

Report Concerning Space Data System Standards

UNIFIED SPACE DATA LINK PROTOCOL (USLP)

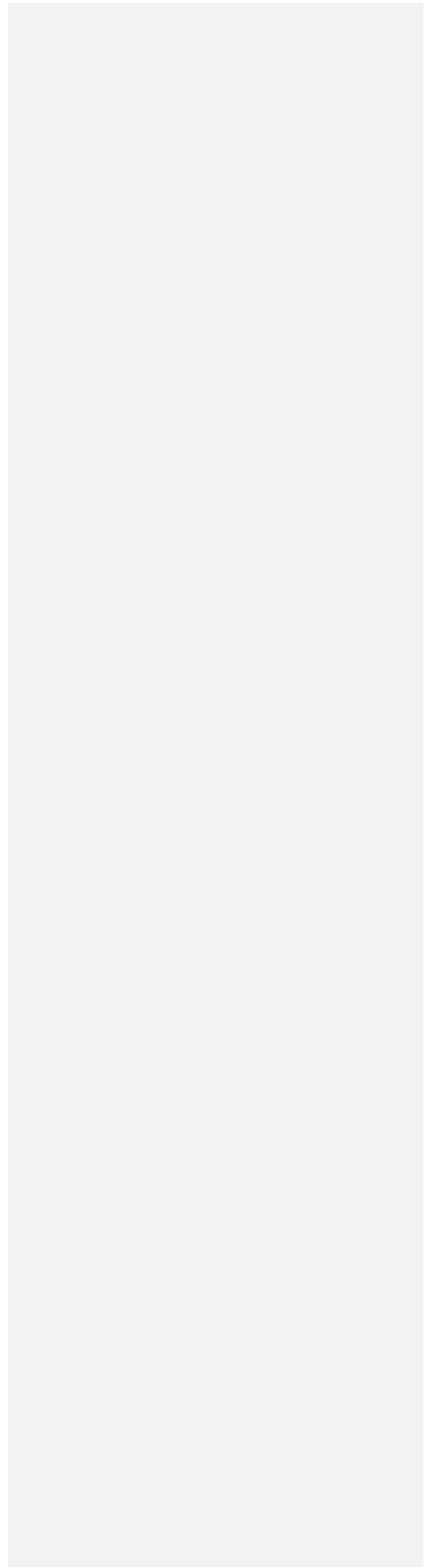
DRAFT INFORMATIONAL REPORT

CCSDS **732.1**-G-0

DRAFT GREEN BOOK

Oct. 6, 2014 Version
November 2014

(London Meeting)



AUTHORITY

Issue:	Draft Green Book, Issue 0
Date:	August 2014
Location:	Not Applicable

(WHEN THIS RECOMMENDED STANDARD IS FINALIZED, IT WILL CONTAIN THE FOLLOWING STATEMENT OF AUTHORITY:)

This document has been approved for publication by the Management Council of the Consultative Committee for Space Data Systems (CCSDS) and represents the consensus technical agreement of the participating CCSDS Member Agencies. The procedure for review and authorization of CCSDS documents is detailed in *Organization and Processes for the Consultative Committee for Space Data Systems* (CCSDS A02.1-Y-3), and the record of Agency participation in the authorization of this document can be obtained from the CCSDS Secretariat at the address below.

This document is published and maintained by:

CCSDS Secretariat
Space Communications and Navigation Office, 7L70
Space Operations Mission Directorate
NASA Headquarters
Washington, DC 20546-0001, USA

FOREWORD

This document is a technical Recommendation for use in developing flight and ground systems for space missions and has been prepared by the Consultative Committee for Space Data Systems (CCSDS). The Unified Space Data Link Protocol described herein is intended for missions that are cross-supported between Agencies of the CCSDS.

This Recommendation specifies a communications protocol to be used by space missions to transfer space application data over space-to-ground or space-to-space communications links. Note that:

- a) this protocol can be used to transfer any data over any space link in either direction;
- b) all CCSDS space link protocols are specified in a unified manner;
- c) the specification matches the OSI Basic Reference Model (references [1] and [2]).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CCSDS shall not be held responsible for identifying any or all such patent rights.

Through the process of normal evolution, it is expected that expansion, deletion, or modification of this document may occur. This Recommended Standard is therefore subject to CCSDS document management and change control procedures, which are defined in *Organization and Processes for the Consultative Committee for Space Data Systems* (CCSDS A02.1-Y-3). Current versions of CCSDS documents are maintained at the CCSDS Web site:

<http://www.ccsds.org/>

Questions relating to the contents or status of this document should be addressed to the CCSDS Secretariat at the address indicated on page i.

