	Position	Notes
Transfer Frame Version Number	Always '01'.	2-bits	0-1	Value of '01' indicates to the receiver that the space data link protocol is Advanced Orbiting Systems (AOS).
Spacecraft ID	Static	8-bits	2-9	'11000010' is the value assigned to DESTINATION #1 C3DL. (second DESTINATION will be assigned different number.) '11000011' is the value assigned to DESTINATION #2 C3DL.
Virtual Channel ID	Variable	6-bits	10-15	The following values are defined: '000001': DESTINATION commands '000010': DESTINATION audio '000011': DESTINATION Telemetry '111111': Idle Frame (CCSDS-defined)
Virtual Channel Frame Count	Variable	24-bits	16-39	This field increments by one with each frame transmitted on a Virtual Channel. This field is zero for an Idle VCDU.
Replay Flag	Always '0'.	1-bit	40	Value of '0' indicates to the receiver that the data stream is "real-time" and not recorded playback data.
Virtual Channel Frame Count Usage Flag	Always '0'.	1-bit	41	Value of '0' indicates that the Virtual Channel Frame Count Cycle field is not used.
Reserved Spare	Always '00'.	2-bits	42-43	Unused.
Virtual Channel Frame Count Cycle	Always '0000'.	4-bits	44-47	Virtual Channel Frame Count field is not used.

Rationale: CCSDS 732.0-B-4 provides the VCDU Transfer Frame structure in Section 4.1.1.1. The VCDU header is mandatory and must be 48- or 64-bits long, the Insert Zone is optional, and the VCDU Data Zone is mandatory and must be an integer number of octets, where an octet is eight-bits long. For C3DL, the VCDU header is 48-bits long and does not include the optional frame header error control bits, the VCDU

Insert Zone contains a Frame Count and Return Link Status Bits, and the VCDU Data Zone contains one of the following: an M_PDU, an encrypted M_PDU, a VCA_SDU, or an encrypted VCA_SDU, each with a Security Header and Trailer.

3.3.3.5 VIRTUAL CHANNEL MULTIPLEXING

The requirements in this section are applicable to the CLDs and to all VV users of the C3DL System.

- A. The DESTINATION shall multiplex the VCDUs for the C3DL forward link.
- B. The VV shall demultiplex the received VCDUs from the C3DL forward link using the VCID in the VCDU header.
- C. The DESTINATION shall create Idle VCDUs for the C3DL forward link when no data is available as described in CCSDS 732.0-B-4.
- D. The VV shall remove the received Idle VCDUs from the C3DL forward link as described in CCSDS 732.0-B-4.

Rationale: Each Virtual Channel is processed differently depending upon whether it contains CCSDS Space Packets, Encrypted CCSDS Space Packets, VCA audio, or Encrypted VCA audio. Once the different types of data are in VCDUs, they can be multiplexed together. The VV uses the VCID to demultiplex the Virtual Channels from the VCDUs.

The radio frequency link continuously sends data. When there is no data to send, CCSDS 732.0-B-4 4.2.5.4 specifies that the Virtual Channel Multiplexing Function send an Idle VCDU instead. CCSDS 732.0-B-4 4.3.5.3 specifies that the Virtual Channel Demultiplexer Function can discard Idle VCDUs. CCSDS 732.0-B-4 4.1.4.1.5 describes the Idle VCDU and calls for a project-specified idle pattern.

3.3.3.6 REED SOLOMON CODING

The requirements in this section are applicable to the CLDs and to all VV users of the C3DL System.

- A. The DESTINATION shall encode the VCDUs for the C3DL forward link using a (252, 220) shortened Reed Solomon Code with an interleave depth of 1 as specified in CCSDS 131.0-B-5, Telemetry Synchronization and Channel Coding.
- B. The VV shall decode the received VCDUs from the C3DL forward link using a (252, 220) shortened Reed Solomon Code with an interleave depth of 1 (no interleaving will be used) as specified in CCSDS 131.0-B-5.

Rationale: CCSDS 131.0-B-5 recommends use of Reed Solomon coding to correct errors, particularly burst errors. The shortened code length and interleave depth of 1 were chosen to allow shorter packets.

3.3.3.7 RANDOMIZATION

The requirements in this section are applicable to the CLDs and to all VV users of the C3DL System.

- A. The DESTINATION shall randomize the coded VCDUs for the C3DL forward link using a 256-bit pseudo-random sequence as specified in CCSDS 131.0-B-5.
- B. The VV shall derandomize the received coded VCDUs from the C3DL forward link using a 256-bit pseudo-random sequence as specified in CCSDS 131.0-B-5.

Rationale: CCSDS 131.0-B-5 recommends use of randomization to ensure sufficient bit transition density to maintain bit and symbol sync. CCSDS 131.0-B-5, Section 10.4.2 specifies the following 256-bit pseudo-random sequence:

$$h(x) = x^8 + x^7 + x^5 + x^3 + 1$$

3.3.3.8 ATTACHED SYNC MARKER

The requirements in this section are applicable to the CLDs and to all VV users of the C3DL System.

- A. The DESTINATION shall apply the 32-bit ASM to the encoded, randomized VCDUs for the C3DL forward link as specified in CCSDS 131.0-B-5 (hexadecimal: 1ACFFC1D).
- B. The VV shall synchronize the received VCDUs from the C3DL forward link using the C3DL forward link 32-bit ASM as specified in CCSDS 131.0-B-5.
- C. The VV shall use the 32-bit ASM to resolve the input data phase ambiguity.

Rationale: CCSDS 131.0-B-5 recommends use of a 32-bit ASM to synchronize frames. Common baseband waveforms are Nonreturn-to-Zero Level (NRZ-L) and Nonreturn-to-Zero Mark (NRZ-M), where NRZ-L gives better energy per bit to noise power spectral density ratio (E_b/N_0) performance, but NRZ-M differential encoding provides phase ambiguity resolution. C3DL will use the ASM to resolve the input data phase ambiguity so that NRZ-L can be used and the degradation incurred with NRZ-M can be avoided.

3.3.3.9 CADU FRAME LENGTH

The requirements in this section are applicable to the CLDs and to all VV users of the C3DL System.

- A. The DESTINATION shall use 2048-bit CADUs for the C3DL forward link with the characteristics in Table 3.3.3.9-1, C3DL Forward Link CADU Structure.
- B. The VV shall use 2048-bit CADUs for the C3DL forward link with the characteristics in Table 3.3.3.9-1.

TABLE 3.3.3.9-1 C3DL FORWARD LINK CADU STRUCTURE

Structure	Length In Bits
ASM	32
VCDU	1760
Reed Solomon Check Symbols	256
Total CADU	2048

Rationale: CCSDS 131.0-B-5 states that the Transfer Frame length must be fixed for each physical channel and mission phase. The CADU length depends upon the length of the ASM and the presence of Reed Solomon coding. Since the use of coding, the coding parameters, and the ASM length are managed parameters (must be separately configured by both sides of a link), they are expected to change infrequently and only with major reconfigurations.

3.3.3.10 CONVOLUTIONAL CODING

The requirements in this Section are applicable to the CLDs and to all VV users of the C3DL System.

- A. The DESTINATION shall encode the CADUs for the C3DL forward link using a rate 1/2 constraint length $K=7$ convolutional code ("Basic Convolutional Encoder") as specified in CCSDS 131.0-B-5.
- B. The VV shall decode the received CADUs from the C3DL forward link using a rate 1/2 constraint length $K=7$ convolutional code ("Basic Convolutional Encoder") as specified in CCSDS 131.0-B-5.

Rationale: CCSDS 131.0-B-5 recommends use of a rate 1/2 constraint length 7 convolutional code if additional error correction is needed for a link.

3.3.3.11 BASEBAND WAVEFORM

The requirements in this Section are applicable to the CLDs and to all VV users of the C3DL System.

- A. The DESTINATION shall transmit an NRZ-L baseband waveform for the C3DL forward link.
- B. The VV shall receive an NRZ-L baseband waveform for the C3DL forward link.

Rationale: Common baseband waveforms are NRZ-L and NRZ-M, where NRZ-L gives better E_b/N_0 performance, but NRZ-M differential encoding provides phase ambiguity resolution. Since phase ambiguity resolution can also be provided by the ASM per CCSDS 131.0-B-5, Section 2.2.4, NRZ-L was selected for its better performance.

3.3.3.12 LATENCY

The requirements in this Section are applicable to the CLDs and to all VV users of the C3DL System.

- A. The DESTINATION shall introduce less than 500 ms of latency for the C3DL forward link from the time the last bit of a data unit enters the DESTINATION to the time the first bit of the CADU containing that data unit is transmitted.
- B. The VV shall introduce less than 749 ms of latency for the C3DL forward link from the time the last bit of a CADU is received to the time the first bit of the first data unit that ends in the CADU is extracted from its CCSDS space packet or VCA_SDU.

Rationale: Request for Comment (RFC) 1242, Benchmarking Terminology for Network Interconnection Devices, defines the latency for a store-and-forward device as: The time interval starting when the last bit of the input frame reaches the input port and ending when the first bit of the output frame is seen on the output port. The last bit of the input frame can be the end of a DESTINATION command packet over the 1553 bus, the end of a DESTINATION telemetry packet over the 1553 bus, or the end of the tenth G.729 audio packet. The first bit of the output frame is the first bit of the CADU. The end-to-end latency can be allocated to the DESTINATION latency, the light speed delay, the time to send one CADU at the minimum symbol rate, and the VV latency. At the maximum range of 30 km, the light speed delay is 0.1 ms. The maximum time to send a CADU at 36 ksps is 114 ms. 500 ms of latency is allocated to the transmitter, and 749 ms is allocated to the receiver, because it takes more time to process the received data stream than to generate it. These values produce a total maximum latency of less than 1.4 sec.

3.4 VV TO DESTINATION C3DL RETURN LINK REQUIREMENTS

3.4.1 SPECTRUM REQUIREMENTS

The requirements in this Section are applicable to the CLDs and to all VV users of the C3DL System. Each DESTINATION will be assigned a C3DL forward and return link frequency pair and so will have one applicable frequency. The frequencies applicable to a VV are those for the CLDs with which it performs RPODU.

3.4.1.1 FREQUENCY

- A. The VV shall transmit the C3DL return link at an assigned center frequency in the 415 Mega Hertz (MHz) to 420 MHz band +/- 3 parts per million (ppm).
- B. The DESTINATION shall receive the return link at the assigned center frequency +/- 3 ppm.

Rationale: The return C3DL UHF Return Link Frequencies have been chosen for the DESTINATION Program based on reasonable spectrum availability, cost, and risk.

3.4.1.2 BANDWIDTH

- A. The VV shall transmit the C3DL return link signal for the 72 ksps symbol rate with a bandwidth less than or equal to 46 kHz **<TBR 3-6>** edge to edge.
- B. The VV shall transmit the C3DL return link signal for the 144 ksps symbol rate with a bandwidth less than or equal to 92 kHz **<TBR 3-7>** edge to edge.

Rationale: The signal bandwidth is defined as the width of a frequency band that contains 99 percent of the total mean power of a given emission (See approved spectrum filing for details).

3.4.2 RADIO FREQUENCY REQUIREMENTS

3.4.2.1 SYMBOL RATE

The C3DL provides two selectable symbol rates; the VV may select which symbol rate(s) to utilize and verify, as indicated in the specific DESTINATION to specific VV ICD. All requirements in this Section are applicable to the CLD.

- A. The VV shall transmit the C3DL return link symbol rates listed in Table 3.4.2.1-1, C3DL Return Link Symbol Rates.
- B. The DESTINATION shall receive the C3DL return link symbol rates listed in Table 3.4.2.1-1.

TABLE 3.4.2.1-1 C3DL RETURN LINK SYMBOL RATES

Link	Rate
Low Symbol Rate	72 ksps +/- 0.1%
Medium Symbol Rate	144 ksps +/- 0.1%

Rationale: The C3DL interface can be moded to support different symbol rates at different ranges. For clarity and verification purposes, the rates are defined as symbol rates at the input to the modulator as shown in Figure 3.4.2.1-1, C3DL Return Link Symbol Definition.

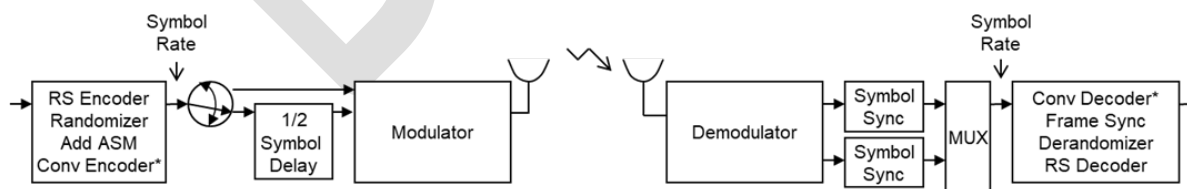


FIGURE 3.4.2.1-1 C3DL RETURN LINK SYMBOL DEFINITION

The VVs will be capable of transmitting and the CLDs will be capable of receiving the data types listed in Table 3.4.2.1-2, C3DL Return Link Data Types by Symbol Rates, when using the corresponding symbol rates.

TABLE 3.4.2.1-2 C3DL RETURN LINK DATA TYPES BY SYMBOL RATES

Link	Data Types
Low Symbol Rate (72 ksps)	VV Commands VV Telemetry
Medium Symbol Rate (144 ksps)	VV Commands VV Telemetry VV Audio

3.4.2.2 MODULATION

All requirements in this section are applicable to the CLDs and to all VV users of the C3DL System.

- A. The VV shall transmit the C3DL return link using Filtered OQPSK modulation with the characteristics listed in Table 3.4.2.2-1, C3DL Return Link Filtered OQPSK Parameters.
- B. The DESTINATION shall receive the Filtered OQPSK modulated C3DL return link with the characteristics listed in Table 3.4.2.2-1.

TABLE 3.4.2.2-1 C3DL RETURN LINK FILTERED OQPSK PARAMETERS

Parameter	Value	Tolerance
QPSK Symbol Mapping	See Figure 2.4.10-2, Constellation Mapping on Page 2.4.10-2 of CCSDS 401-0-B-30	
Q sinusoid phase relative to I sinusoid	90-degree delay (at RF, e.g. after the last upconverter and before the first downconverter)	+/- 3 degrees
Q data delay relative to I data (OKPSK)	½ symbol	+/- 3%
I:Q power ratio	1:1	+/-0.4 dB
Filter Type	SRRC Filter ($\alpha = 0.5$)	

Rationale: Space systems typically use OQPSK modulation because it is more spectrally efficient than BPSK without costing additional power. Filtered OQPSK is more spectrally efficient than OQPSK.

3.4.2.3 POLARIZATION

The requirements in this Section are applicable to the CLDs and to all VV users of the C3DL System.

- A. The VV shall transmit the C3DL return link using RHCP.
- B. The DESTINATION shall receive the C3DL return link using RHCP.

Rationale: Space systems typically use circular polarization to avoid the large mismatches possible with linear polarization.

3.4.2.4 MINIMUM POWER AT CLD

The VV shall produce an RF signal with a received power at an isotropic antenna at the DESTINATION antenna locations no less than the values in Table 3.4.2.4-1, VV Signal Prec at CLD, for the C3DL return link.

Rationale: This requirement allows the VVs to reduce their power as their range to a DESTINATION decreases. The C3DL link margin analysis shows that the specified received power is sufficient to provide the desired CWER and margin for the applicable symbol rates at the desired ranges.

TABLE 3.4.2.4-1 VV SIGNAL PREC AT CLD

Range/Symbol Rate	LDR	MDR
30 km $\geq$ range > 10 km <TBR 3-8>	<TBD 3-8> dBWi	<TBD 3-9> dBWi
10 km <TBR 3-9> $\geq$ range	<TBD 3-10> dBWi	<TBD 3-11> dBWi

3.4.2.5 TRANSMIT SIGNAL PARAMETERS

The requirement in this section is applicable to all VV users of the C3DL System. The CLDs must function with distortion on the return link from the VVs.

The VVs shall transmit a signal with an EVM no greater than 10 percent.

Rationale: The EVM is a measure of the difference between the reference waveform and the measured waveform. This difference is called the error vector. In order to achieve the desired SER and margin, the transmit signal must meet certain parameters so the receiver can process it.

3.4.2.6 CODE WORD ERROR RATE

The requirements in this section are applicable to the CLDs.

The DESTINATION shall provide a CWER no greater than 4×10^{-7} when VV meets its EVM and provides a received power at a 0 dB gain (isotropic) DESTINATION antenna no less than the values in Table 3.4.2.6-1, DESTINATION Prec for DESTINATION CWER.

TABLE 3.4.2.6-1 DESTINATION PREC FOR DESTINATION CWER

Symbol Rate	Prec (dBW)
72 ksps	<TBD 3-12>
144 ksps	<TBD 3-13>

Rationale: The CWER is the rate that Reed Solomon codewords are discarded due to Reed Solomon decoder failures. The DESTINATION is only required to provide the specified CWER when the VV provides the specified Prec.

3.4.3 BASEBAND REQUIREMENTS

3.4.3.1 VIRTUAL CHANNEL DATA

3.4.3.1.1 VV COMMANDS

The requirements in this section are applicable to VVs that transmit VV Commands via the C3DL return link.

- A. The VV shall insert the VV commands for the C3DL return link into CCSDS Space Packets with the characteristics in Table 3.4.3.1.1-1, as specified in CCSDS 133.0-B-2, Space Packet Protocol.
- B. The DESTINATION shall extract the received commands from the C3DL return link from CCSDS Space Packets with the characteristics in Table 3.4.3.1.1-1, C3DL CCSDS Space Packet Structure, as specified in CCSDS 133.0-B-2.

TABLE 3.4.3.1.1-1 C3DL CCSDS SPACE PACKET STRUCTURE

Structure	Length In Bits
Packet Primary Header	48
User Data Field	variable

Rationale: All of the C3DL data, except for audio, is placed into CCSDS space packets. CCSDS space packets are defined in CCSDS 133.0-B-2, and they consist of a packet primary header, a variable packet secondary header, and a variable user data field. The C3DL packets will not use a packet secondary header to minimize overhead.

The content of the VV commands will be controlled in the specific DESTINATION to specific VV ICD.

3.4.3.1.2 VV TELEMETRY

The requirements in this section are applicable to the CLDs and to VVs that transmit VV Telemetry to the DESTINATION via the C3DL.

- A. The VV shall insert the VV Telemetry for the C3DL return link into CCSDS space packets with the characteristics in Table 3.3.3.1.1-1 as specified in CCSDS 133.0-B-2.
- B. The DESTINATION shall extract the received VV Telemetry from the C3DL return link from CCSDS Space Packets with the characteristics in Table 3.3.3.1.1-1 as specified in CCSDS 133.0-B-2.

Rationale: All of the C3DL data, except for audio, is placed into CCSDS space packets. CCSDS space packets are defined in CCSDS 133.0-B-2, and they consist of a packet primary header, a variable packet secondary header, and a variable user data field. The C3DL packets will not use a packet secondary header to minimize overhead.

The content of the VV telemetry will be controlled in the specific DESTINATION to specific VV ICD.

3.4.3.1.3 VV AUDIO

The requirements in this Section are applicable to the CLDs and to VVs that support a voice link to DESTINATION via the C3DL System.

- A. The VV shall send VV audio consisting of a 96-bit RTP header in accordance with IETF RFC 3550 and IETF RFC 3551 and ten 80-bit 10 ms G.729 audio frames in accordance with ITU-T G.729 on the C3DL return link to the CLD.
- B. The DESTINATION shall receive VV audio consisting of a 96-bit RTP header in accordance with IETF RFC 3550 and IETF RFC 3551 and ten 80-bit 10 ms G.729 audio frames in accordance with ITU-T G.729 on the C3DL return link.

Rationale: ITU-T G.729, Sections 2, 3, and 4 define a standard for how audio is encoded and decoded. IETF RFC 3550 specifies a network transport function for real-time audio, and IETF 3551 specifies a profile for use of RTP for audio and video multiparticipant conferences with minimal control.

3.4.3.2 VIRTUAL CHANNEL PACKAGING

3.4.3.2.1 CCSDS SPACE PACKETS FOR UNENCRYPTED VIRTUAL CHANNELS

The requirements in this section are applicable to the CLDs and to VV users that transmit any of the following data types to CLD: unencrypted VV Commands and unencrypted VV Telemetry.

3.4.3.2.1.1 CCSDS SPACE PACKETS MULTIPLEXING PROTOCOL DATA UNITS FOR UNENCRYPTED VIRTUAL CHANNELS

- A. The VV shall insert the CCSDS Space Packets for unencrypted virtual channels on the C3DL return link into M_PDUs with the characteristics in Table 3.4.3.2.1.1-1, C3DL Return Link M_PDU Structure for Unencrypted Virtual Channels as specified in CCSDS 732.0-B-4.
- B. The DESTINATION shall extract the received CCSDS Space Packets from unencrypted virtual channels on the C3DL return link from the M_PDUs with the characteristics in Table 3.4.3.2.1.1-1 as specified in CCSDS 732.0-B-4.
- C. The VV shall generate an Idle Space Packet as specified in CCSDS 732.0-B-4 and CCSDS 133.0-B-2 when insufficient CCSDS Space Packets are available to fill the M_PDU Packet Zone for unencrypted virtual channels on the C3DL return link.
- D. The DESTINATION shall remove Idle Space Packets as specified in CCSDS 732.0-B-24 from the received M_PDUs for unencrypted virtual channels on the C3DL return link.

TABLE 3.4.3.2.1.1-1 C3DL RETURN LINK M_PDU STRUCTURE FOR UNENCRYPTED VIRTUAL CHANNELS

Structure	Length In Bits
M_PDU Header	16
M_PDU Packet Zone	1520

Rationale: Each C3DL virtual channel can be configured to be encrypted or not encrypted. When a C3DL return link virtual channel containing CCSDS space packets is not encrypted, the requirements in this section apply. CCSDS 732.0-B-4 provides the M_PDU structure in Section 4.1.4.2. The M_PDU header is mandatory and must be 16-bits long, and the M_PDU Packet Zone is mandatory and must be an integer number of octets, where an octet is eight-bits long. Each M_PDU can only contain data for one Virtual Channel. The M_PDU goes into the Data Zone of the VCDUs.

When insufficient CCSDS Space Packets are available, the remaining space in the M_PDU Packet Zone can be filled with an Idle CCSDS Space Packet so that the CCSDS Space Packets that are available will not be delayed. CCSDS 732.0-B-4 4.2.2.5 says that the Packet Processing Function can generate an Idle Packet of appropriate length to fill in the M_PDU. CCSDS 732.0-B-4 4.3.2.5 says that the Packet Extraction Function can discard Idle Packets. Idle CCSDS Space Packets are described in CCSDS 133.0-B-2, but the idle pattern is left for the project to specify.

When no user data is available, CCSDS 732.0-B-4 4.2.2.6 specifies that the Packet Processing Function may generate an Idle M_PDU with fill data in the Packet Zone. CCSDS 732.0-B-4 4.3.2.5 says that the Packet Extraction Function can discard an Idle M_PDU. CCSDS 732.0-B-4, Section 4.1.4.2.4.4 describes the Idle M_PDU and Section 4.1.4.2.4.2 calls for a fixed-length project-specified idle pattern.

3.4.3.2.1.2 SECURITY HEADER

- A. The VV shall add a 64-bit security header to the M_PDUs for unencrypted virtual channels on the C3DL return link with the fields listed in Table 3.4.3.2.1.2-1, Security Header for M_PDUs as specified in CCSDS 355.0-B-2.
- B. The DESTINATION shall extract a 64-bit security header from before the M_PDUs for unencrypted virtual channels on the C3DL return link with the fields listed in Table 3.4.3.2.1.2-1 as specified in CCSDS 355.0-B-2.

Rationale: CCSDS 355.0-B-2 specifies the security header to be used with the M_PDUs. The sequence number and pad length fields are not used for C3DL. The fields of the Security Header and their usage are defined in Annex A of this document. (Note: Distribution of Annex A is limited to those having a need to know.)

TABLE 3.4.3.2.1.2-1 SECURITY HEADER FOR M_PDUs

Security Header Field	Length In Bits
Security Parameter Index	16
Initialization Vector	48

3.4.3.2.1.3 SECURITY TRAILER

- A. The VV shall add a 96-bit security trailer to the M_PDUs for unencrypted virtual channels on the C3DL return link as specified in CCSDS 355.0-B-2.
- B. The DESTINATION shall extract a 96-bit security trailer from after the M_PDUs for unencrypted virtual channels on the C3DL return link as specified in CCSDS 355.0-B-2.

Rationale: CCSDS 355.0-B-2 specifies the security trailer to be used with the M_PDUs. The fields of the Security Trailer and their usage are defined in Annex A of this document. (Note: Distribution of Annex A is limited to those having a need to know.)

3.4.3.2.2 CCSDS SPACE PACKETS FOR ENCRYPTED VIRTUAL CHANNELS

The requirements in this section are applicable to the CLDs and to VV users that encrypt any of the following data types: encrypted VV Commands and encrypted VV Telemetry.

3.4.3.2.2.1 CCSDS SPACE PACKETS MULTIPLEXING PROTOCOL DATA UNITS FOR ENCRYPTED VIRTUAL CHANNELS

- A. The VV shall insert the CCSDS Space Packets for encrypted virtual channels on the C3DL return link into M_PDUs with the characteristics in Table 3.4.3.2.2.1-1, C3DL Return Link M_PDU Structure for Encrypted Virtual Channels as specified in CCSDS 732.0-B-4.
- B. The DESTINATION shall extract the received CCSDS Space packets from encrypted virtual channels on the C3DL return link from the M_PDUs with the characteristics in Table 3.4.3.2.2.1-1 as specified in CCSDS 732.0-B-4.

TABLE 3.4.3.2.2.1-1 C3DL RETURN LINK M_PDU STRUCTURE FOR ENCRYPTED VIRTUAL CHANNELS

Structure	Length In Bits
M_PDU Header	16
M PDU Packet Zone	1520

- C. The VV shall generate an Idle Space Packet as specified in CCSDS 732.0-B-4 and CCSDS 133.0-B-2 when insufficient CCSDS Space Packets are available to fill the M_PDU Packet Zone for encrypted virtual channels on the C3DL return link.

- D. The DESTINATION shall remove Idle Space Packets as specified in CCSDS 732.0-B-4 from the received M_PDUs for encrypted virtual channels on the C3DL return link.
- E. The VV shall generate an Idle M_PDU as specified in CCSDS 732.0-B-4 when no CCSDS Space Packets are available for encrypted virtual channels on the C3DL return link.
- F. The DESTINATION shall remove Idle M_PDUs as specified in CCSDS 732.0-B-4 from the received M_PDUs from encrypted virtual channels on the C3DL return link.

Rationale: Each C3DL virtual channel can be configured to be encrypted or not encrypted. When a C3DL return link virtual channel containing CCSDS space packets is encrypted, the requirements in this section apply. CCSDS 732.0-B-4 provides the M_PDU structure in Section 4.1.4.2. The M_PDU header is mandatory and must be 16-bits long, and the M_PDU packet zone is mandatory and must be an integer number of octets, where an octet is eight-bits long. Each M_PDU can only contain data for one virtual channel. The M_PDU goes into the Data Zone of the Virtual Channel Data Units.

When insufficient CCSDS Space Packets are available, the remaining space in the M_PDU Packet Zone can be filled with an Idle CCSDS Space Packet so that the CCSDS Space Packets that are available will not be delayed. CCSDS 732.0-B-4 4.2.2.5 says that the Packet Processing Function can generate an Idle Packet of appropriate length to fill in the M_PDU. CCSDS 732.0-B-4 4.3.2.5 says that the Packet Extraction Function can discard Idle Packets. Idle CCSDS Space Packets are described in CCSDS 133.0-B-2, but the idle pattern is left for the project to specify.

When no user data is available, CCSDS 732.0-B-4 4.2.2.6 specifies that the Packet Processing Function may generate an Idle M_PDU with fill data in the Packet Zone. CCSDS 732.0-B-4 4.3.2.5 says that the Packet Extraction Function can discard an Idle M_PDU. CCSDS 732.0-B-4, Section 4.1.4.2.4.4 describes the Idle M_PDU and Section 4.1.4.2.4.2 calls for a fixed-length project-specified idle pattern.

3.4.3.2.2.2 MULTIPLEXING PROTOCOL DATA UNIT ENCRYPTION

- A. The VV shall encrypt the Multiplexing Protocol Data Units for virtual channels configured to be encrypted on the C3DL return link.
- B. The DESTINATION shall decrypt the Multiplexing Protocol Data Units for virtual channels configured to be encrypted on the C3DL return link.

Rationale: Each C3DL virtual channel can be configured to be encrypted or not encrypted. CCSDS 355.0-B-2 specifies that data link layer encryption is performed on M_PDUs.

3.4.3.2.2.3 SECURITY HEADER

- A. The VV shall add a 64-bit security header to the encrypted M_PDUs for encrypted virtual channels on the C3DL return link with the fields listed in Table 3.4.3.2.2.3-1, Security Header for Encrypted M_PDUs as specified in CCSDS 355.0-B-2.
- B. The DESTINATION shall extract a 64-bit security header from before the encrypted M_PDUs for encrypted virtual channels on the C3DL return link with the fields listed in Table 3.4.3.2.2.3-1 as specified in CCSDS 355.0-B-2.

Rationale: CCSDS 355.0-B-2 specifies the security header to be used with the M_PDUs. The sequence number and pad length fields are not used for C3DL. The fields of the Security Header and their usage are defined in Annex A of this document. (Note: Distribution of Annex A is limited to those having a need to know.)

TABLE 3.4.3.2.2.3-1 SECURITY HEADER FOR ENCRYPTED M_PDUs

Security Header Field	Length In Bits
Security Parameter Index	16
Initialization Vector	48

3.4.3.2.2.4 SECURITY TRAILER

- A. The VV shall add a 96-bit security trailer to the encrypted M_PDUs for encrypted virtual channels on the C3DL return link as specified in CCSDS 355.0-B-2.
- B. The DESTINATION shall extract a 96-bit security trailer from after the encrypted M_PDUs for encrypted virtual channels on the C3DL return link as specified in CCSDS 355.0-B-2.

Rationale: CCSDS 355.0-B-2 specifies the security trailer to be used with the M_PDUs. The fields of the Security Trailer and their usage are defined in Annex A of this document. (Note: Distribution of Annex A is limited to those having a need to know.)

3.4.3.2.3 G.729 AUDIO FOR UNENCRYPTED VIRTUAL CHANNELS

The requirements in this Section are applicable to the CLDs and to VV users that support unencrypted audio to CLDs via the C3DL System.

3.4.3.2.3.1 VV AUDIO VCA_SDU FOR UNENCRYPTED VIRTUAL CHANNELS

- A. The VV shall insert the VV audio and fill for unencrypted virtual channels on the C3DL return link into a VCA_SDU with the characteristics in Table 3.4.3.2.3.1-1, C3DL Return Link VCA_SDU Structure for Unencrypted Virtual Channels as specified in CCSDS 732.0-B-4.
- B. The DESTINATION shall extract the received VV audio from unencrypted virtual channels on the C3DL return link from the VCA_SDUs with the characteristics in Table 3.4.3.2.3.1-1 as specified in CCSDS 732.0-B-4.

TABLE 3.4.3.2.3.1-1 C3DL RETURN LINK VCA_SDU STRUCTURE FOR UNENCRYPTED VIRTUAL CHANNELS

Structure	Length In Bits
RTP Header	96
G.729 Audio Frames	800
Fill	640

RTP HEADER	TEN G.729 AUDIO FRAMES										FILL
	G.729 AUDIO FRAME #1	G.729 AUDIO FRAME #2	G.729 AUDIO FRAME #3	G.729 AUDIO FRAME #4	G.729 AUDIO FRAME #5	G.729 AUDIO FRAME #6	G.729 AUDIO FRAME #7	G.729 AUDIO FRAME #8	G.729 AUDIO FRAME #9	G.729 AUDIO FRAME #10	
96 bits	80 bits	80 bits	80 bits	80 bits	80 bits	80 bits	80 bits	80 bits	80 bits	80 bits	640 bits

FIGURE 3.4.3.2.3.1-1 VCA_SDU STRUCTURE FOR UNENCRYPTED AUDIO (RETURN LINK)

Rationale: Each C3DL virtual channel can be configured to be encrypted or not encrypted. When a C3DL return link virtual channel containing VV audio is not encrypted, the requirements in this Section apply. CCSDS 732.0-B-4 provides for a VCA service that uses privately formatted data of a fixed length. This service is used for the VV audio. The VCA_SDU length matches the length of the M_PDUs of the other data formats. The VV audio consists of a 96-bit RTP header and ten 80-bit long G.729 audio frames. In order to match the length of the M_PDUs, 640-bits of fill finish the VCA_SDU. The VCA_SDU goes into the Data Zone of the VCDUs.

3.4.3.2.3.2 SECURITY HEADING

- A. The VV shall add a 64-bit security header to the VCA_SDUs for unencrypted virtual channels on the C3DL return link with the fields listed in Table 3.4.3.2.3.2-1, Security Header for VCA_SDUs as specified in CCSDS 355.0-B-2.
- B. The DESTINATION shall extract a 64-bit security header from before the VCA_SDUs for unencrypted virtual channels on the C3DL return link with the fields listed in Table 3.4.3.2.3.2-1 as specified in CCSDS 355.0-B-2.

Rationale: CCSDS 355.0-B-2 specifies the security header to be used with the VCA_SDUs. The sequence number and pad length fields are not used for C3DL. The fields of the Security Header and their usage are defined in Annex A of this document. (Note: Distribution of Annex A is limited to those having a need to know.)

TABLE 3.4.3.2.3.2-1 SECURITY HEADER FOR VCA_SDUs

Security Header Field	Length In Bits
Security Parameter Index	16
Initialization Vector	48

3.4.3.2.3.3 SECURITY TRAILER

- A. The VV shall add a 96-bit security trailer to the VCA_SDUs for unencrypted virtual channels on the C3DL return link as specified in CCSDS 355.0-B-2.
- B. The DESTINATION shall extract a 96-bit security trailer from after the VCA_SDUs for unencrypted virtual channels on the C3DL return link as specified in CCSDS 355.0-B-2.

Rationale: CCSDS 355.0-B-2 specifies the security trailer to be used with the VCA_SDUs. The fields of the Security Trailer and their usage are defined in Annex A of this document. (Note: Distribution of Annex A is limited to those having a need to know.)

3.4.3.2.4 G.729 AUDIO FOR ENCRYPTED VIRTUAL CHANNELS

The requirements in this Section are applicable to the CLDs and to VV users that support encrypted audio to CLDs via the C3DL System.

3.4.3.2.4.1 VV AUDIO VCA_SDU FOR ENCRYPTED VIRTUAL CHANNELS

- A. The VV shall insert the VV audio for encrypted virtual channels on the C3DL return link into a VCA_SDU with the characteristics in Table 3.4.3.2.4.1-1, C3DL Return Link VCA_SDU Structure for Encrypted Virtual Channels as specified in CCSDS 732.0-B-4.
- B. The DESTINATION shall extract the received VV audio from encrypted virtual channels on the C3DL return link from the VCA_SDUs with the characteristics in Table 3.4.3.2.4.1-1 as specified in CCSDS 732.0-B-4.

TABLE 3.4.3.2.4.1-1 C3DL RETURN LINK VCA_SDU STRUCTURE FOR ENCRYPTED VIRTUAL CHANNELS

Structure	Length In Bits
RTP Header	96
G.729 Audio Frames	800
Fill	640

RTP HEADER	TEN G.729 AUDIO FRAMES										FILL
	G.729 AUDIO FRAME #1	G.729 AUDIO FRAME #2	G.729 AUDIO FRAME #3	G.729 AUDIO FRAME #4	G.729 AUDIO FRAME #5	G.729 AUDIO FRAME #6	G.729 AUDIO FRAME #7	G.729 AUDIO FRAME #8	G.729 AUDIO FRAME #9	G.729 AUDIO FRAME #10	
96 bits	80 bits	80 bits	80 bits	80 bits	80 bits	80 bits	80 bits	80 bits	80 bits	80 bits	640 bits

FIGURE 3.4.3.2.4.1-1 VCA_SDU STRUCTURE FOR ENCRYPTED AUDIO (RETURN LINK)

Rationale: Each C3DL virtual channel can be configured to be encrypted or not encrypted. When a C3DL return link virtual channel containing VV audio is encrypted,

the requirements in this section apply. CCSDS 732.0-B-4 provides for a VCA service that uses privately formatted data of a fixed length. This service is used for the VV audio. The VCA_SDU length matches the length of the M_PDUs of the other data formats. The VV audio consists of a 96-bit RTP header and ten 80-bit long G.729 audio frames. In order to match the length of the M_PDUs, 640-bits of fill finish the VCA_SDU. The VCA_SDU goes into the Data Zone of the VCDUs.

3.4.3.2.4.2 VCA_SDU ENCRYPTION

- A. The VV shall encrypt the VCA_SDUs for virtual channels configured to be encrypted on the C3DL return link.
- B. The DESTINATION shall decrypt the VCA_SDUs for virtual channels configured to be encrypted on the C3DL return link.

Rationale: Each C3DL virtual channel can be configured to be encrypted or not encrypted. CCSDS 355.0-B-2 specifies that data link layer encryption is performed on VCA_SDUs.

3.4.3.2.4.3 SECURITY HEADER

- A. The VV shall add a security header to the encrypted VCA_SDUs for encrypted virtual channels on the C3DL return link with the fields listed in Table 3.4.3.2.4.3-1, Security Header for Encrypted VCA_SDUs as specified in CCSDS 355.0-B-2.
- B. The DESTINATION shall extract a security header from before the encrypted VCA_SDUs for encrypted virtual channels on the C3DL return link with the fields listed in Table 3.4.3.2.4.3-1 as specified in CCSDS 355.0-B-2.

Rationale: CCSDS 355.0-B-2 specifies the security header to be used with the VCA_SDUs. The sequence number and pad length fields are not used for C3DL. The fields of the Security Header and their usage are defined in Annex A of this document. (Note: Distribution of Annex A is limited to those having a need to know.)