At time of publication, the active Member and Observer Agencies of the CCSDS were:

Member Agencies

- Agenzia Spaziale Italiana (ASI)/Italy.
- Canadian Space Agency (CSA)/Canada.
- Centre National d'Etudes Spatiales (CNES)/France.
- China National Space Administration (CNSA)/People's Republic of China.
- Deutsches Zentrum für Luft- und Raumfahrt (DLR)/Germany.
- European Space Agency (ESA)/Europe.
- Federal Space Agency (FSA)/Russian Federation.
- Instituto Nacional de Pesquisas Espaciais (INPE)/Brazil.
- Japan Aerospace Exploration Agency (JAXA)/Japan.
- National Aeronautics and Space Administration (NASA)/USA.
- UK Space Agency/United Kingdom.

Observer Agencies

- Austrian Space Agency (ASA)/Austria.
- Belgian Federal Science Policy Office (BFSPPO)/Belgium.
- Central Research Institute of Machine Building (TsNIIMash)/Russian Federation.
- China Satellite Launch and Tracking Control General, Beijing Institute of Tracking and Telecommunications Technology (CLTC/BITTT)/China.
- Chinese Academy of Sciences (CAS)/China.
- Chinese Academy of Space Technology (CAST)/China.
- Commonwealth Scientific and Industrial Research Organization (CSIRO)/Australia.
- CSIR Satellite Applications Centre (CSIR)/Republic of South Africa.
- Danish National Space Center (DNSC)/Denmark.
- Departamento de Ciência e Tecnologia Aeroespacial (DCTA)/Brazil.
- European Organization for the Exploitation of Meteorological Satellites (EUMETSAT)/Europe.
- European Telecommunications Satellite Organization (EUTELSAT)/Europe.
- Geo-Informatics and Space Technology Development Agency (GISTDA)/Thailand.
- Hellenic National Space Committee (HNSC)/Greece.
- Indian Space Research Organization (ISRO)/India.
- Institute of Space Research (IKI)/Russian Federation.
- KFKI Research Institute for Particle & Nuclear Physics (KFKI)/Hungary.
- Korea Aerospace Research Institute (KARI)/Korea.
- Ministry of Communications (MOC)/Israel.
- National Institute of Information and Communications Technology (NICT)/Japan.
- National Oceanic and Atmospheric Administration (NOAA)/USA.
- National Space Agency of the Republic of Kazakhstan (NSARK)/Kazakhstan.
- National Space Organization (NSPO)/Chinese Taipei.
- Naval Center for Space Technology (NCST)/USA.
- Scientific and Technological Research Council of Turkey (TUBITAK)/Turkey.
- Space and Upper Atmosphere Research Commission (SUPARCO)/Pakistan.
- Swedish Space Corporation (SSC)/Sweden.
- United States Geological Survey (USGS)/USA.

DOCUMENT CONTROL

Document	Title	Date	Status
CCSDS 000.0-G-0	[Document Title], Informational Report, Issue 0	Draft July 2013	Current draft

CONTENTS

<u>Section</u>	<u>Page</u>
1 INTRODUCTION	1-1
1.1 PURPOSE.....	1-1
1.2 SCOPE.....	1-1
1.3 APPLICABILITY.....	1-1
1.4 RATIONALE	<u>1-1</u>
1.5 DOCUMENT STRUCTURE	1-2
1.6 CONVENTIONS AND DEFINITIONS	1-2
1.7 REFERENCES	1-6
2 PROTOCOL OVERVIEW	2-1
2.1 CONCEPT OF UNIFIED SPACE DATA LINK PROTOCOL.....	2-1
2.2 SUMMARY OF PROTOCOL REQUIREMENTS	
2.2 OVERVIEW OF SERVICES.....	<u>ERROR! BOOKMARK NOT DEFINED,</u>
2.3 OVERVIEW OF FUNCTIONS	2-12
2.4 SERVICES ASSUMED FROM LOWER LAYERS	<u>2-15</u>
3 USLP OVERVIEW FOR MISSION SERVICES <u>ERROR! BOOKMARK NOT DEFINED,</u>	
3.1 USER APPLICATIONS.....	<u>ERROR! BOOKMARK NOT DEFINED,</u>
3.2 OBSERVATIONAL SCIENCE	<u>ERROR! BOOKMARK NOT DEFINED,</u>
3.3 EXPERIMENTAL SCIENCE	<u>ERROR! BOOKMARK NOT DEFINED,</u>
3.4 ROBOTIC PLATFORMS/VEHICLES	<u>ERROR! BOOKMARK NOT DEFINED,</u>
3.5 MANNED PLATFORMS/VEHICLES	<u>ERROR! BOOKMARK NOT DEFINED,</u>
3.6 LAUNCH VEHICLES	<u>ERROR! BOOKMARK NOT DEFINED,</u>
3.7 CORE OPERATIONS.....	<u>ERROR! BOOKMARK NOT DEFINED,</u>
3.8 SPACE NETWORKING ENVIRONMENT	<u>ERROR! BOOKMARK NOT DEFINED,</u>