TABLE 3.4.3.2.4.3-1 SECURITY HEADER FOR ENCRYPTED VCA_SDUs

Security Header Field	Length In Bits
Security Parameter Index	16
Initialization Vector	48

3.4.3.2.4.4 SECURITY TRAILER

- A. The VV shall add a 96-bit security trailer to the encrypted VCA_SDUs for encrypted virtual channels on the C3DL return link as specified in CCSDS 355.0-B-2.
- B. The DESTINATION shall extract a 96-bit security trailer from after the encrypted VCA_SDUs for encrypted virtual channels on the C3DL return link as specified in CCSDS 355.0-B-2.

Rationale: CCSDS 355.0-B-2 specifies the security trailer to be used with the VCA_SDUs. The fields of the Security Trailer and their usage are defined in Annex A of this document. (Note: Distribution of Annex A is limited to those having a need to know.)

3.4.3.3 VIRTUAL CHANNEL DATA UNIT INSERT ZONE

- A. The VV shall place the latest Frame Count received from the C3DL forward link in the VCDU 16 bit Insert Zone for the VCDUs on the C3DL return link as shown in Table 3.4.3.3-1, C3DL Return Link Insert Zone.
- B. The DESTINATION shall extract the Frame Count from the VCDU 16 bit Insert Zone for the received VCDUs on the C3DL return link as shown in Table 3.4.3.3-1.

Rationale: In order to provide insight into the status of the C3DL link, the DESTINATION will transmit a Frame Count and Return Link Status Bits to the VV. The VV will return the Frame Count in the C3DL return link so the DESTINATION can assess the status of the forward link. The Insert Zone Service allows for data to be sent in each VCDU, so it is an ideal place to put the Frame Count. The bit positions in the table are based on the CCSDS bit numbering convention, where bit 0 is the first bit to be transmitted and the MSB for a field containing a binary value, such as a counter.

TABLE 3.4.3.3-1 C3DL RETURN LINK INSERT ZONE

Field	Length	Position	Notes
Unused	2-bits	0 - 1	Unused
C3DL Comm Unit VV Echoed Frame Counter	14-bits	2 - 15	Returned DESTINATION Frame Count

3.4.3.4 VIRTUAL CHANNEL DATA UNITS

The requirements in this Section are applicable to the CLDs and to all VV users of the C3DL System.

- A. The VV shall place the Virtual Channel Data Zones and Insert Zones for the C3DL return link in 1760-bit VCDUs with the characteristics in Table 3.4.3.4-1, C3DL Return Link VCDU Structure with the VCDU Header shown in Figure 3.4.3.4 and Table 3.4.3.4-2 as specified in CCSDS 732.0-B-4.
- B. The DESTINATION shall extract the received Virtual Channel Data Zones and Insert Zones from the C3DL return link from the 1760-bit VCDUs with the characteristics in Table 3.4.3.4-1 with the VCDU Header shown in Figure 3.4.3.4 and Table 3.4.3.4-2 as specified in CCSDS 732.0-B-4.

TABLE 3.4.3.4-1 C3DL RETURN LINK VCDU STRUCTURE

Structure	Length In Bits
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VCDU Header	48
VCDU Insert Zone	16
VCDU Data Zone (M_PDU or VCA_SDU)	1696

MASTER CHANNEL ID		VIRTUAL CHANNEL ID	VIRTUAL CHANNEL FRAME COUNT	SIGNALING FIELD			
TRANSFER FRAME VERSION NUMBER	SPACECRAFT ID			REPLAY FLAG	VC FRAME COUNT USAGE FLAG	RSVD SPARE	VC FRAME COUNT CYCLE
2 bits	8 bits	6 bits	24 bits	1 bit	1 bit	2 bits	4 bits
2 octets			3 octets	1 octet			

FIGURE 3.4.3.4-1 VCDU HEADER (RETURN LINK)

TABLE 3.3.3.4-2 VCDU HEADER FIELDS (RETURN LINK)

Field	Value	Length	Position	Notes
Transfer Frame Version Number	Always '01'.	2-bits	0-1	Value of '01' indicates to the receiver that the space data link protocol is Advanced Orbiting Systems (AOS).
Spacecraft ID	Static	8-bits	2-9	'11000010' is the value assigned to DESTINATION #1 C3DL. (second DESTINATION will be assigned different number.) '11000011' is the value assigned to DESTINATION #2 C3DL.
Virtual Channel ID	Variable	6-bits	10-15	The following values are defined: '000001': DESTINATION commands '000010': DESTINATION audio '000011': DESTINATION Telemetry '111111': Idle Frame (CCSDS-defined)
Virtual Channel Frame Count	Variable	24-bits	16-39	This field increments by one with each frame transmitted on a Virtual Channel. This field is zero for an Idle VCDU.
Replay Flag	Always '0'.	1-bit	40	Value of '0' indicates to the receiver that the data stream is "real-time" and not recorded playback data.
Virtual Channel Frame Count Usage Flag	Always '0'.	1-bit	41	Value of '0' indicates that the Virtual Channel Frame Count Cycle field is not used.
Reserved Spare	Always '00'.	2-bits	42-43	Unused.
Virtual Channel Frame Count Cycle	Always '0000'.	4-bits	44-47	Virtual Channel Frame Count field is not used.

Rationale: CCSDS 732.0-B-4 provides the VCDU Transfer Frame structure in Section 4.1.1.1. In CCSDS 732.0-B-4, the VCDU header is mandatory and must be 48 or 64-bits long, the Insert Zone is optional, and the VCDU Data Zone is mandatory and must be an integer number of octets, where an octet is eight-bits long. For C3DL, the VCDU header is 48-bits long and does not include the optional error control bits, the VCDU Insert Zone contains a Frame Count, and the VCDU Data Zone contains one of the following: an M_PDU, an encrypted M_PDU, a VCA_SDU, or an encrypted VCA_SDU, each with a Security Header and Trailer.

3.4.3.5 VIRTUAL CHANNEL MULTIPLEXING

The requirements in this Section are applicable to the CLDs and to all VV users of the C3DL System.

- A. The VV shall multiplex the VCDUs for the C3DL return link.
- B. The DESTINATION shall demultiplex the received VCDUs from the C3DL return link using the VCID in the VCDU header.
- C. The VV shall create Idle VCDUs for the C3DL return link when no data is available as described in CCSDS 732.0-B-4.
- D. The DESTINATION shall remove the received Idle VCDUs from the VCDUs on the C3DL return link as described in CCSDS 732.0-B-4.

Rationale: Each Virtual Channel is processed differently depending upon whether it contains CCSDS Space Packets, Encrypted CCSDS Space Packets, VCA audio, or Encrypted VCA audio. Once the different types of data are in VCDUs, they can be multiplexed together. The DESTINATION uses the VCID to demultiplex the Virtual Channels from the VCDUs.

The radio frequency link continuously sends data. When there is no data to send, CCSDS 732.0-B-4 4.2.5.4 specifies that the Virtual Channel Multiplexing Function send an Idle VCDU instead. CCSDS 732.0-B-4 4.3.5.3 specifies that the Virtual Channel Demultiplexer Function can discard Idle VCDUs. CCSDS 732.0-B-4 4.1.4.1.5 describes the Idle VCDU and calls for a project-specified idle pattern.

3.4.3.6 REED SOLOMON CODING

The requirements in this Section are applicable to the CLDs and to all VV users of the C3DL System.

- A. The VV shall encode the VCDUs for the C3DL return link using a (252, 220) shortened Reed Solomon Code with an interleave depth of 1 as specified in CCSDS 131.0-B-5.
- B. The DESTINATION shall decode the received VCDUs from the C3DL return link using a (252, 220) shortened Reed Solomon Code with an interleave depth of 1 (no interleaving will be used) as specified in CCSDS 131.0-B-5.

Rationale: CCSDS 131.0-B-5 recommends use of Reed Solomon coding to correct errors, particularly burst errors. The shortened code length and interleave depth of 1 were chosen to allow shorter packets.

3.4.3.7 RANDOMIZATION

The requirements in this Section are applicable to the CLDs and to all VV users of the C3DL System.

- A. The VV shall randomize the coded VCDUs for the C3DL return link using a 256-bit pseudo-random sequence as specified in CCSDS 131.0-B-5.
- B. The DESTINATION shall derandomize the received coded VCDUs from the C3DL return link using a 256-bit pseudo-random sequence as specified in CCSDS 131.0-B-5.

Rationale: CCSDS 131.0-B-5 recommends use of randomization to ensure sufficient bit transition density to maintain bit and symbol sync. CCSDS 131.0-B-5, Section 10.4.2 specifies the following 256-bit pseudo-random sequence:

$$h(x) = x^8 + x^7 + x^5 + x^3 + 1$$

3.4.3.8 ATTACHED SYNC MARKERS

The requirements in this Section are applicable to the CLDs and to all VV users of the C3DL System.

- A. The VV shall apply the 32-bit ASM to the coded, randomized VCDUs for the C3DL return link as specified in CCSDS 131.0-B-5 (hexadecimal 1ACFFC1D).
- B. The DESTINATION shall synchronize the received VCDUs from the C3DL return link using the 32-bit ASM as specified in CCSDS 131.0-B-5.
- C. The DESTINATION shall use the 32-bit ASM to resolve the input data phase ambiguity.

Rationale: CCSDS 131.0-B-5 recommends use of a 32-bit ASM to synchronize frames.

Common baseband waveforms are NRZ-L and NRZ-M, where NRZ-L gives better E_b/N_0 performance, but NRZ-M differential encoding provides phase ambiguity resolution. C3DL will use the ASM to resolve the input data phase ambiguity so that NRZ-L can be used and the degradation incurred with NRZ-M can be avoided.

3.4.3.9 CADU FRAME LENGTH

The requirements in this Section are applicable to the CLDs and to all VV users of the C3DL System.

- A. The VV shall use 2048-bit CADUs for the C3DL return link with the characteristics in Table 3.4.3.9-1, C3DL Return Link CADU Structure.
- B. The DESTINATION shall use 2048-bit CADUs for the C3DL return link with the characteristics in Table 3.4.3.9-1.

TABLE 3.4.3.9-1 C3DL RETURN LINK CADU STRUCTURE

Structure	Length In Bits
ASM	32
VCDU	1760
Reed Solomon Check Symbols	256
Total CADU	2048

Rationale: CCSDS 131.0-B-5 states that the Transfer Frame length must be fixed for each physical channel and mission phase. The CADU length depends upon the length of the ASM and the presence of Reed Solomon coding. Since the use of coding, the coding parameters, and the ASM length are managed parameters (must be separately configured by both sides of a link), they are expected to change infrequently and only with major reconfigurations.

3.4.3.10 CONVOLUTIONAL CODING

The requirements in this Section are applicable to the CLDs and to all VV users of the C3DL System.

- A. The VV shall encode the CADUs for the C3DL return link using a rate 1/2 constraint length 7 convolutional code ("Basic Convolutional Encoder") as specified in CCSDS 131.0-B-5.
- B. The DESTINATION shall decode the received CADUs from the C3DL return link using a rate 1/2 constraint length 7 convolutional code ("Basic Convolutional Encoder") as specified in CCSDS 131.0-B-5.

Rationale: CCSDS 131.0-B-5 recommends use of a rate 1/2 constraint length 7 convolutional code if additional error correction is needed for a link.

3.4.3.11 BASEBAND WAVEFORM

The requirements in this Section are applicable to the CLDs and to all VV users of the C3DL System.

- A. The VV shall transmit an NRZ-L baseband waveform for the C3DL return link.
- B. The DESTINATION shall receive an NRZ-L baseband waveform for the C3DL return link.

Rationale: Common baseband waveforms are NRZ-L and NRZ-M, where NRZ-L gives better E_b/N_0 performance, but NRZ-M differential encoding provides phase ambiguity resolution. Since phase ambiguity resolution can also be provided by the ASM per CCSDS 131.0-B-5, Section 2.2.4, NRZ-L was selected for its better performance.

3.4.3.12 LATENCY

The requirements in this Section are applicable to the CLDs and to all VV users of the C3DL System.

- A. The VV shall introduce less than 249 ms of latency for the C3DL return link from the time the last bit of a data unit is available to be packaged in a CCSDS space packet or VCA_SDU to the time the first bit of the CADU containing that data unit is transmitted.
- B. The DESTINATION shall introduce less than 749 ms of latency for the C3DL return link from the time the last bit of a CADU is received to the time the first bit of the first data unit that ends in the CADU is provided at the C3DL output ports.

Rationale: RFC 1242 defines the latency for a store-and-forward device as: The time interval starting when the last bit of the input frame reaches the input port and ending when the first bit of the output frame is seen on the output port. The last bit of the input frame can be the end of a VV cyclic data packet, the end of a VV pass-through data packet, the end of a video packet, or the end of the tenth G.729 audio packet. The first bit of the output frame is the first bit of the CADU. The end-to-end latency can be allocated to the VV latency, the light speed delay, the time to send one CADU at the minimum symbol rate, and the DESTINATION latency. At the maximum range of 30 km, the light speed delay is 0.1 ms. The maximum time to send a CADU at 36 ksps is 114 ms. 249 ms of latency is allocated to the transmitter, and 749 ms of latency is allocated to the receiver because it takes more time to process the received data stream than to generate it. These values produce a total maximum latency of less than 1.2 sec.

4.0 VERIFICATION REQUIREMENTS

This section provides the complete set of Verification Requirements (VRs) necessary to ensure compliance with the interface and design requirements contained in Section 3.0.

4.1 VERIFICATION METHODS

C3DL verification will be conducted by inspection, analysis, demonstration, or test.

These methods are defined as follows:

- A. Inspection is a method that determines conformance to requirements by the review of drawings, data or by visual examination of the item using standard quality control methods, without the use of special laboratory procedures.
- B. Analysis is a process used in lieu of, or in addition to, other methods to ensure compliance to specification requirements. The selected techniques may include, but not be limited to, engineering analysis, statistics and qualitative analysis, computer and hardware simulations, and analog modeling. Analysis may also include assessing the results of lower-level qualification activity. Analysis may be used when it can be determined that (1) rigorous and accurate analysis is possible, (2) test is not cost effective, and (3) verification by inspection is not adequate. Verification by similarity is the process of analyzing the specification criteria for hardware configuration, and application for an article to determine if it is similar or identical in design, manufacturing process, and quality control to an existing article that has previously been qualified to equivalent or more stringent specification criteria. Special effort will be made to avoid duplication of previous tests from this or similar programs. If the previous application is considered to be similar, but not equal to or greater in severity, additional qualification tests shall concentrate on the areas of new or increased requirements.
- C. Demonstration consists of a qualitative determination of the properties of a test article. This qualitative determination is made through observation, with or without special test equipment or instrumentation, which verifies characteristics such as human engineering features, services, access features, and transportability. Demonstration requirements are normally implemented within a test plan, operations plan, or test procedure.
- D. Test is a method in which technical means, such as the use of special equipment, instrumentation, simulation techniques, and the application of established principles and procedures are used for the evaluation of components, subsystems, and systems to determine compliance with requirements. Test shall be selected as the primary method when analytical techniques do not produce adequate results; failure modes exist which could compromise personnel safety, adversely affect flight systems or payload operation, or result in a loss of mission objectives; or for any components directly associated with the CLDs interfaces. The analysis of data derived from tests is

an integral part of the test program and should not be confused with analysis as defined above. Tests shall be used to determine quantitative compliance to requirements and produce quantitative results.

The document's requirement verification method was determined for each requirement as follows. Requirements that can be verified with a one-sided test will be verified by an inspection of lower-level test data. Requirements that must be verified by an ETE test involving both sides of the interface will be verified by test. Requirements on the physical layer (RF requirements) will be verified by an RF compatibility test. Some requirements will be verified by a combination of lower-level inspection and higher-level testing.

4.2 REQUIREMENTS

4.2.1 INTERFACE DEFINITION

4.2.2 GENERAL REQUIREMENTS

4.2.2.1 CONCURRENT C3DL FORWARD LINK AND C3DL RETURN LINK

- A. The DESTINATION concurrent reception of the C3DL return link and transmission of the C3DL forward link shall be verified by joint test. A joint test will be performed using the DESTINATION and the VV. The joint test will be performed with combinations of symbol rate, encryption, modulation, and received power. The verification shall be considered successful when the joint test shows that the DESTINATION receives return link data in compliance with the CWER specified in Paragraph 3.4.2.6 while concurrently transmitting a forward link and the VV receives the forward link data in compliance with CWER specified in Paragraph 3.3.2.6.

Rationale: Verification of concurrent reception and transmission by joint test is necessary because it requires the concurrent operation of both sides of the link. Receipt of data in compliance with the CWER requirements at the same time on both the C3DL forward link and the C3DL return link shows that the DESTINATION can concurrently receive and transmit.

- B. The VV concurrent reception of the C3DL forward link and transmission of the C3DL return link shall be verified by joint test. A joint test will be performed using the VV and the CLD. The joint test will be performed with combinations of symbol rate, encryption, modulation, and received power. The verification shall be considered successful when the joint test shows that the VV receives forward link data in compliance with CWER specified in Paragraph 3.3.2.6 while concurrently transmitting a return link and the DESTINATION receives the return link data in compliance with the CWER specified in Paragraph 3.4.2.6.

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Rationale: Verification of concurrent reception and transmission by joint test is necessary because it requires the concurrent operation of both sides of the link. Receipt of data in compliance with the CWER requirements at the same time on both the C3DL forward link and the C3DL return link shows that the VV can concurrently receive and transmit.

4.2.2.2 MAXIMUM POWER

- A. The VV production of an RF signal with no greater than -50 dBWi **<TBR 4-1>** received power at an isotropic antenna at the DESTINATION antenna locations when the VV is 5 or more meters away from the DESTINATION antennas shall be verified by inspection. An inspection of lower-level analysis of test data will be performed. The verification shall be considered successful when the inspection shows that the VV produces an RF signal with no greater than -50 dBWi **<TBR 4-1>** received power at an isotropic antenna at the DESTINATION antenna locations when the VV is 5 or more meters away from the DESTINATION antennas.

Rationale: Verification of the received power by inspection of lower-level analysis is appropriate because the received power can be determined at a lower level by the VV without CLD.

4.2.2.3 SECURITY

- A. The DESTINATION usage of AES-256 per FIPS PUB 197 using the GCM mode as stated in NIST Special Publication 800-38D for encryption and decryption of the C3DL forward link data and the C3DL return link data, respectively, shall be verified by demonstration and inspection. A demonstration proves the successful communications between the DESTINATION security module and a flight equivalent representation of a VV security module to validate the use of 256-bit keys and the proper usage of an Initialization Vector (IV). An inspection of lower-level Security module designs integrated with the data communications formats will validate proper usage of the Key and the Initialization Vector (IV). The verification shall be considered successful when both the demonstration and the inspection validates that the DESTINATION uses the AES-256 standard GCM mode with an acceptable IV to encrypt the C3DL forward link and decrypt the C3DL return link.
- B. The VV usage of AES-256 per FIPS PUB 197 using the GCM mode as stated in NIST Special Publication 800-38D for decryption and encryption of the C3DL forward link data and the C3DL return link data, respectively, shall be verified by demonstration and inspection. A demonstration proves the successful communications between the VV security module and a flight equivalent representation of a DESTINATION security module to validate the use of 256-bit keys and the proper usage of an IV. An inspection of lower-level Security module designs integrated with the data communications formats will validate

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proper usage of the Key and the IV. The verification shall be considered successful when both the demonstration and the inspection validates that the VV uses the AES-256 standard GCM mode with an acceptable IV to encrypt the VV return link and decrypt the C3DL forward link.

Rationale: NIST has implementation guidance and appropriate usage of AES-GCM Keys and IVs that must be followed. To successfully verify that the implementation is sound and appropriately configured, a demonstration to prove communications effectiveness is warranted. And an inspection of the design implementation to integrate the DESTINATION security module with the communications formats/protocols is necessary to ensure adherence to SP 800-38D.

- C. The DESTINATION link security configuration change by command shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION is able to change the security configuration by command for each virtual channel for both the C3DL forward link and the C3DL return link.
- D. The VV link security configuration change by command shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV is able to change the security configuration by command for each virtual channel for both the C3DL forward link and the C3DL return link.

Rationale: Verification of the link security configuration change by command by inspection of lower-level test data is appropriate because the change in link security configuration can be determined at a lower-level by the DESTINATION without the VV and by the VV without the CLD.

- E. The VV processing of the encrypted C3DL forward link DESTINATION command virtual channel shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV processes the encrypted C3DL forward link DESTINATION command virtual channel.
- F. The DESTINATION processing of the encrypted C3DL return link VV command virtual channel shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION processes the encrypted C3DL return link VV command virtual channel.

Rationale: Verification of processing of the encrypted C3DL forward link DESTINATION command virtual channel by inspection of lower-level test data is appropriate because the encryption can be determined at a lower level by the VV without the CLD. Verification of processing of the encrypted C3DL return link VV command virtual channel by inspection of lower-level test data is appropriate because the encryption can be determined at a lower level by the DESTINATION without the VV.

- G. The VV discarding the time-tagged commands that do not agree with the VV time within one minute shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV discards a time-tagged command that does not agree with the VV time within one minute.
- H. The DESTINATION discarding the time-tagged commands that do not agree with the DESTINATION time within one minute shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION discards a time-tagged command that does not agree with the DESTINATION time within one minute.

Rationale: Verification of discarding time-tagged commands by inspection is appropriate because discarding time-tagged commands can be determined at a lower-level by the DESTINATION without the VV and by the VV without the CLD.

- I. The DESTINATION compliance with the security procedures in CCSDS 355.0-B-2, Section 4.2 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION complies with the security procedures in CCSDS 355.0-B-2, Section 4.2.
- J. The VV compliance with the security procedures in CCSDS 355.0-B-2, Section 4.2 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV complies with the security procedures in CCSDS 355.0-B-2, Section 4.2.

Rationale: Verification of compliance with CCSDS 355.0-B-2, Section 4.2 by inspection is appropriate because compliance with CCSDS 355.0-B-2, Section 4.2 can be determined at a lower-level by the DESTINATION without the VV and by the VV without the CLD.

- K. This requirement shall be verified by inspection of the FIPS Pub 140-3 certification letter from a NIST approved Laboratory. The DESTINATION shall verify its hardware and software for encryption and decryption module requirements in accordance with FIPS Pub 140-3 and ANSI 9X9.52 certification, for a security Level 2. A NIST validated Laboratory (e.g., INFOGARD) is responsible for performing the verification.
- L. This requirement shall be verified by inspection of the FIPS Pub 140-3 certification letter from a NIST approved Laboratory. The VV shall verify its hardware and software for encryption and decryption module requirements in accordance with FIPS Pub 140-3 and ANSI 9X9.52 certification, for a security Level 2. A NIST validated Laboratory (e.g., INFOGARD) is responsible for performing the verification.

Rationale: Verification of compliance with FIPS Pub 140-3 and ANSI 9X9.52 certification by inspection is appropriate because certification is performed by a NIST Laboratory.

4.2.3 DESTINATION TO VV C3DL FORWARD LINK REQUIREMENTS

4.2.3.1 SPECTRUM REQUIREMENTS

4.2.3.1.1 FREQUENCY

- A. The DESTINATION transmission of the C3DL forward link at the assigned frequency shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION transmits the assigned frequency.

Rationale: Verification of transmit frequency by inspection of lower-level test data is appropriate because the transmit frequency can be determined at a lower level by the DESTINATION without the VV.

- B. The VV reception of the C3DL forward link at the assigned frequency shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV receives the assigned frequency.

Rationale: Verification of receive frequency by inspection of lower-level test data is appropriate because the receive frequency can be determined at a lower level by the VV without the CLD.

4.2.3.1.2 BANDWIDTH

- A. The DESTINATION transmission of the C3DL forward link signal at the 72 ksps symbol rate with a bandwidth less than or equal to 46 kHz shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION uses a 99 percent power transmit bandwidth less than or equal to 46 kHz for the C3DL 72 ksps forward link.

Rationale: Verification of transmit bandwidth by inspection of lower-level test data is appropriate because the transmit bandwidth can be determined at a lower level by the DESTINATION without the VV.

- B. The DESTINATION transmission of the C3DL forward link signal at the 144 ksps symbol rate with a bandwidth less than or equal to 92 kHz shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION uses a 99 percent power transmit bandwidth less than or equal to 92 kHz for the C3DL 144 ksps forward link.

Rationale: Verification of transmit bandwidth by inspection of lower-level test data is appropriate because the transmit bandwidth can be determined at a lower level by the DESTINATION without the VV.

4.2.3.2 RADIO FREQUENCY REQUIREMENTS

4.2.3.2.1 SYMBOL RATE

- A. The DESTINATION transmission of the C3DL forward link symbol rates listed in Table 3.3.2.1-1 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION produces all of the symbol rates in Table 3.3.2.1-1.

Rationale: Verification of transmit symbol rate by inspection of lower-level test data is appropriate because the transmit symbol rate can be determined at a lower-level by the DESTINATION without the VV.

- B. The VV reception of the C3DL forward link symbol rates listed in Table 3.3.2.1-1 that are also listed as applicable to the VV in the specific DESTINATION to specific VV ICD shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV receives all applicable symbol rates in Table 3.3.2.1-1.

Rationale: Verification of receive symbol rate by inspection of lower-level test data is appropriate because the receive symbol rate can be determined at a lower-level by VV without the CLD.

4.2.3.2.2 MODULATION

- A. The DESTINATION transmission of the C3DL forward link using Filtered OQPSK modulation with the characteristics listed in Table 3.3.2.2-1 shall be verified by inspection and joint test. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the DESTINATION uses Filtered OQPSK modulation with the characteristics listed in Table 3.3.2.2-1. A joint test will be performed using the VV and the CLD. The DESTINATION will transmit the C3DL forward link using each symbol rate and Filtered OQPSK modulation. The transmitted signals will be attenuated so they are received within the VV's dynamic range. The VV lock indicators will be recorded. The joint test shall be considered successful when it shows the VV reports that it has lock in each symbol rate.

Rationale: Verification of modulation by inspection of lower-level test data is appropriate because the modulation can be determined at a lower-level by the DESTINATION without the VV. Verification of modulation by joint test is necessary to include the cascade effect of all hardware and software.

- B. The VV reception of the Filtered OQPSK modulated C3DL forward link with the characteristics listed in Table 3.3.2.2-1 shall be verified by inspection and joint test. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the VV demodulates the specified Filtered OQPSK modulation and produces valid lock indicators. A test will be performed using the DESTINATION and the VV. The DESTINATION will transmit the C3DL forward link using Filtered OQPSK with the characteristics listed in Table 3.3.2.2-1. The transmitted signals will be attenuated so they are received within the VV's dynamic range. The VV lock indicators will be recorded. The test shall be considered successful when it shows the VV reports that it has lock for each symbol rate.

Rationale: Verification of demodulation by inspection of lower-level test data is appropriate because the demodulation can be determined at a lower-level by VV without the CLD. Verification of demodulation by joint test is necessary to include the cascade effect of all hardware and software.

4.2.3.2.3 POLARIZATION

- A. The DESTINATION transmission of the C3DL forward link using RHCP shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION transmits the C3DL forward link using RHCP.

Rationale: Verification of polarization by inspection of lower-level test data is appropriate because polarization can be determined at a lower level by the DESTINATION without the VV.

- B. The VV reception of the C3DL forward link using RHCP shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV receives the C3DL forward link using RHCP.

Rationale: Verification of polarization by inspection of lower-level test data is appropriate because polarization can be determined at a lower-level by the VV without the CLD.

4.2.3.2.4 MINIMUM POWER AT VV

The DESTINATION production of an RF signal with a received power at an isotropic antenna at the VV antenna locations no less than the values in Table 3.3.2.4-1 for the C3DL forward link shall be verified by inspection. An inspection of the lower-level analysis of test data will be performed. The verification shall be considered successful when the inspection shows that the DESTINATION produces an RF signal with a received power at an isotropic antenna at the VV antenna locations for the C3DL forward link no less than the values in Table 3.3.2.4-1.

Rationale: Verification of production of an RF signal with a received power at an isotropic antenna at the VV antenna locations by inspection of lower-level analysis is appropriate because the received power can be determined using only the transmit side of the link and so it can be determined at a lower-level by the DESTINATION without the VV. Lower-level measured data for EIRP or lower level analysis of measured antenna gain, cable loss, and transmit power or lower level test data for the EIRP can be used with the calculated space loss to determine the received power.

4.2.3.2.5 TRANSMIT SIGNAL PARAMETERS

The DESTINATION transmission of a signal with an EVM no greater than 10 percent shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION produces an EVM no greater than 10 percent.

Rationale: Verification of EVM by inspection of lower-level test data is appropriate because EVM can be determined at a lower-level by the DESTINATION without the VV.

4.2.3.2.6 CODE WORD ERROR RATE

The VV provision of a CWER no greater than 4×10^{-7} when the DESTINATION meets its EVM and provides a received power at a 0 dB gain (isotropic) VV antenna no less than the values in Table 3.3.2.4-1 shall be verified by joint test and analysis. A joint test will be performed using the VV and the CLD. The DESTINATION will transmit the C3DL forward link at each symbol rate, encryption, and modulation combination. Operational packet data or a pseudorandom bit pattern of 32,767-bits or longer will be used, with appropriate C3DL forward error correction coding applied. The Doppler effect on the received signal will be taken into account, and both zero Doppler and the worst-case Doppler will be used. The transmitted signals will be attenuated so they are received at the VV at received power levels associated with measurable CWERs. The received data will be compared with the transmitted data, and the CWER will be measured with 95 percent confidence level for each symbol rate, encryption, and modulation combination. If joint tests cannot be run long enough to measure the CWER at the specified received power, analysis will be performed to extend the measured CWER results to determine the CWER at the specified received power. The verification shall be considered successful when the joint test and analysis shows the VV provides a CWER no more than 4×10^{-7} for each symbol rate, and modulation combination with 95 percent confidence level when the DESTINATION provides specified received power.

Rationale: Verification of CWER by joint test is necessary to include the cascade effect of all hardware and software. Verification of CWER by analysis is necessary if the joint test time for the CWER is prohibitively long.

4.2.3.3 BASEBAND REQUIREMENTS

4.2.3.3.1 VIRTUAL CHANNEL DATA

4.2.3.3.1.1 DESTINATION COMMANDS

- A. The DESTINATION insertion of the DESTINATION commands for the C3DL forward link into CCSDS Space Packets with the characteristics in Table 3.3.3.1.1-1 as specified in CCSDS 133.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION inserts the DESTINATION commands into CCSDS Space Packets.

Rationale: Verification of insertion of DESTINATION commands by inspection of lower-level test data is appropriate because insertion of DESTINATION commands can be determined at a lower-level by the DESTINATION without the VV.

- B. The VV extraction of the received DESTINATION commands from the C3DL forward link from CCSDS Space Packets with the characteristics in Table 3.3.3.1.1-1 as specified in CCSDS 133.0-B-2 shall be verified by joint test. A joint test will be performed using the VV and the CLD. The verification shall be considered successful when the joint test shows the VV extracts the DESTINATION commands from CCSDS Space Packets.

Rationale: Verification of extraction of DESTINATION commands by joint test is necessary to include the cascade effect of all hardware and software.

4.2.3.3.1.2 DESTINATION TELEMETRY

- A. The DESTINATION insertion of the DESTINATION Telemetry for the C3DL forward link into CCSDS Space Packets with the characteristics in Table 3.3.3.1.1-1 as specified in CCSDS 133.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION inserts the DESTINATION Telemetry into CCSDS Space Packets.

Rationale: Verification of insertion of DESTINATION Telemetry by inspection of lower-level test data is appropriate because insertion of DESTINATION Telemetry can be determined at a lower-level by the DESTINATION without the VV.

- B. The VV extraction of the received DESTINATION Telemetry from the C3DL forward link from CCSDS Space Packets with the characteristics in Table 3.3.3.1.1-1 as specified in CCSDS 133.0-B-2 shall be verified by joint test. A joint test will be performed using the VV and the CLD. The verification shall be considered successful when the joint test shows the VV extracts the DESTINATION Telemetry from CCSDS Space Packets.

Rationale: Verification of extraction of DESTINATION Telemetry by joint test is necessary to include the cascade effect of all hardware and software.

4.2.3.3.1.3 DESTINATION AUDIO

- A. The DESTINATION sending DESTINATION audio consisting of a 96-bit RTP header in accordance with IETF RFC 3550 and IETF RFC 3551 and ten 80-bit 10 ms G.729 audio frames in accordance with ITU-T G.729 on the C3DL forward link to the VV shall be verified by inspection. An inspection of lower-level test data will be performed. The DESTINATION will transmit DESTINATION audio data on the C3DL forward link. All applicable combinations of symbol rate, encryption, and modulation will be used. The inspection shall be considered successful when it shows the DESTINATION transmits audio consisting of a 96-bit RTP header in accordance with IETF RFC 3550 and IETF RFC 3551 and ten 80-bit 10 ms G.729 audio frames in accordance with ITU-T G.729.

Rationale: Verification of DESTINATION audio formats by inspection of lower-level test data is appropriate because the use of DESTINATION audio formats can be determined at a lower-level by DESTINATION without the VV.

- B. The VV reception of DESTINATION audio consisting of a 96-bit RTP header in accordance with IETF RFC 3550 and IETF RFC 3551 and ten 80-bit 10 ms G.729 audio frames in accordance with ITU-T G.729 on the C3DL forward link shall be verified by joint test. A joint test will be performed using the DESTINATION and the VV. The DESTINATION will transmit DESTINATION audio data on the C3DL forward link. All applicable combinations of symbol rate, encryption, and modulation will be used. The transmitted signals will be attenuated so they are received within the VV's dynamic range. The received DESTINATION audio data will be compared with the transmitted DESTINATION audio data. The joint test shall be considered successful when it shows the VV receives DESTINATION audio data with an error rate in compliance with the CWER specified in Paragraph 3.3.2.6-1 for all applicable combinations of symbol rate, encryption, and modulation.

Rationale: Verification of reception of DESTINATION audio by joint test is necessary to include the cascade effect of all hardware and software.

4.2.3.3.2 VIRTUAL CHANNEL PACKAGING

4.2.3.3.2.1 CCSDS SPACE PACKETS FOR UNENCRYPTED VIRTUAL CHANNELS

4.2.3.3.2.1.1 CCSDS SPACE PACKETS MULTIPLEXING PROTOCOL DATA UNITS FOR UNENCRYPTED VIRTUAL CHANNELS

- A. The DESTINATION insertion of the CCSDS Space Packets for unencrypted virtual channels on the C3DL forward link into M_PDUs with the characteristics in Table 3.3.3.2.1.1-1 as specified in CCSDS 732.0-B-4 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION inserts the CCSDS Space Packets into M_PDUs with the characteristics in Table 3.3.3.2.1.1-1 as specified in CCSDS 732.0-B-4.

Rationale: Verification of insertion of CCSDS Space Packets into M_PDUs by inspection of lower-level test data is appropriate because insertion of CCSDS Space Packets into M_PDUs can be determined at a lower level by the DESTINATION without the VV.

- B. The VV extraction of the received CCSDS Space Packets from unencrypted virtual channels on the C3DL forward link from the M_PDUs with the characteristics in Table 3.3.3.2.1.1-1 as specified in CCSDS 732.0-B-4 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV extracts the CCSDS Space Packets from M_PDUs with the characteristics in Table 3.3.3.2.1.1-1 as specified in CCSDS 732.0-B-4.

Rationale: Verification of extraction of CCSDS Space Packets from M_PDUs by inspection of lower-level test data is appropriate because extraction of CCSDS Space Packets from M_PDUs can be determined at a lower-level by the VV without the CLD.

- C. The DESTINATION generation of an Idle Space Packet as specified in CCSDS 732.0-B-4 and CCSDS 133.0-B-2 when insufficient CCSDS Space Packets are available to fill the M_PDU Packet Zone for unencrypted virtual channels on the C3DL forward link shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION generates Idle Space Packets as specified in CCSDS 732.0-B-4 and CCSDS 133.0-B-2 when insufficient CCSDS Space Packets are available to fill the M_PDU Packet Zone for unencrypted channels on the C3DL forward link.

Rationale: Verification of generation of Idle Space Packets by inspection of lower-level test data is appropriate because generation of Idle Space Packets can be determined at a lower-level by the DESTINATION without the VV.

- D. The VV removal of Idle Space Packets as specified in CCSDS 732.0-B-4 from the received M_PDUs for unencrypted channels on the C3DL forward link shall

be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV removes Idle Space Packets as specified in CCSDS 732.0-B-4 from the received M_PDUs.

Rationale: Verification of removal of Idle Space Packets by inspection of lower-level test data is appropriate because removal of Idle Space Packets can be determined at a lower-level by the VV without the CLD.

4.2.3.3.2.1.2 SECURITY HEADER

- A. The DESTINATION addition of a security header to the M_PDUs for unencrypted virtual channels on the C3DL forward link with the fields listed in Table 3.3.3.2.1.2-1 as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the DESTINATION adds the specified security header to M_PDUs for unencrypted virtual channels on the C3DL forward link.

Rationale: Verification of addition of a security header by inspection of lower-level test data is appropriate because addition of a security header can be determined at a lower-level by the DESTINATION without the VV.

- B. The VV extraction of a security header from before the M_PDUs for unencrypted virtual channels on the C3DL forward link with the fields listed in Table 3.3.3.2.1.2-1 as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the VV extracts the specified security header from before the M_PDUs for unencrypted virtual channels on the C3DL forward link.

Rationale: Verification of extraction of a security header by inspection of lower-level test data is appropriate because extraction of a security header can be determined at a lower-level by the VV without the CLD.

4.2.3.3.2.1.3 SECURITY TRAILER

- A. The DESTINATION addition of a 96-bit security trailer to the M_PDUs for unencrypted virtual channels on the C3DL forward link as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the DESTINATION adds the specified security trailer to the M_PDUs for unencrypted virtual channels on the C3DL forward link.

Rationale: Verification of addition of a security trailer by inspection of lower-level test data is appropriate because addition of a security trailer can be determined at a lower-level by the DESTINATION without the VV.