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 1-2

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 2-4

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 2-14

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 3-1

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 3-1

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 3-1

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 3-3

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 3-7

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 3-10

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 3-13

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 3-16

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 3-18

CONTENTS (continued)

Section	Page
4 MANAGED PARAMETERS	4-1
4.1 MANAGED PARAMETERS FOR A PHYSICAL CHANNEL	4-1
4.2 MANAGED PARAMETERS FOR A MASTER CHANNEL	4-2
4.3 MANAGED PARAMETERS FOR A VIRTUAL CHANNEL	4-2
4.4 MANAGED PARAMETERS FOR PACKET TRANSFER	4-2
5 EXAMPLE PROTOCOL SPECIFICATION	5-1
5.1 OVERVIEW	5-1
5.2 USE OF SDLS PROTOCOL	5-1
5.3 USLP TRANSFER FRAME	5-2
5.4 SENDING END PROTOCOL PROCEDURES	5-9
5.5 RECEIVING END PROTOCOL PROCEDURES	ERROR! BOOKMARK NOT DEFINED
5.6 MANAGED PARAMETERS	ERROR! BOOKMARK NOT DEFINED
ANNEX A ACRONYMS	A-1
ANNEX B INFORMATIVE REFERENCES	B-1
ANNEX C RELATIONSHIP OF THE TRANSFER FRAME TO CODE BLOCK	ERROR! BOOKMARK NOT DEFINED
ANNEX D USLP USE CASES	D-1

Figure

1-1 Bit Numbering Convention	1-5
2-1 Relationship with OSI Layers	Error! Bookmark not defined
2-2 Relationships Between Channels	Error! Bookmark not defined
2-3 Asynchronous Service Model	Error! Bookmark not defined
2-4 Synchronous Service Model	Error! Bookmark not defined
2-5 Internal Organization of Protocol Entity (Sending End)	2-13
2-6 Internal Organization of Protocol Entity (Receiving End)	2-14
2-7 USLP Space Data Link Protocol Channel Tree	2-15
4-1 USLP Transfer Frame Structural Components	Error! Bookmark not defined
4-2 Transfer Frame Primary Header	Error! Bookmark not defined
4-3 Transfer Frame Data Field Status	Error! Bookmark not defined
4-4 Transfer Frame Secondary Header	Error! Bookmark not defined
4-5 Logic Diagram of the Encoder	Error! Bookmark not defined
4-6 Logic Diagram of the Decoder	Error! Bookmark not defined
4-7 Internal Organization of Protocol Entity (Sending End)	Error! Bookmark not defined
4-8 Abstract Model of Packet Processing Function	Error! Bookmark not defined
4-9 Abstract Model of Virtual Channel Generation Function	Error! Bookmark not defined
4-10 Abstract Model of Virtual Channel Multiplexing Function	Error! Bookmark not defined

Deleted: 4-1
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 4-1
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 4-2
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 4-2
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 4-2
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 5-1
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 5-1
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 5-1
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 5-4
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 5-7
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 5-9
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: C-1
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 2-1
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 2-3
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 2-5
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 2-6
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 2-13
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 2-14
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 4-2
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 4-3
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 4-6
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 4-9
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 4-14
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 4-15
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 4-16
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 4-17
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 4-19
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 4-21