- B. The VV extraction of a 96-bit security trailer from after the M_PDUs for unencrypted virtual channels on the C3DL forward link as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the VV extracts the specified security trailer from M_PDUs for unencrypted virtual channels on the C3DL forward link.

Rationale: Verification of extraction of a security trailer by inspection of lower-level test data is appropriate because extraction of a security trailer can be determined at a lower-level by the VV without the CLD.

4.2.3.3.2.2 CCSDS SPACE PACKETS FOR ENCRYPTED VIRTUAL CHANNELS

4.2.3.3.2.2.1 CCSDS SPACE PACKETS MULTIPLEXING PROTOCOL DATA UNITS FOR ENCRYPTED VIRTUAL CHANNELS

- A. The DESTINATION insertion of the CCSDS Space Packets for encrypted virtual channels on the C3DL forward link into M_PDUs with the characteristics in Table 3.3.3.2.2.1-1 as specified in CCSDS 732.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION inserts the CCSDS Space Packets into M_PDUs with the characteristics in Table 3.3.3.2.2.1-1 as specified in CCSDS 732.0-B-4.

Rationale: Verification of insertion of CCSDS Space Packets into M_PDUs by inspection of lower-level test data is appropriate because insertion of CCSDS Space Packets into M_PDUs can be determined at a lower-level by the DESTINATION without the VV.

- B. The VV extraction of the received CCSDS Space packets from encrypted virtual channels on the C3DL forward link from the M_PDUs with the characteristics in Table 3.3.3.2.2.1-1 as specified in CCSDS 732.0-B-4 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV extracts the CCSDS Space Packets from M_PDUs with the characteristics in Table 3.3.3.2.2.1-1 as specified in CCSDS 732.0-B-4.

Rationale: Verification of extraction of CCSDS Space Packets from M_PDUs by inspection of lower-level test data is appropriate because extraction of CCSDS Space Packets from M_PDUs can be determined at a lower-level by the VV without the CLD.

- C. The DESTINATION generation of an Idle Space Packet as specified in CCSDS 732.0-B-4 and CCSDS 133.0-B-2 when insufficient CCSDS Space Packets are available to fill the M_PDU Packet Zone for encrypted virtual channels on the C3DL forward link shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION generates Idle Space Packets as specified in CCSDS 732.0-B-4 and CCSDS 133.0-B-2 when insufficient CCSDS Space Packets are available to fill the M_PDU Packet Zone for encrypted virtual channels on the C3DL forward link.

Rationale: Verification of generation of Idle Space Packets by inspection of lower-level test data is appropriate because generation of Idle Space Packets can be determined at a lower-level by the DESTINATION without the VV.

- D. The VV removal of Idle Space Packets as specified in CCSDS 732.0-B-4 from the received M_PDUs for encrypted virtual channels on the C3DL forward link shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV removes Idle Space Packets as specified in CCSDS 732.0-B-4 from the received M_PDUs for encrypted virtual channels on the C3DL forward link.

Rationale: Verification of removal of Idle Space Packets by inspection of lower-level test data is appropriate because removal of Idle Space Packets can be determined at a lower-level by the VV without the CLD.

4.2.3.3.2.2 MULTIPLEXING PROTOCOL DATA UNIT ENCRYPTION

- A. The DESTINATION encryption of the Multiplexing Protocol Data Units for virtual channels configured to be encrypted on the C3DL forward link shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the DESTINATION encrypts M_PDUs for virtual channels configured to be encrypted on the C3DL forward link.

Rationale: Verification of encryption of M_PDUs by inspection of lower-level test data is appropriate because encryption of M_PDUs can be determined at a lower-level by the DESTINATION without the VV.

- B. The VV decryption of the Multiplexing Protocol Data Units for virtual channels configured to be encrypted on the C3DL forward link shall be verified by joint test. A joint test will be performed using the DESTINATION and the VV. The DESTINATION will encrypt M_PDUs and transmit the encrypted M_PDUs on the C3DL forward link. A representative range of data values and types will be used. All applicable combinations of symbol rate, and modulation will be used. The transmitted signals will be attenuated so they are received within the VV's dynamic range. The received encrypted M_PDUs will be decrypted and

compared with the transmitted M_PDUs. The joint test shall be considered successful when it shows the VV receives M_PDUs with an error rate in compliance with the CWER specified in Paragraph 3.3.2.6-1 for all applicable combinations of symbol rate and modulation.

Rationale: Verification of decryption of M_PDUs by joint test is necessary to include the cascade effect of all hardware and software.

4.2.3.3.2.2.3 SECURITY HEADER

- A. The DESTINATION addition of a security header to the M_PDUs for encrypted virtual channels on the C3DL forward link with the fields listed in Table 3.3.3.2.2.3-1 as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the DESTINATION adds the specified security header to M_PDUs for encrypted virtual channels on the C3DL forward link.

Rationale: Verification of addition of a security header by inspection of lower-level test data is appropriate because addition of a security header can be determined at a lower-level by the DESTINATION without the VV.

- B. The VV extraction of a security header from before the M_PDUs for encrypted virtual channels on the C3DL forward link with the fields listed in Table 3.3.3.2.2.3-1 as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the VV extracts the specified security header from before the M_PDUs for encrypted virtual channels on the C3DL forward link.

Rationale: Verification of extraction of a security header by inspection of lower-level test data is appropriate because extraction of a security header can be determined at a lower-level by the VV without the CLD.

4.2.3.3.2.2.4 SECURITY TRAILER

- A. The DESTINATION addition of a 96-bit security trailer to the M_PDUs for encrypted virtual channels on the C3DL forward link as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the DESTINATION adds the specified security trailer to the M_PDUs for encrypted virtual channels on the C3DL forward link.

Rationale: Verification of addition of a security trailer by inspection of lower-level test data is appropriate because addition of a security trailer can be determined at a lower-level by the DESTINATION without the VV.

- B. The VV extraction of a 96-bit security trailer from after the M_PDUs for encrypted virtual channels on the C3DL forward link as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the VV extracts the specified security trailer from M_PDUs for encrypted virtual channels on the C3DL forward link.

Rationale: Verification of extraction of a security trailer by inspection of lower-level test data is appropriate because extraction of a security trailer can be determined at a lower-level by the VV without the CLD.

4.2.3.3.2.3 G.729 AUDIO FOR UNENCRYPTED VIRTUAL CHANNELS

4.2.3.3.2.3.1 DESTINATION AUDIO VCA_SDU FOR UNENCRYPTED VIRTUAL CHANNELS

- A. The DESTINATION insertion of DESTINATION audio for unencrypted virtual channels on the C3DL forward link into a VCA_SDU with the characteristics in Table 3.3.3.2.3.1-1 as specified in CCSDS 732.0-B-4 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION inserts the DESTINATION audio into a VCA_SDU with the characteristics in Table 3.3.3.2.3.1-1 as specified in CCSDS 732.0-B-4.

Rationale: Verification of insertion of DESTINATION audio into VCA_SDUs by inspection of lower-level test data is appropriate because insertion of DESTINATION audio into VCA_SDUs can be determined at a lower-level by the DESTINATION without the VV.

- B. The VV extraction of the received DESTINATION audio from unencrypted virtual channels on the C3DL forward link from VCA_SDUs with the characteristics in Table 3.3.3.2.3.1-1 as specified in CCSDS 732.0-B-4 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV extracts the DESTINATION audio from VCA_SDUs with the characteristics in Table 3.3.3.2.3.1-1 as specified in CCSDS 732.0-B-4.

Rationale: Verification of extraction of DESTINATION audio from VCA_SDUs by inspection of lower-level test data is appropriate because extraction of DESTINATION audio from VCA_SDUs can be determined at a lower-level by the VV without the CLD.

4.2.3.3.2.3.2 SECURITY HEADER

- A. The DESTINATION addition of a security header to the VCA_SDUs for unencrypted virtual channels on the C3DL forward link with the fields listed in Table 3.3.3.2.3.2-1 as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the DESTINATION adds the specified security header to the VCA_SDUs for unencrypted virtual channels on the C3DL forward link.

Rationale: Verification of addition of a security header by inspection of lower-level test data is appropriate because addition of a security header can be determined at a lower-level by the DESTINATION without the VV.

- B. The VV extraction of a security header from before the VCA_SDUs for unencrypted virtual channels on the C3DL forward link with the fields listed in Table 3.3.3.2.3.2-1 as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the VV extracts the specified security header before the VCA_SDUs for unencrypted virtual channels on the C3DL forward link.

Rationale: Verification of extraction of a security header by inspection of lower-level test data is appropriate because extraction of a security header can be determined at a lower-level by the VV without the CLD.

4.2.3.3.2.3.3 SECURITY TRAILER

- A. The DESTINATION addition of a 96-bit security trailer to the VCA_SDUs for unencrypted virtual channels on the C3DL forward link as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the DESTINATION adds the specified security trailer to the VCA_SDUs for unencrypted virtual channels on the C3DL forward link.

Rationale: Verification of addition of a security trailer by inspection of lower-level test data is appropriate because addition of a security trailer can be determined at a lower-level by the DESTINATION without the VV.

- B. The VV extraction of a 96-bit security trailer from after the VCA_SDUs for unencrypted virtual channels on the C3DL forward link as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the VV extracts the specified security trailer from after the VCA_SDUs for unencrypted virtual channels on the C3DL forward link.

Rationale: Verification of extraction of a security trailer by inspection of lower-level test data is appropriate because extraction of a security trailer can be determined at a lower-level by the VV without the CLD.

4.2.3.3.2.4 G.729 AUDIO FOR ENCRYPTED VIRTUAL CHANNELS

4.2.3.3.2.4.1 DESTINATION AUDIO VCA_SDUs FOR ENCRYPTED VIRTUAL CHANNELS

- A. The DESTINATION insertion of the DESTINATION audio for encrypted virtual channels on the C3DL forward link into a VCA_SDU with the characteristics in Table 3.3.3.2.4.1-1 specified in CCSDS 732.0-B-4 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION inserts the DESTINATION audio into a VCA_SDU with the characteristics in Table 3.3.3.2.4.1-1 as specified in CCSDS 732.0-B-4.

Rationale: Verification of insertion of DESTINATION audio into VCA_SDUs by inspection of lower-level test data is appropriate because insertion of DESTINATION audio into VCA_SDUs can be determined at a lower-level by the DESTINATION without the VV.

- B. The VV extraction of the received DESTINATION audio from encrypted virtual channels on the C3DL forward link from VCA_SDUs with the characteristics in Table 3.3.3.2.4.1-1 as specified in CCSDS 732.0-B-4 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV extracts the DESTINATION audio from the VCA_SDUs with the characteristics in Table 3.3.3.2.4.1-1 as specified in CCSDS 732.0-B-4.

Rationale: Verification of extraction of DESTINATION audio from VCA_SDUs by inspection of lower-level test data is appropriate because extraction of DESTINATION audio from the VCA_SDUs can be determined at a lower-level by the VV without the CLD.

4.2.3.3.2.4.2 VCA_SDU ENCRYPTION

- A. The DESTINATION encryption of the VCA_SDUs for virtual channels configured to be encrypted on the C3DL forward link shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the DESTINATION encrypts VCA_SDUs for virtual channels configured to be encrypted on the C3DL forward link.

Rationale: Verification of encryption of VCA_SDUs by inspection of lower-level test data is appropriate because encryption of VCA_SDUs can be determined at a lower-level by the DESTINATION without the VV.

- B. The VV decryption of the VCA_SDUs for virtual channels configured to be encrypted on the C3DL forward link shall be verified by joint test. A joint test will

be performed using the DESTINATION and the VV. The DESTINATION will encrypt VCA_SDUs and transmit the encrypted VCA_SDUs on the C3DL forward link. A representative range of data values and types will be used. All applicable combinations of symbol rate, and modulation will be used. The transmitted signals will be attenuated so they are received within the VV's dynamic range. The received encrypted VCA_SDUs will be decrypted and compared with the transmitted VCA_SDUs. The joint test shall be considered successful when it shows the VV receives VCA_SDUs with an error rate in compliance with the CWER specified in Paragraph 3.3.2.6-1 for all applicable combinations of symbol rate, and modulation.

Rationale: Verification of decryption of VCA_SDUs by inspection of lower-level test data is appropriate because decryption of VCA_SDUs can be determined at a lower-level by the VV without the CLD. Verification of decryption of VCA_SDUs by joint test is necessary to include the cascade effect of all hardware and software.

4.2.3.3.2.4.3 SECURITY HEADER

- A. The DESTINATION addition of a security header to the encrypted VCA_SDUs for encrypted virtual channels on the C3DL forward link with the fields listed in Table 3.3.3.2.4.3-1 as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the DESTINATION adds the specified security header to the encrypted VCA_SDUs for encrypted virtual channels on the C3DL forward link.

Rationale: Verification of addition of a security header by inspection of lower-level test data is appropriate because addition of a security header can be determined at a lower-level by the DESTINATION without the VV.

- B. The VV extraction of a security header from before the encrypted VCA_SDUs for encrypted virtual channels on the C3DL forward link with the fields listed in Table 3.3.3.2.4.3-1 as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the VV extracts the specified security header from before the encrypted VCA_SDUs for encrypted virtual channels on the C3DL forward link.

Rationale: Verification of extraction of a security header by inspection of lower-level test data is appropriate because extraction of a security header can be determined at a lower-level by the VV without the CLD.

4.2.3.3.2.4.4 SECURITY TRAILER

- A. The DESTINATION addition of a 96-bit security trailer to the encrypted VCA_SDUs for encrypted virtual channels on the C3DL forward link as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level

test data will be performed. The inspection shall be considered successful when it shows the DESTINATION adds the specified security trailer to the encrypted VCA_SDUs for encrypted virtual channels on the C3DL forward link.

Rationale: Verification of addition of a security trailer by inspection of lower-level test data is appropriate because addition of a security trailer can be determined at a lower-level by the DESTINATION without the VV.

- B. The VV extraction of a 96-bit security trailer from after the encrypted VCA_SDUs for encrypted virtual channels on the C3DL forward link as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the VV extracts the specified security trailer from after the encrypted VCA_SDUs for encrypted virtual channels on the C3DL forward link.

Rationale: Verification of extraction of a security trailer by inspection of lower-level test data is appropriate because extraction of a security trailer can be determined at a lower-level by the VV without the CLD.

4.2.3.3.3 VIRTUAL CHANNEL DATA UNIT INSERT ZONE

- A. The DESTINATION placement of a Frame Count and Return Link Status Bits in the VCDU 16-bit Insert Zone for the VCDUs on the C3DL forward link as shown in Table 3.3.3.3-1 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION places a Frame Count and Return Link Status Bits in the VCDU 16-bit Insert Zone for VCDUs on the C3DL forward link as shown in Table 3.3.3.3-1.

Rationale: Verification of placement of a Frame Count and Return Link Status Bits in the Insert Zone by inspection of lower-level test data is appropriate because placement of a Frame Count and Return Link Status Bits in the Insert Zone can be determined at a lower-level by the DESTINATION without the VV.

- B. The VV extraction of the Frame Count and Return Link Status Bits from the VCDU 16-bit Insert Zone for the received VCDUs on the C3DL forward link as shown in Table 3.3.3.3-1 shall be verified by joint test. A joint test will be performed using the DESTINATION and the VV. The DESTINATION will transmit representative Frame Counts and Return Link Status Bits on the C3DL forward link. All applicable combinations of symbol rate, and modulation will be used. The transmitted signals will be attenuated so they are received within the VV's dynamic range. The received Frame Counts and Return Link Status Bits will be compared with the transmitted Frame Counts and Return Link Status Bits. The joint test shall be considered successful when it shows the VV extracts Frame Counts and Return Link Status Bits with an error rate in compliance with the CWER specified in Paragraph 3.3.2.6-1 for all applicable combinations of symbol rate and modulation.

Rationale: Verification of extraction of Frame Counts and Return Link Status Bits from the Insert Zone of the VCDU by joint test is necessary to include the cascade effect of all hardware and software.

4.2.3.3.4 VIRTUAL CHANNEL DATA UNITS

- A. The DESTINATION placement of the VCDU Data Zones and Insert Zones for the C3DL forward link in 1760-bit VCDUs with the characteristics in Table 3.3.3.4-1 with the VCDU Header structure in Figure 3.3.3.4-1 and Table 3.3.3.4-2 as specified in CCSDS 732.0-B-4 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION places the VCDU Data Zones and Insert Zones into 1760-bit VCDUs with the characteristics in Table 3.3.3.4-1 with the VCDU Header structure in Figure 3.3.3.4-1 and Table 3.3.3.4-2.

Rationale: Verification of placement of the VCDU Data Zones and Insert Zones into VCDUs by inspection of lower-level test data is appropriate because placement of the VCDU Data Zones and Insert Zones into VCDUs can be determined at a lower-level by the DESTINATION without the VV.

- B. The VV extraction of the received VCDU Data Zones and Insert Zones from the C3DL forward link from the 1760-bit VCDUs with the characteristics in Table 3.3.3.4-1 with the VCDU Header structure in Figure 3.3.3.4-1 and Table 3.3.3.4-2 as specified in CCSDS 732.0-B-4 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV extracts the VCDU Data Zones and Insert Zones from the 1760-bit VCDU with the characteristics in Table 3.3.3.4-1 with the VCDU Header structure in Figure 3.3.3.4-1 and Table 3.3.3.4-2.

Rationale: Verification of extraction of the VCDU Data Zones and Insert Zones from the VCDUs by inspection of lower-level test data is appropriate because extraction of the VCDU Data Zones and Insert Zones from the VCDUs can be determined at a lower-level by the VV without the CLD.

4.2.3.3.5 VIRTUAL CHANNEL MULTIPLEXING

- A. The DESTINATION multiplexing the VCDUs for the C3DL forward link shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION multiplexes the VCDUs for the C3DL forward link.

Rationale: Verification of VCDU multiplexing by inspection of lower-level test data is appropriate because VCDU multiplexing can be determined at a lower-level by the DESTINATION without the VV.

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- B. The VV demultiplexing the received VCDUs from the C3DL forward link using the VCID in the VCDU header shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV demultiplexes the received VCDUs from the C3DL forward link using the VCID in the VCDU header.

Rationale: Verification of VCDU demultiplexing by inspection of lower-level test data is appropriate because VCDU demultiplexing can be determined at a lower-level by the VV without the CLD.

- C. The DESTINATION creation of Idle VCDUs for the C3DL forward link when no data is available as described in CCSDS 732.0-B-4 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION creates Idle VCDUs for the C3DL forward link when no data is available.

Rationale: Verification of creating Idle VCDUs by inspection of lower-level test data is appropriate because creating Idle VCDUs can be determined at a lower-level by the DESTINATION without the VV.

- D. The VV removal of the received Idle VCDUs from the C3DL forward link as described in CCSDS 732.0-B-4 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV removes the received Idle VCDUs from the C3DL forward link.

Rationale: Verification of removal of Idle VCDUs by inspection of lower-level test data is appropriate because removal of Idle VCDUs can be determined at a lower-level by the VV without the CLD.

4.2.3.3.6 REED SOLOMON CODING

- A. The DESTINATION encoding the VCDUs for the C3DL forward link using a (252, 220) shortened Reed Solomon Code with an interleave depth of 1 as specified in CCSDS 131.0-B-5 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION encodes the VCDUs for the C3DL forward link using a (252, 220) shortened Reed Solomon Code with an interleave depth of 1 as specified in CCSDS 131.0-B-5.

Rationale: Verification of encoding using Reed Solomon coding by inspection of lower-level test data is appropriate because encoding using Reed Solomon coding can be determined at a lower-level by the DESTINATION without the VV.

- B. The VV decoding the received VCDUs from the C3DL forward link using a (252, 220) shortened Reed Solomon Code with an interleave depth of 1 as specified in CCSDS 131.0-B-5 shall be verified by inspection and joint test. An inspection of

lower-level test data will be performed. The inspection shall be considered successful when it shows the VV decodes the VCDUs. A joint test will be performed using the DESTINATION and the VV. The DESTINATION will transmit the C3DL forward link using all applicable combinations of symbol rate, and modulation. The data used for these joint tests will be representative of mission data or a rigorously selected set of test codewords. The transmitted signals will be attenuated so they are received within the VV's dynamic range. The VV CWER will be recorded. The joint test shall be considered successful when it shows the VV CWER complies with the CWER requirement specified in Paragraph 3.3.2.6-1 for all applicable combinations of symbol rate and modulation.

Rationale: Verification of decoding by inspection of lower-level test data is appropriate because the decoding can be determined at a lower level by the VV without the CLD. Verification of decoding by joint test is necessary to include the cascade effect of all hardware and software.

4.2.3.3.7 RANDOMIZATION

- A. The DESTINATION randomizing the coded VCDUs for the C3DL forward link as specified in CCSDS 131.0-B-5 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION randomizes the VCDUs for the C3DL forward link as specified in CCSDS 131.0-B-5.

Rationale: Verification of randomization by inspection of lower-level test data is appropriate because randomization can be determined at a lower-level by the DESTINATION without the VV.

- B. The VV derandomizing the received coded VCDUs from the C3DL forward link as specified in CCSDS 131.0-B-5 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV derandomizes the received coded VCDUs from the C3DL forward link as specified in CCSDS 131.0-B-5.

Rationale: Verification of derandomization by inspection of lower-level test data is appropriate because derandomization can be determined at a lower-level by the VV without the CLD.

4.2.3.3.8 ATTACHED SYNC MARKER

- A. The DESTINATION application of the 32-bit ASM to the coded randomized VCDUs for the C3DL forward link as specified in CCSDS 131.0-B-5 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION applies a 32-bit ASM to the coded randomized VCDUs for the C3DL forward link as specified in CCSDS 131.0-B-5.

Rationale: Verification of application of a 32-bit ASM by inspection of lower-level test data is appropriate because application of a 32-bit ASM can be determined at a lower-level by the DESTINATION without the VV.

- B. The VV synchronization of the received coded randomized VCDUs from the C3DL forward link using the C3DL forward link 32-bit ASM as specified in CCSDS 131.0-B-5 shall be verified by inspection and joint test. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the VV syncs the received coded randomized VCDUs and produces a valid frame sync flag. A joint test will be performed using the DESTINATION and the VV. The DESTINATION will transmit the C3DL forward link using all applicable combinations of symbol rate and modulation. The data used for these tests will be representative of mission data. The transmitted signals will be attenuated so they are received at the VV with the Prec specified in the CWER requirement. The VV frame sync flag and the CWER will be recorded. The joint test shall be considered successful when it shows the VV reports that it has frame sync and meets the CWER requirement specified in Paragraph 3.3.2.6-1 for all applicable combinations of symbol rate, and modulation.

Rationale: Verification of synchronization by inspection of lower-level test data is appropriate because synchronization can be determined at a lower level by the VV without the CLD. Verification of synchronization by joint test is necessary to include the cascade effect of all hardware and software. The CWER performance under the applicable E_b/N_0 for a link cannot be met without a well-designed frame synchronizer. Not all possible frame synchronizer failures can be detected in strong-signal tests.

- C. The VV resolution of the input data phase ambiguity using the 32-bit ASM shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the VV resolves the input data phase ambiguity using the 32-bit ASM for all possible phase conditions.

Rationale: Verification of resolution of input data phase ambiguity using the 32-bit ASM is appropriate because resolution of data phase ambiguity can be determined at a lower-level by the VV without CLD.

4.2.3.3.9 CADU FRAME LENGTH

- A. The DESTINATION usage of 2048-bit CADUs for the C3DL forward link with the characteristics in Table 3.3.3.9-1 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION uses a 2048-bit CADU with the characteristics in Table 3.3.3.9-1.

Rationale: Verification of usage of a 2048-bit CADU by inspection of lower-level test data is appropriate because usage of a 2048-bit CADU can be determined at a lower-level by the DESTINATION without the VV.

- B. The VV usage of 2048-bit CADUs for the C3DL forward link with the characteristics in Table 3.3.3.9-1 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV uses a 2048-bit CADU with the characteristics in Table 3.3.3.9-1.

Rationale: Verification of usage of a 2048-bit CADU by inspection of lower-level test data is appropriate because usage of a 2048-bit CADU can be determined at a lower-level by the VV without the CLD.

4.2.3.3.10 CONVOLUTIONAL CODING

- A. The DESTINATION encoding the CADUs for the C3DL forward link using a rate 1/2 constraint length 7 convolutional code as specified in CCSDS 131.0-B-5 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION encodes the CADUs for the C3DL forward link using a rate 1/2 constraint length 7 convolutional code as specified in CCSDS 131.0-B-5.

Rationale: Verification of encoding using convolutional coding by inspection of lower-level test data is appropriate because encoding using convolutional coding can be determined at a lower-level by the DESTINATION without the VV.

- B. The VV decoding the received CADUs from the C3DL forward link using a rate 1/2 constraint length 7 convolutional code as specified in CCSDS 131.0-B-5 shall be verified by inspection and joint test. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the VV decodes the received CADUs and produces valid ASMs. A test will be performed using the DESTINATION and the VV. The DESTINATION will transmit the C3DL forward link using all applicable combinations of symbol rate and modulation. The data used for these tests will be representative of mission data. The transmitted signals will be attenuated so they are received within the VV's dynamic range. The VV ASM will be recorded. The joint test shall be considered successful when it shows the VV reports that it has valid ASMs for all applicable combinations of symbol rate, modulation, and spreading.

Rationale: Verification of decoding by inspection of lower-level test data is appropriate because the decoding can be determined at a lower level by the VV without the CLD. Verification of decoding by joint test is necessary to include the cascade effect of all hardware and software.

4.2.3.3.11 BASEBAND WAVEFORM

- A. The DESTINATION transmission of an NRZ-L baseband waveform for the C3DL forward link shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION uses an NRZ-L waveform for the C3DL forward link.

Rationale: Verification of usage of NRZ-L by inspection of lower-level test data is appropriate because usage of NRZ-L can be determined at a lower-level by the DESTINATION without the VV.

- B. The VV reception of an NRZ-L baseband waveform for the C3DL forward link shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV uses an NRZ-L waveform for the C3DL forward link.

Rationale: Verification of usage of NRZ-L by inspection of lower-level test data is appropriate because usage of NRZ-L can be determined at a lower-level by the VV without the CLD.

4.2.3.3.12 LATENCY

The DESTINATION introduction of less than 500 ms and the VV introduction of less than 749 ms of latency (max total latency: 1,249 ms) for the C3DL forward link from the time the last bit of a data unit enters the DESTINATION to the time the first data unit that ends in the CADU is extracted by the VV shall be verified by joint test. A joint test will be performed using the VV and the CLD. The verification shall be considered successful when the joint test shows the total latency from the DESTINATION to the VV is less than 1,249 ms.

Rationale: Verification of latency by joint test is necessary to include the cascade effect of all hardware and software. Verification of latency by joint test is necessary because it is impractical to measure the one-sided (transmit only, receive only) latency.

4.2.4 VV TO DESTINATION C3DL RETURN LINK REQUIREMENTS

4.2.4.1 SPECTRUM REQUIREMENTS

4.2.4.1.1.1 FREQUENCY

- A. The VV transmission of the C3DL return link at the assigned frequency shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV transmits the assigned frequency.

Rationale: Verification of transmit frequency by inspection of lower-level test data is appropriate because the transmit frequency can be determined at a lower-level by the VV without the CLD.

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- B. The DESTINATION reception of the C3DL return link at the assigned frequency shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION receives the assigned frequency.

Rationale: Verification of receive frequency by inspection of lower-level test data is appropriate because the receive frequency can be determined at a lower-level by the DESTINATION without the VV.

4.2.4.1.2 BANDWIDTH

- A. The VV transmission of the C3DL return link at the 72 ksps symbol rate with a bandwidth less than or equal to 46 kHz shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV uses a 99 percent power transmit bandwidth less than or equal to 46 kHz for the C3DL 72 ksps return link.

Rationale: Verification of transmit bandwidth by inspection of lower-level test data is appropriate because the transmit bandwidth can be determined at a lower-level by the VV without the CLD.

- B. The VV transmission of the C3DL return link signal at the 144 ksps symbol rate with a bandwidth less than or equal to 92 kHz shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV uses a 99 percent power transmit bandwidth less than or equal to 92 kHz for the C3DL 144 ksps return link.

Rationale: Verification of transmit bandwidth by inspection of lower-level test data is appropriate because the transmit bandwidth can be determined at a lower-level by the VV without CLD.

4.2.4.2 RADIO FREQUENCY REQUIREMENTS

4.2.4.2.1 SYMBOL RATE

- A. The VV transmission of the C3DL return link symbol rates listed in Table 3.4.2.1-1 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV produces all of the symbol rates in Table 3.4.2.1-1.

Rationale: Verification of transmit symbol rate by inspection of lower-level test data is appropriate because the transmit symbol rate can be determined at a lower-level by the VV without the CLD.

- B. The DESTINATION reception of the C3DL return link symbol rates listed in Table 3.4.2.1-1 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION receives all of the symbol rates in Table 3.4.2.1-1.

Rationale: Verification of receive symbol rate by inspection of lower-level test data is appropriate because the receive symbol rate can be determined at a lower-level by the DESTINATION without the VV.

4.2.4.2.2 MODULATION

- A. The VV transmission of the C3DL return link using Filtered OQPSK modulation with the characteristics listed in Table 3.4.2.2-1 shall be verified by inspection and joint test. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the VV uses Filtered OQPSK modulation with the characteristics listed in Table 3.4.2.2-1. A joint test will be performed using the DESTINATION and the VV. The VV will transmit the C3DL return link using each symbol rate and Filtered OQPSK modulation with the characteristics listed in Table 3.4.2.2-1. The transmitted signals will be attenuated so they are received within the CLD's dynamic range. The DESTINATION lock indicators will be recorded. The joint test shall be considered successful when it shows the DESTINATION reports that it has lock for each symbol rate.

Rationale: Verification of modulation by inspection of lower-level test data is appropriate because the modulation can be determined at a lower-level by the VV without the CLD. Verification of modulation by joint test is necessary to include the cascade effect of all hardware and software.

- B. The DESTINATION reception of the Filtered OQPSK modulated C3DL return link with the characteristics listed in Table 3.4.2.2-1 shall be verified by inspection and joint test. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the DESTINATION demodulates the Filtered OQPSK modulation with the characteristics listed in Table 3.4.2.2-1 and produces valid lock indicators. A joint test will be performed using the VV. The VV will transmit the C3DL return link using Filtered OQPSK with the characteristics listed in Table 3.4.2.2-1. The transmitted signals will be attenuated so they are received within CLD's dynamic range. The DESTINATION lock indicators will be recorded. The joint test shall be considered successful when it shows the DESTINATION reports that it has lock for each symbol rate.

Rationale: Verification of demodulation by inspection of lower-level test data is appropriate because the demodulation can be determined at a lower-level by the DESTINATION without the VV. Verification of demodulation by joint test is necessary to include the cascade effect of all hardware and software.

4.2.4.2.3 POLARIZATION

- A. The VV transmission of the C3DL return link using RHCP shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV transmits the C3DL return link using RHCP.

Rationale: Verification of polarization by inspection of lower-level test data is appropriate because polarization can be determined at a lower-level by the VV without the CLD.

- B. The DESTINATION reception of the C3DL return link using RHCP shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows DESTINATION receives the C3DL return link using RHCP.

Rationale: Verification of polarization by inspection of lower-level test data is appropriate because polarization can be determined at a lower-level by the DESTINATION without the VV.

4.2.4.2.4 MINIMUM POWER AT CLD

The VV production of an RF signal with a received power at an isotropic antenna at the DESTINATION antenna locations no less than the values in Table 3.4.2.4-1 for the C3DL return link shall be verified by inspection. An inspection of the lower-level analysis of test data will be performed. The verification shall be considered successful when the inspection shows that the VV produces an RF signal with a received power at an isotropic antenna at the DESTINATION antenna locations for the C3DL return link no less than the values in Table 3.4.2.4-1.

Rationale: Verification of production of an RF signal with a received power at an isotropic antenna at the DESTINATION antenna locations by inspection of lower-level analysis is appropriate because the received power can be determined using only the transmit side of the link and so it can be determined at a lower level by the VV without the CLD. Lower-level measured data for EIRP or lower-level analysis of measured antenna gain, cable loss, and transmit power or lower level test data for the EIRP can be used with the calculated space loss to determine the received power.

4.2.4.2.5 TRANSMIT SIGNAL PARAMETERS

The VV transmission of a signal with an EVM no greater than 10 percent shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV produces an EVM no greater than 10 percent.

Rationale: Verification of EVM by inspection of lower-level test data is appropriate because EVM can be determined at a lower-level by the VV without the CLD.

4.2.4.2.6 CODE WORD ERROR RATE

The DESTINATION provision of a CWER no greater than 4×10^{-7} when the VV meets its EVM and provides a received power at a 0 dB gain (isotropic) DESTINATION antenna no less than the values in Table 3.4.2.4-1 shall be verified by joint test and analysis. A joint test will be performed using the VV and the CLD. The VV will transmit the C3DL return link at each symbol rate, encryption, and modulation combination. Operational packet data or a pseudorandom bit pattern of 32,767-bits or longer will be used, with appropriate forward error correction coding applied. The Doppler effect on the received signal will be taken into account, and both zero Doppler and the worst-case Doppler will be used. The transmitted signals will be attenuated so they are received at the DESTINATION at received power levels associated with measurable CWERs. The received data will be compared with the transmitted data, and the CWER will be measured with 95 percent confidence level for each symbol rate, and modulation combination. If joint tests cannot be run long enough to measure the CWER at the specified received power, analysis will be performed to extend the measured CWER results to determine the CWER at the specified received power. The verification shall be considered successful when the joint test and analysis shows the DESTINATION provides a CWER no more than 4×10^{-7} for each symbol rate, encryption, and modulation combination with 95 percent confidence level when the VV provides the specified received power.

Rationale: Verification of CWER by joint test is necessary to include the cascade effect of all hardware and software. Verification of CWER by analysis is necessary if the joint test time for the CWER is prohibitively long.

4.2.4.3 BASEBAND REQUIREMENTS

4.2.4.3.1 VIRTUAL CHANNEL DATA

4.2.4.3.1.1 VV COMMANDS

- A. The VV insertion of the VV Commands for the C3DL return link into CCSDS Space Packets with the characteristics in Table 3.3.3.1.1-1 as specified in CCSDS 133.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV inserts the VV Commands into CCSDS Space Packets.

Rationale: Verification of insertion of VV Commands by inspection of lower-level test data is appropriate because insertion of VV Commands can be determined at a lower-level by the VV without the CLD.

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- B. The DESTINATION extraction of the VV Commands from the C3DL return link from CCSDS Space Packets with the characteristics in Table 3.3.3.1.1-1 as specified in CCSDS 133.0-B-2 shall be verified by joint test. A joint test will be performed using the DESTINATION and the VV. The verification shall be considered successful when the joint test shows the DESTINATION extracts the VV Commands from CCSDS Space Packets.

Rationale: Verification of extraction of VV Commands by joint test is necessary to include the cascade effect of all hardware and software.

4.2.4.3.1.2 VV TELEMETRY

- A. The VV insertion of the VV Telemetry for the C3DL return link into CCSDS space packets with the characteristics in Table 3.3.3.1.1-1 as specified in CCSDS 133.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV inserts the VV Telemetry into CCSDS Space Packets.

Rationale: Verification of insertion of VV Telemetry into CCSDS space packets by inspection of lower-level test data is appropriate because insertion of VV Telemetry in CCSDS space packets can be determined at a lower-level by the VV without the CLD.

- B. The DESTINATION extraction of the VV Telemetry from the C3DL return link from CCSDS Space Packets with the characteristics in Table 3.3.3.1.1-1 as specified in CCSDS 133.0-B-2 shall be verified by joint test. A joint test will be performed using the DESTINATION and the VV. The verification shall be considered successful when the joint test shows the DESTINATION extracts the VV Telemetry from CCSDS Space Packets.

Rationale: Verification of extraction of VV Telemetry by joint test is necessary to include the cascade effect of all hardware and software.

4.2.4.3.1.3 VV AUDIO

- A. The VV sending VV audio consisting of a 96-bit RTP header in accordance with IETF RFC 3550 and IETF RFC 3551 and ten 80-bit 10 ms G.729 audio frames in accordance with ITU-T G.729 on the C3DL return link to the DESTINATION shall be verified by inspection. An inspection of lower-level test data will be performed. The VV will transmit VV audio on the C3DL return link. All applicable combinations of symbol rate, encryption, and modulation will be used. The inspection shall be considered successful when it shows the VV transmits audio consisting of a 96-bit RTP header in accordance with IETF RFC 3550 and IETF RFC 3551 and ten 80-bit 10 ms G.729 audio frames in accordance with ITU-T G.729.

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Rationale: Verification of VV audio formats by inspection of lower-level test data is appropriate because the use of VV audio formats can be determined at a lower-level by the VV without the CLD.

- B. The DESTINATION reception of VV audio consisting of a 96-bit RTP header in accordance with IETF RFC 3550 and IETF RFC 3551 and ten 80-bit 10 ms G.729 audio frames in accordance with ITU-T G.729 on the C3DL return link from the VV shall be verified by joint test. A joint test will be performed using the VV and the CLD. The VV will transmit VV audio on the C3DL return link. All applicable combinations of symbol rate, encryption, and modulation will be used. The transmitted signals will be attenuated so they are received within CLD's dynamic range. The received VV audio data will be compared with the transmitted VV audio data. The joint test shall be considered successful when it shows the DESTINATION receives VV audio data with an error rate in compliance with the CWER specified in Paragraph 3.4.2.6-1 for all applicable combinations of symbol rate, encryption, and modulation.

Rationale: Verification of VV audio reception by test is necessary to include the cascade effect of all hardware and software.

4.2.4.3.2 VIRTUAL CHANGE PACKAGING

4.2.4.3.2.1 CCSDS SPACE PACKETS FOR UNENCRYPTED VIRTUAL CHANNELS

4.2.4.3.2.1.1 CCSDS SPACE PACKETS MULTIPLEXING PROTOCOL DATA UNITS FOR UNENCRYPTED VIRTUAL CHANNELS

- A. The VV insertion of the CCSDS Space Packets for unencrypted virtual channels on the C3DL return link into M_PDUs with the characteristics in Table 3.4.3.2.1.1-1 as specified in CCSDS 732.0-B-4 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV inserts the CCSDS Space Packets into M_PDUs with the characteristics in Table 3.4.3.2.1.1-1 as specified in CCSDS 732.0-B-4.

Rationale: Verification of insertion of CCSDS Space Packets into M_PDUs by inspection of lower-level test data is appropriate because insertion of CCSDS Space Packets into M_PDUs can be determined at a lower-level by the VV without the CLD.

- B. The DESTINATION extraction of the received CCSDS Space Packets from unencrypted virtual channels on the C3DL return link from the M_PDUs with the characteristics in Table 3.4.3.2.1.1-1 as specified in CCSDS 732.0-B-4 shall be verified by joint test. A joint test will be performed using the VV and the CLD. The verification shall be considered successful when the joint test shows the DESTINATION extracts the CCSDS Space Packets from M_PDUs with the characteristics in Table 3.4.3.2.1.1-1 as specified in CCSDS 732.0-B-4.

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Rationale: Verification of extraction of the received CCSDS Space Packets from M_PDUs by test is necessary to include the cascade effect of all hardware and software.

- C. The VV generation of an Idle Space Packet as specified in CCSDS 732.0-B-4 and CCSDS 133.0-B-2 when insufficient CCSDS Space Packets are available to fill the M_PDU Packet Zone for unencrypted virtual channels on the C3DL return link shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV generates Idle Space Packets as specified in CCSDS 732.0-B-4 and CCSDS 133.0-B-2 when insufficient CCSDS Space Packets are available to fill the M_PDU Packet Zone for unencrypted channels on the C3DL return link.

Rationale: Verification of generation of Idle Space Packets by inspection of lower-level test data is appropriate because generation of Idle Space Packets can be determined at a lower-level by the VV without the CLD.

- D. The DESTINATION removal of Idle Space Packets as specified in CCSDS 732.0-B-4 from the received M_PDUs for unencrypted virtual channels on the C3DL return link shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION removes Idle Space Packets as specified in CCSDS 732.0-B-4 from the received M_PDUs.

Rationale: Verification of removal of Idle Space Packets by inspection of lower-level test data is appropriate because removal of Idle Space Packets can be determined at a lower-level by the DESTINATION without the VV.

- E. The VV generation of an Idle M_PDU as specified in CCSDS 732.0-B-4 when no CCSDS Space Packets are available for unencrypted virtual channels on the C3DL return link shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV generates Idle M_PDUs as specified in CCSDS 732.0-B-4 when no CCSDS Space Packets are available for unencrypted virtual channels on the C3DL return link.

Rationale: Verification of generation of Idle M_PDUs by inspection of lower-level test data is appropriate because generation of Idle M_PDUs can be determined at a lower-level by the VV without the CLD.

- F. The DESTINATION removal of Idle M_PDUs as specified in CCSDS 732.0-B-4 from the received M_PDUs for unencrypted virtual channels on the C3DL return link shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION removes Idle M_PDUs as specified in CCSDS 732.0-B-4 from the received M_PDUs.

Rationale: Verification of removal of Idle M_PDUs by inspection of lower-level test data is appropriate because removal of Idle M_PDUs can be determined at a lower-level by the DESTINATION without the VV.

4.2.4.3.2.1.2 SECURITY HEADER

- A. The VV addition of a security header to the M_PDUs for unencrypted virtual channels on the C3DL return link with the fields listed in Table 3.4.3.2.1.2-1 as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the VV adds the specified security header to the M_PDUs for unencrypted virtual channels on the C3DL return link.

Rationale: Verification of addition of a security header by inspection of lower-level test data is appropriate because addition of a security header can be determined at a lower-level by the VV without the CLD.

- B. The DESTINATION extraction of a security header from before the M_PDUs for unencrypted virtual channels on the C3DL return link with the fields listed in Table 3.4.3.2.1.2-1 as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the DESTINATION extracts the specified security header from before the M_PDUs for unencrypted virtual channels on the C3DL return link.

Rationale: Verification of extraction of a security header by inspection of lower-level test data is appropriate because extraction of a security header can be determined at a lower-level by the DESTINATION without the VV.

4.2.4.3.2.1.3 SECURITY TRAILER

- A. The VV addition of a 96-bit security trailer to the M_PDUs for unencrypted virtual channels on the C3DL return link as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the VV adds the specified security trailer to the M_PDUs for unencrypted virtual channels on the C3DL return link.

Rationale: Verification of addition of a security trailer by inspection of lower-level test data is appropriate because addition of a security trailer can be determined at a lower-level by the VV without the CLD.

- B. The DESTINATION extraction of a 96-bit security trailer from after the M_PDUs for unencrypted virtual channels on the C3DL return link as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the DESTINATION extracts the specified security trailer from after the M_PDUs for unencrypted virtual channels on the C3DL return link.

Rationale: Verification of extraction of a security trailer by inspection of lower-level test data is appropriate because extraction of a security trailer can be determined at a lower-level by the DESTINATION without the VV.

4.2.4.3.2.2 CCSDS SPACE PACKETS VIRTUAL CHANNELS FOR ENCRYPTED VIRTUAL CHANNELS

4.2.4.3.2.2.1 CCSDS SPACE PACKETS MULTIPLEXING PROTOCOL DATA UNITS FOR ENCRYPTED VIRTUAL CHANNELS

- A. The VV insertion of the CCSDS Space Packets for encrypted virtual channels on the C3DL return link into M_PDUs with the characteristics in Table 3.4.3.2.2.1-1 as specified in CCSDS 732.0-B-4 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV inserts the CCSDS Space Packets into M_PDUs with the characteristics in Table 3.4.3.2.2.1-1 as specified in CCSDS 732.0-B-4.

Rationale: Verification of insertion of Encrypted CCSDS Space Packets into M_PDUs by inspection of lower-level test data is appropriate because insertion of Encrypted CCSDS Space Packets into M_PDUs can be determined at a lower-level by the VV without the CLD.

- B. The DESTINATION extraction of the received CCSDS Space packets from encrypted virtual channels on the C3DL return link from the M_PDUs with the characteristics in Table 3.4.3.2.2.1-1 as specified in CCSDS 732.0-B-4 shall be verified by joint test. A joint test will be performed using the DESTINATION and the VV. The verification shall be considered successful when the inspection shows the DESTINATION extracts the Encrypted CCSDS Space Packets from M_PDUs with the characteristics in Table 3.4.3.2.2.1-1 as specified in CCSDS 732.0-B-4.

Rationale: Verification of extraction of received Encrypted CCSDS Space Packets from M_PDUs by joint test is necessary to include the cascade effect of all hardware and software.

- C. The VV generation of an Idle Space Packet as specified in CCSDS 732.0-B-4 and CCSDS 133.0-B-2 when insufficient CCSDS Space Packets are available to fill the M_PDU Packet Zone for encrypted virtual channels on the C3DL return link shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV generates Idle Space Packets as specified in CCSDS 732.0-B-4 and CCSDS 133.0-B-2 when insufficient CCSDS Space Packets are available to fill the M_PDU Packet Zone for encrypted virtual channels on the C3DL return link.

Rationale: Verification of generation of Idle Space Packets by inspection of lower-level test data is appropriate because generation of Idle Space Packets can be determined at a lower-level by the VV without the CLD.

- D. The DESTINATION removal of Idle Space Packets as specified in CCSDS 732.0-B-4 from the received M_PDUs for encrypted virtual channels on the C3DL return link shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION removes Idle Space Packets as specified in CCSDS 732.0-B-4 from the received M_PDUs for encrypted virtual channels on the C3DL return link.

Rationale: Verification of removal of Idle Space Packets by inspection of lower-level test data is appropriate because removal of Idle Space Packets can be determined at a lower-level by the DESTINATION without the VV.

- E. The VV generation of an Idle M_PDU as specified in CCSDS 732.0-B-4 when no CCSDS Space Packets are available for encrypted virtual channels on the C3DL return link shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV generates Idle M_PDUs as specified in CCSDS 732.0-B-4 when no CCSDS Space Packets are available for encrypted virtual channels on the C3DL return link.

Rationale: Verification of generation of Idle M_PDUs by inspection of lower-level test data is appropriate because generation of Idle M_PDUs can be determined at a lower-level by the VV without the CLD.

- F. The DESTINATION removal of Idle M_PDUs as specified in CCSDS 732.0-B-4 from the received M_PDUs on encrypted virtual channels on the C3DL return link shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION removes Idle M_PDUs as specified in CCSDS 732.0-B-4 from the received M_PDUs on encrypted virtual channels on the C3DL return link.

Rationale: Verification of removal of Idle M_PDUs by inspection of lower-level test data is appropriate because removal of Idle M_PDUs can be determined at a lower-level by the DESTINATION without the VV.

4.2.4.3.2.2 MULTIPLEXING PROTOCOL DATA UNIT ENCRYPTION

- A. The VV encryption of the Multiplexing Protocol Data Units for virtual channels configured to be encrypted on the C3DL return link shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the VV encrypts M_PDUs for virtual channels configured to be encrypted on the C3DL return link.

Rationale: Verification of encryption of M_PDUs by inspection of lower-level test data is appropriate because encryption of M_PDUs can be determined at a lower-level by the VV without the CLD.

- B. The DESTINATION decryption of the Multiplexing Protocol Data Units for virtual channels configured to be encrypted on the C3DL return link shall be verified by joint test. A joint test will be performed using the VV and the CLD. The VV will encrypt M_PDUs and transmit the encrypted M_PDUs on the C3DL return link. A representative range of data values and types will be used. All applicable combinations of symbol rate, and modulation will be used. The transmitted signals will be attenuated so they are received within the CLD's dynamic range. The received encrypted M_PDUs will be decrypted and compared with the transmitted M_PDUs. The joint test shall be considered successful when it shows the DESTINATION receives M_PDUs with an error rate in compliance with the CWER specified in Paragraph 3.4.2.6-1 for all applicable combinations of symbol rate, and modulation.

Rationale: Verification of decryption of M_PDUs by joint test is necessary to include the cascade effect of all hardware and software.

4.2.4.3.2.2.3 SECURITY HEADER

- A. The VV addition of a security header to the encrypted M_PDUs for encrypted virtual channels on the C3DL return link with the fields listed in Table 3.4.3.2.2.3-1 as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the VV adds the specified security header to the encrypted M_PDUs for encrypted virtual channels on the C3DL return link.

Rationale: Verification of addition of a security header by inspection of lower-level test data is appropriate because addition of a security header can be determined at a lower-level by the VV without the CLD.

- B. The DESTINATION extraction of a security header from before the encrypted M_PDUs for encrypted virtual channels on the C3DL return link with the fields listed in Table 3.4.3.2.2.3-1 as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the DESTINATION extracts the specified security header from before the encrypted M_PDUs for encrypted virtual channels on the C3DL return link.

Rationale: Verification of extraction of a security header by inspection of lower-level test data is appropriate because extraction of a security header can be determined at a lower-level by the DESTINATION without the VV.

4.2.4.3.2.4 SECURITY TRAILER

- A. The VV addition of a 96-bit security trailer to the encrypted M_PDUs for encrypted virtual channels on the C3DL return link as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the VV adds the specified security trailer to the encrypted M_PDUs for encrypted virtual channels on the C3DL return link.

Rationale: Verification of addition of a security trailer by inspection of lower-level test data is appropriate because addition of a security trailer can be determined at a lower-level by the VV without the CLD.

- B. The DESTINATION extraction of a 96-bit security trailer from after the encrypted M_PDUs for encrypted virtual channels on the C3DL return link as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the DESTINATION extracts the specified security trailer from after the encrypted M_PDUs for encrypted virtual channels on the C3DL return link.

Rationale: Verification of extraction of a security trailer by inspection of lower-level test data is appropriate because extraction of a security trailer can be determined at a lower-level by the DESTINATION without the VV.

4.2.4.3.2.3 G.729 AUDIO FOR UNENCRYPTED VIRTUAL CHANNELS

4.2.4.3.2.3.1 VV AUDIO VCA_SDU FOR UNENCRYPTED VIRTUAL CHANNELS

- A. The VV insertion of the VV audio and fill for unencrypted virtual channels on the C3DL return link into a VCA_SDU with the characteristics in Table 3.4.3.2.3.1-1 as specified in CCSDS 732.0-B-4 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV inserts the VV audio into a VCA_SDU with the characteristics in Table 3.4.3.2.3.1-1 specified in CCSDS 732.0-B-4.

Rationale: Verification of insertion of VV audio into VCA_SDUs by inspection of lower-level test data is appropriate because insertion of VV audio into VCA_SDUs can be determined at a lower-level by the VV without the CLD.

- B. The DESTINATION extraction of the received VV audio from unencrypted virtual channels on the C3DL return link from the VCA_SDUs with the characteristics in Table 3.4.3.2.3.1-1 as specified in CCSDS 732.0-B-4 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION extracts the VV audio from the VCA_SDUs with the characteristics in Table 3.4.3.2.3.1-1 as specified in CCSDS 732.0-B-4.

Rationale: Verification of extraction of VV audio from the VCA_SDUs by inspection of lower-level test data is appropriate because extraction of VV audio from the VCA_SDUs can be determined at a lower-level by the DESTINATION without the VV.

4.2.4.3.2.3.2 SECURITY HEADER

- A. The VV addition of a security header to the VCA_SDUs for unencrypted virtual channels on the C3DL return link with the fields listed in Table 3.4.3.2.3.2-1 as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the VV adds the specified security header to the VCA_SDUs for unencrypted virtual channels on the C3DL return link.

Rationale: Verification of addition of a security header by inspection of lower-level test data is appropriate because addition of a security header can be determined at a lower-level by the VV without the CLD.

- B. The DESTINATION extraction of a security header from before the VCA_SDUs for unencrypted virtual channels on the C3DL return link with the fields listed in Table 3.4.3.2.3.2-1 as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the DESTINATION extracts the specified security header before the VCA_SDUs for unencrypted virtual channels on the C3DL return link.

Rationale: Verification of extraction of a security header by inspection of lower-level test data is appropriate because extraction of a security header can be determined at a lower-level by the DESTINATION without the VV.

4.2.4.3.2.3.3 SECURITY TRAILER

- A. The VV addition of a 96-bit security trailer to the VCA_SDUs for unencrypted virtual channels on the C3DL return link as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the VV adds the specified security trailer to the VCA_SDUs for unencrypted virtual channels on the C3DL return link.

Rationale: Verification of addition of a security trailer by inspection of lower-level test data is appropriate because addition of a security trailer can be determined at a lower-level by the VV without the CLD.

- B. The DESTINATION extraction of a 96-bit security trailer from after the VCA_SDUs for unencrypted virtual channels on the C3DL return link as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the DESTINATION extracts the specified security trailer from after the VCA_SDUs for unencrypted virtual channels on the C3DL return link.

Rationale: Verification of extraction of a security trailer by inspection of lower-level test data is appropriate because extraction of a security trailer can be determined at a lower-level by the DESTINATION without the VV.

4.2.4.3.2.4 G.729 AUDIO FOR ENCRYPTED VIRTUAL CHANNELS

4.2.4.3.2.4.1 VV AUDIO VCA_SDUs FOR ENCRYPTED VIRTUAL CHANNELS

- A. The VV insertion of the VV audio for encrypted virtual channels on the C3DL return link into a VCA_SDU with the characteristics in Table 3.4.3.2.4.1-1 as specified in CCSDS 732.0-B-4 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV inserts the VV audio into a VCA_SDU with the characteristics in Table 3.4.3.2.4.1-1 as specified in CCSDS 732.0-B-4.

Rationale: Verification of insertion of VV audio into VCA_SDUs by inspection of lower-level test data is appropriate because insertion of VV audio into VCA_SDUs can be determined at a lower-level by the VV without the CLD.

- B. The DESTINATION extraction of the received VV audio from encrypted virtual channels on the C3DL return link from the VCA_SDUs with the characteristics in Table 3.4.3.2.4.1-1 as specified in CCSDS 732.0-B-4 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION extracts the VV audio from the VCA_SDUs with the characteristics in Table 3.4.3.2.4.1-1 as specified in CCSDS 732.0-B-4.

Rationale: Verification of extraction of VV audio from the VCA_SDUs by inspection of lower-level test data is appropriate because extraction of VV audio from the VCA_SDUs can be determined at a lower-level by the DESTINATION without the VV.

4.2.4.3.2.4.2 VCA_SDU ENCRYPTION

- A. The VV encryption of the VCA_SDUs for virtual channels configured to be encrypted on the C3DL return link shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the VV encrypts VCA_SDUs for virtual channels configured to be encrypted on the C3DL return link.

Rationale: Verification of encryption of VCA_SDUs by inspection of lower-level test data is appropriate because encryption of VCA_SDUs can be determined at a lower-level by the VV without the CLD.

- B. The DESTINATION decryption of the VCA_SDUs for virtual channels configured to be encrypted on the C3DL return link shall be verified by joint test. A joint test will be performed using the VV and the CLD. The VV will encrypt VCA_SDUs and transmit the encrypted VCA_SDUs on the C3DL return link. A representative range of data values and types will be used. All applicable combinations of symbol rate, and modulation will be used. The transmitted signals will be attenuated so they are received within the CLD's dynamic range. The received encrypted VCA_SDUs will be decrypted and compared with the transmitted VCA_SDUs. The joint test shall be considered successful when it shows the DESTINATION receives VCA_SDUs with an error rate in compliance with the CWER specified in Paragraph 3.4.2.6-1 for all applicable combinations of symbol rate, and modulation.

Rationale: Verification of decryption of VCA_SDUs by inspection of lower-level test data is appropriate because decryption of VCA_SDUs can be determined at a lower-level by the DESTINATION without the VV. Verification of decryption of VCA_SDUs by joint test is necessary to include the cascade effect of all hardware and software.

4.2.4.3.2.4.3 SECURITY HEADER

- A. The VV addition of a security header to the encrypted VCA_SDUs for encrypted virtual channels on the C3DL return link with the fields listed in Table 3.4.3.2.4.3-1 as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the VV adds the specified security header to the encrypted VCA_SDUs for encrypted virtual channels on the C3DL return link.

Rationale: Verification of addition of a security header by inspection of lower-level test data is appropriate because addition of a security header can be determined at a lower-level by the VV without the CLD.

- B. The DESTINATION extraction of a security header from before the encrypted VCA_SDUs for encrypted virtual channels on the C3DL return link with the fields listed in Table 3.4.3.2.4.3-1 as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the DESTINATION extracts the specified security header from before the encrypted VCA_SDUs for encrypted virtual channels on the C3DL return link.

Rationale: Verification of extraction of a security header by inspection of lower-level test data is appropriate because extraction of a security header can be determined at a lower-level by the DESTINATION without the VV.

4.2.4.3.2.4.4 SECURITY TRAILER

- A. The VV addition of a 96-bit security trailer to the encrypted VCA_SDUs for encrypted virtual channels on the C3DL return link as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the VV adds the specified security trailer to the encrypted VCA_SDUs for encrypted virtual channels on the C3DL return link.

Rationale: Verification of addition of a security trailer by inspection of lower-level test data is appropriate because addition of a security trailer can be determined at a lower-level by the VV without the CLD.

- B. The DESTINATION extraction of a 96-bit security trailer from after the encrypted VCA_SDUs for encrypted virtual channels on the C3DL return link as specified in CCSDS 355.0-B-2 shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the DESTINATION extracts the specified security trailer from after the encrypted VCA_SDUs for encrypted virtual channels on the C3DL return link.

Rationale: Verification of placement of a Frame Count in the Insert Zone by inspection of lower-level test data is appropriate because placement of a Frame Count in the Insert Zone can be determined at a lower-level by the VV without the CLD.

4.2.4.3.3 VIRTUAL CHANNEL DATA UNIT INSERT ZONE

- A. The VV placement of the latest Frame Count received from the C3DL forward link in the VCDU 16-bit Insert Zone for the VCDUs on the C3DL return link as shown in Table 3.4.3.3-1 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV places the latest Frame Count received from the C3DL forward link in the VCDU 16-bit Insert Zone for VCDUs on the C3DL return link as shown in Table 3.4.3.3-1.

Rationale: Verification of placement of a Frame Count in the Insert Zone by inspection of lower-level test data is appropriate because placement of a Frame Count in the Insert Zone can be determined at a lower-level by the VV without the CLD.

- B. The DESTINATION extraction of the Frame Count from the VCDU 16-bit Insert Zone for the received VCDUs on the C3DL return link as shown in Table 3.4.3.3-1 shall be verified by joint test. A joint test will be performed using the VV and the CLD. The VV will transmit representative Frame Counts on the C3DL return link. All applicable combinations of virtual channel usage, symbol rate, and modulation will be used. The transmitted signals will be attenuated so they are received within CLD's dynamic range. The received Frame Counts will be compared with the transmitted Frame Counts. The joint test shall be considered successful when it shows the DESTINATION extracts Frame Counts with an error rate in compliance with the CWER specified in Paragraph 3.4.2.6-1 for all applicable combinations of symbol rate and modulation.

Rationale: Verification of extraction of Frame Counts from the Insert Zone of the VCDU by joint test is necessary to include the cascade effect of all hardware and software.

4.2.4.3.4 VIRTUAL CHANNEL DATA UNITS

- A. The VV placement of the Virtual Channel Data Zones and Insert Zones for the C3DL return link in 1760-bit VCDUs with the characteristics in Table 3.4.3.4-1 with the VCDU Header structure in Figure 3.4.3.4-1 and Table 3.4.3.4-2 as specified in CCSDS 732.0-B-4 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV places the VCDU Data Zones and Insert Zones into 1760-bit VCDUs with the characteristics in Table 3.4.3.4-1 with the VCDU Header structure in Figure 3.4.3.4-1 and Table 3.4.3.4-2.

Rationale: Verification of placement of the VCDU Data Zones and Insert Zones into VCDUs by inspection of lower-level test data is appropriate because placement of the VCDU Data Zones and Insert Zones into VCDUs can be determined at a lower-level by the VV without the CLD.

- B. The DESTINATION extraction of the received Virtual Channel Data Zones and Insert Zones from the C3DL return link from the 1760-bit VCDUs with the characteristics in Table 3.4.3.4-1 with the VCDU Header structure in Figure 3.4.3.4-1 and Table 3.4.3.4-2 as specified in CCSDS 732.0-B-4 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION extracts the VCDU Data Zones and Insert Zones from the 1760-bit VCDU with the characteristics in Table 3.4.3.4-1 with the VCDU Header structure in Figure 3.4.3.4-1 and Table 3.4.3.4-2.

Rationale: Verification of extraction of the VCDU Data Zones and Insert Zones from the VCDUs by inspection of lower-level test data is appropriate because extraction of the

VCDU Data Zones and Insert Zones from the VCDUs can be determined at a lower-level by the DESTINATION without the VV.

4.2.4.3.5 VIRTUAL CHANGE MULTIPLEXING

- A. The VV multiplexing the VCDUs for the C3DL return link shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV multiplexes the VCDUs for the C3DL return link.

Rationale: Verification of VCDU multiplexing by inspection of lower-level test data is appropriate because VCDU multiplexing can be determined at a lower-level by the VV without the CLD.

- B. The DESTINATION demultiplexing the received VCDUs from the C3DL return link using the VCID in the VCDU header shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION demultiplexes the received VCDUs from the C3DL return link using the VCID in the VCDU header.

Rationale: Verification of VCDU demultiplexing by inspection of lower-level test data is appropriate because VCDU demultiplexing can be determined at a lower-level by the DESTINATION without the VV.

- C. The VV creation of Idle VCDUs for the C3DL return link when no data is available as described in CCSDS 732.0-B-4 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV creates Idle VCDUs for the C3DL return link when no data is available.

Rationale: Verification of creating Idle VCDUs by inspection of lower-level test data is appropriate because creating Idle VCDUs can be determined at a lower-level by the VV without the CLD.

- D. The DESTINATION removal of the received Idle VCDUs from the VCDUs on the C3DL return link as described in CCSDS 732.0-B-4 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION removes the received Idle VCDUs from the C3DL return link.

Rationale: Verification of removal of Idle VCDUs by inspection of lower-level test data is appropriate because removal of Idle VCDUs can be determined at a lower-level by the DESTINATION without the VV.

4.2.4.3.6 REED SOLOMON CODING

- A. The VV encoding the VCDUs for the C3DL return link using a (252, 220) shortened Reed Solomon Code with an interleave depth of 1 as specified in CCSDS 131.0-B-5 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV encodes the VCDUs for the C3DL return link using a (252, 220) shortened Reed Solomon Code with an interleave depth of 1 as specified in CCSDS 131.0-B-5.

Rationale: Verification of encoding using Reed Solomon coding by inspection of lower-level test data is appropriate because encoding using Reed Solomon coding can be determined at a lower-level by the VV without the CLD.

- B. The DESTINATION decoding the received VCDUs from the C3DL return link using a (252, 220) shortened Reed Solomon Code with an interleave depth of 1 as specified in CCSDS 131.0-B-5 shall be verified by inspection and joint test. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the DESTINATION decodes the VCDUs. A joint test will be performed using the VV. The VV will transmit the C3DL return link using all applicable combinations of symbol rate, and modulation. The data used for these tests will be representative of mission data or a rigorously selected set of test codewords. The transmitted signals will be attenuated so they are received within CLD's dynamic range. The DESTINATION CWER will be recorded. The joint test shall be considered successful when it shows the DESTINATION CWER complies with the CWER requirement specified in Paragraph 3.4.2.6-1 for all applicable combinations of symbol rate and modulation.

Rationale: Verification of decoding by inspection of lower-level test data is appropriate because the decoding can be determined at a lower-level by the DESTINATION without the VV. Verification of decoding by joint test is necessary to include the cascade effect of all hardware and software.

4.2.4.3.7 RANDOMIZATION

- A. The VV randomizing the coded VCDUs for the C3DL return link as specified in CCSDS 131.0-B-5 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV randomizes the VCDUs for the C3DL return link as specified in CCSDS 131.0-B-5.

Rationale: Verification of randomization by inspection of lower-level test data is appropriate because randomization can be determined at a lower-level by the VV without the CLD.

- B. The DESTINATION derandomizing the received coded VCDUs from the C3DL return link as specified in CCSDS 131.0-B-5 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION derandomizes the received coded VCDUs from the C3DL return link as specified in CCSDS 131.0-B-5.

Rationale: Verification of derandomization by inspection of lower-level test data is appropriate because derandomization can be determined at a lower-level by the DESTINATION without the VV.

4.2.4.3.8 ATTACHED SYNC MARKER

- A. The VV application of the 32-bit ASM to the coded randomized VCDUs for the C3DL return link as specified in CCSDS 131.0-B-5 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV applies a 32-bit ASM to the coded randomized VCDUs for the C3DL return link as specified in CCSDS 131.0-B-5.

Rationale: Verification of application of a 32-bit ASM by inspection of lower-level test data is appropriate because application of a 32-bit ASM can be determined at a lower-level by VV without the CLD.

- B. The DESTINATION synchronization of the received coded randomized VCDUs from the C3DL return link using the 32-bit ASM as specified in CCSDS 131.0-B-5 shall be verified by inspection and joint test. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the DESTINATION syncs the received coded randomized VCDUs and produces a valid frame sync flag. A joint test will be performed using the VV. The VV will transmit the C3DL return link using all applicable combinations of symbol rate, and modulation. The data used for these tests will be representative of mission data. The transmitted signals will be attenuated so they are received at the DESTINATION with the Prec specified in the CWER requirement. The DESTINATION frame sync flag and the CWER will be recorded. The joint test shall be considered successful when it shows the DESTINATION reports that it has frame sync and meets the CWER requirement specified in Paragraph 3.4.2.6-1 for all applicable combinations of symbol rate and modulation.

Rationale: Verification of synchronization by inspection of lower-level test data is appropriate because the synchronization can be determined at a lower level by the DESTINATION without the VV. Verification of synchronization by joint test is necessary to include the cascade effect of all hardware and software. The CWER performance under the applicable E_b/N_0 for a link cannot be met without a well-designed frame

synchronizer. Not all possible frame synchronizer failures can be detected in strong-signal tests.

- C. The DESTINATION resolution of the input data phase ambiguity using the 32-bit ASM shall be verified by inspection. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the DESTINATION resolves the input data phase ambiguity using the 32-bit ASM for all possible phase conditions.

Rationale: Verification of resolution of input data phase ambiguity using the 32-bit ASM is appropriate because resolution of data phase ambiguity can be determined at a lower-level by the DESTINATION without the VV.

4.2.4.3.9 CADU FRAME LENGTH

- A. The VV usage of 2048-bit CADUs for the C3DL return link with the characteristics in Table 3.4.3.9-1 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV uses a 2048-bit CADU with the characteristics in Table 3.4.3.9-1.

Rationale: Verification of usage of a 2048-bit CADU by inspection of lower-level test data is appropriate because usage of a 2048-bit CADU can be determined at a lower-level by the VV without the CLD.

- B. The DESTINATION usage of 2048-bit CADUs for the C3DL return link with the characteristics in Table 3.4.3.9-1 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION uses a 2048-bit CADU with the characteristics in Table 3.4.3.9-1.

Rationale: Verification of usage of a 2048-bit CADU by inspection of lower-level test data is appropriate because usage of a 2048-bit CADU can be determined at a lower-level by the DESTINATION without the VV.

4.2.4.3.10 CONVOLUTIONAL CODING

- A. The VV encoding the CADUs for the C3DL return link using a rate 1/2 constraint length 7 convolutional code as specified in CCSDS 131.0-B-5 shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV encodes the CADUs for the C3DL return link using a rate 1/2 constraint length 7 convolutional code as specified in CCSDS 131.0-B-5.

Rationale: Verification of encoding using convolutional coding by inspection of lower-level test data is appropriate because encoding using convolutional coding can be determined at a lower-level by the VV without the CLD.

- B. The DESTINATION decoding the received CADUs from the C3DL return link using a rate 1/2 constraint length 7 convolutional code as specified in CCSDS 131.0-B-5 shall be verified by inspection and joint test. An inspection of lower-level test data will be performed. The inspection shall be considered successful when it shows the DESTINATION decodes the received CADUs and produces valid ASMs. A joint test will be performed using the VV. The VV will transmit the C3DL return link using all applicable combinations of symbol rate, and modulation. The data used for these tests will be representative of mission data. The transmitted signals will be attenuated so they are received within CLD's dynamic range. The DESTINATION ASM will be recorded. The joint test shall be considered successful when it shows the DESTINATION reports that it has valid ASMs for all applicable combinations of symbol rate and modulation.

Rationale: Verification of decoding by inspection of lower-level test data is appropriate because the decoding can be determined at a lower level by the DESTINATION without the VV. Verification of decoding by joint test is necessary to include the cascade effect of all hardware and software.

4.2.4.3.11 BASEBAND WAVEFORM

- A. The VV transmission of an NRZ-L baseband waveform for the C3DL return link shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the VV uses an NRZ-L waveform for the C3DL return link.

Rationale: Verification of usage of NRZ-L by inspection of lower-level test data is appropriate because usage of NRZ-L can be determined at a lower-level by the VV without the CLD.

- B. The DESTINATION reception of an NRZ-L baseband waveform for the C3DL return link shall be verified by inspection. An inspection of lower-level test data will be performed. The verification shall be considered successful when the inspection shows the DESTINATION uses an NRZ-L waveform for the C3DL return link.

Rationale: Verification of usage of NRZ-L by inspection of lower-level test data is appropriate because usage of NRZ-L can be determined at a lower-level by the DESTINATION without the VV.

4.2.4.3.12 LATENCY

The VV introduction of less than 249 ms and the DESTINATION introduction of less than 749 ms of latency (max total latency: 998 ms) for the C3DL return link from the time the last bit of a data unit enters the VV to the time the first data unit that ends in the CADU is extracted by the DESTINATION shall be verified by joint test. A joint test will be performed using the VV and the CLD. The verification shall be considered

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successful when the joint test shows the total latency from the VV to the DESTINATION is less than 998 ms.

Rationale: Verification of latency by joint test is necessary to include the cascade effect of all hardware and software. Verification of latency by joint test is necessary because it is impractical to measure the one-sided (transmit only, receive only) latency.

APPENDIX A - ACRONYMS AND ABBREVIATIONS

AAC	Advanced Audio Coding
AES	Advanced Encryption Standard
ANSI	American National Standards Institute
AOS	Advanced Orbiting Systems
ASM	Attached Sync Marker
BPSK	Binary Phase Shift Key
C2V2	Common Communications for Visiting Vehicles
C3DL	Common Communications for Commercial Destinations in Low-Earth Orbit
CADU	Channel Access Data Unit
CCP	Commercial Crew Program
CCSDS	Consultative Committee for Space Data Systems
CFR	Code of Federal Regulations
CLD	Commercial LEO Destination
CLDP	Commercial Low-Earth Orbit Development Program
CLDS	Commercial LEO Destination System
CM	Configuration Management
Comm	Communication
CS-ACELP	Conjugate-Structure Algebraic-Code-Excited Linear Prediction
CVV	Crew Visiting Vehicle
CWER	Code Word Error Rate
Db	Decibel
Dbw	Decibel Watts
dBWi	Decibels referenced to one-watt isotopically radiated power
DQA	Document Quality Assurance
e.g.	for example
E_b/N_0	energy per bit to noise power spectral density ratio
EFF	Effective
EIRP	Effective Isotropic Radiated Power
ETE	End-to-End
EVM	Error Vector Magnitude
FIPS	Federal Information Processing standard
GCM	Galois/Counter Mode

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GMAC	GCM Message Authentication Code
i.e.	that is
ICD	Interface Control Document
ID	Identification
IETF	Internet Engineering Task Force
ISO	International Organization for Standardization
ITAR	International Traffic in Arms Regulation
ITU	International Telecommunication Union
IV	Initialization Vector
JPCB	Joint Program Control Board
JPRCB	Joint Program Requirements Control Board
Kbit/s	kilobits per second
kHz	kilohertz
km	kilometer
ksps	kilo symbols per second
LDR	Low Data Rate
LEO	Low-Earth Orbit
M_PDU	Multiplexing Protocol Data Unit
max	maximum (dimension)
MDR	Medium Data Rate
MHz	Mega Hertz
ms	millisecond
MSB	Most Significant Bit
NASA	National Aeronautics and Space Administration
NIST	National Institute of Standards and Technology
NRZ-L	Nonreturn-to-zero Level
NRZ-M	Nonreturn-to-zero Mark
OPR	Office of Primary Responsibility
OQPSK	Offset Quadrature Phase Shift Keying
ORG	Organization
PDU	Protocol Data Unit
ppm	parts per million
QPSK	Quadrature Phase Shift Key

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REV	Revision
RF	Radio Frequency
RFC	Request for Comment
RFP	Real-Time Transport Protocol
RHCP	Right Hand Circular Polarization
RPOD	Rendezvous, Proximity Operations, and Docking
RPODU	Rendezvous, Proximity, Operations, Docking, and Undocking
RS	Reed Solomon
s	second
SDU	Service Data Unit
SE&I	Systems Engineering and Integration
sec	second
SER	Symbol Error Rate
SP	Special Publication
SRRC	Standardized Rank Regression Coefficient
Sync	Synchronizer
TBD	To Be Determined
TBD-V	To Be Determined by the Vendor
TBR	To Be Resolved
TBR-V	To Be Resolved by the Vendor
TBS	To Be Supplied
TM	Telemetry
UHF	Ultra-High Frequency
U.S.	United States
VCA	Virtual Channel Access
VCA_SDU	Virtual Channel Access Service Data Unit
VCDU	Virtual Channel Data Unit
VCID	Virtual Channel Identifier
VR	Verification Requirement
VV	Visiting Vehicle

APPENDIX B - GLOSSARY

<RESERVED>

APPENDIX C - OPEN WORK

Table C-1 lists the specific To Be Determined (TBD) items in the document that are not yet known. The TBD is inserted as a placeholder wherever the required data is needed and is formatted in bold type within brackets. The TBD item is numbered based on the section where the first occurrence of the item is located as the first digit and a consecutive number as the second digit (i.e., <TBD 4-1> is the first undetermined item assigned in Section 4 of the document). As each TBD is solved, the updated text is inserted in each place that the TBD appears in the document and the item is removed from this table. As new TBD items are assigned, they will be added to this list in accordance with the above-described numbering scheme. Original TBDs will not be renumbered.

TABLE C-1 TO BE DETERMINED ITEMS

TBD	Section	Description
3-1	3.3.2.4	See Section 1.4 Convention and Notation for explanation of ALL TBDs/TBRs.
3-2	3.3.2.4	
3-3	3.3.2.4	
3-4	3.3.2.4	
3-5	3.3.2.6	
3-6	3.3.2.6	
3-7	3.3.3.1.2	
3-8	3.4.2.4	
3-9	3.4.2.4	
3-10	3.4.2.4	
3-11	3.4.2.4	
3-12	3.3.2.6	
3-13	3.3.2.6	

Table C-2 lists the specific To Be Resolved (TBR) issues in the document that are not yet known. The TBR is inserted as a placeholder wherever the required data is needed and is formatted in bold type within brackets. The TBR issue is numbered based on the section where the first occurrence of the issue is located as the first digit and a consecutive number as the second digit (i.e., <TBR 4-1> is the first unresolved issue assigned in Section 4 of the document). As each TBR is resolved, the updated text is inserted in each place that the TBR appears in the document and the issue is removed from this table. As new TBR issues are assigned, they will be added to this list in accordance with the above-described numbering scheme. Original TBRs will not be renumbered.

TABLE C-2 TO BE RESOLVED ISSUES

TBR	Section	Description
3-1	3.3.1.1	See Section 1.4 Convention and Notation for explanation of ALL TBDs/TBRs.
3-2	3.3.1.2	
3-3	3.3.1.2	
3-4	3.3.2.4	
3-5	3.3.2.4	
3-6	3.3.1.2	
3-7	3.3.1.2	
3-8	3.4.2.4	
3-9	3.4.2.4	
4-1	4.3.2.2	
D-1	3.1 and D-1	

APPENDIX D - CONCEPTUAL BLOCK DIAGRAMS

<TBR D-1>