CONTENTS (continued)SectionPage

4-11 Abstract Model of Master Channel Generation Function	Error! Bookmark not defined.
4-12 Abstract Model of Master Channel Multiplexing Function	Error! Bookmark not defined.
4-13 Abstract Model of All Frames Generation Function	Error! Bookmark not defined.
4-14 Internal Organization of Protocol Entity (Receiving End)	Error! Bookmark not defined.
4-15 Abstract Model of Packet Extraction Function.....	Error! Bookmark not defined.
4-16 Abstract Model of Virtual Channel Reception Function	Error! Bookmark not defined.
4-17 Abstract Model of Virtual Channel Demultiplexing Function	Error! Bookmark not defined.
4-18 Abstract Model of Master Channel Reception Function	Error! Bookmark not defined.
4-19 Abstract Model of Master Channel Demultiplexing Function	Error! Bookmark not defined.
4-20 Abstract Model of All Frames Reception Function.....	Error! Bookmark not defined.
6-1 Frame without SDLS Compared to Frame with SDLS	5-2

Table

2-1 Summary of Services Provided by Unified Space Data Link Protocol	2-9
2-2 Summary of USLP Services Supported by the Space Data Link Security Protocol	Error! Bookmark not defined.
5-1 Managed Parameters for a Physical Channel	4-1
5-2 Managed Parameters for a Master Channel.....	4-2
5-3 Managed Parameters for a Virtual Channel.....	4-2
5-4 Managed Parameters for Packet Transfer.....	4-3
6-1 Additional Managed Parameters for a Virtual Channel when USLP Space Data Link Protocol Supports SDLS.....	Error! Bookmark not defined.
C-1 Mapping of Terms of Reference [B3] That Have Been Redefined	Error! Bookmark not defined.

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 4-22
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 4-23
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 4-24
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 4-25
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 4-26
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 4-27
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 4-28
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 4-29
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 4-30
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 4-31
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 6-2
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 2-7
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 2-8
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 5-1
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 5-2
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 5-2
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 5-3
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 6-9
Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: C-2

1 INTRODUCTION

1.1 PURPOSE

The prime purpose of this Informational Report is to describe the new general purpose CCSDS Data Link layer protocol, here in called the Unified Space Link layer Protocol (USLP). This new space data link layer protocol utilizes the proven features of existing CCSDS protocols, providing backward compatibility, and adds options that allow missions to tailor their link layer constructs. The USLP provides the required services for all the CCSDS space links (Direct from Earth, Direct to Earth and space to space links). It is targeted for the emerging missions, both human and robotic. USLP is designed to support: the anticipated increase in data rates as technologies mature, the identification of an increasing number of new space vehicles, the use of Variable Code Modulation (VCM), and the delivery of low latency messages. In addition this Green Book references emerging CCSDS coding options that offer significant performance gains for communications links that terminate in space vehicles, and describes the advantages of operating the link in which the transfer frame is not aligned with the forward error correcting code block.

1.2 SCOPE

This Informational Report examines the Unified Space Data Link Protocol in terms of:

- a) design requirements of the protocol;
- b) services provided to the users of this protocol;
- c) protocol data units employed by the protocol;
- d) procedures performed by the protocol;
- e) use cases for various types of space data links;

1.3 APPLICABILITY

This document is a CCSDS Informational Report and contains descriptive materials and supporting rationale about the use of the proposed Unified Space Link Protocol (USLP). USLP is envisioned for application in future missions as the data link layer protocol and will require support from elements operated by CCSDS member agencies. USLP structures may be utilized for all space links i.e., Direct from Earth (DFE), Direct to Earth (DTE) and Space to Space (Proximity) thus enabling the implementing technology to be used by all types of missions hopefully improving the cost benefit performance for new implementations for agency missions.

1.4 RATIONALE

There are two major reasons for developing a new CCSDS Space Data Link Layer Protocol:

First, the CCSDS Space Link Protocols WG has identified the following major deficiencies in the existing link layer protocols: 1) Transfer Frame Size and Accountability is too limited for CCSDS agencies envisioned future mission set; 2) there are inadequate spacecraft ID assignments available in the current CCSDS link layer protocols.

1.5 DOCUMENT STRUCTURE

This document is divided into five numbered sections and three annexes:

- section 1 presents the purpose, scope, applicability and rationale of this Recommendation and lists the conventions, definitions, and references used throughout the Recommendation.
- section 2 provides an overview of the Unified Space Data Link Protocol including the design requirements.
- section 3 defines the overview for mission services.
- section 4 specifies the managed parameters used by the protocol entity
- section 5 specifies the protocol data units and procedures employed by the protocol entity including their rationale.
- annex A lists all acronyms used within this document.
- annex B provides a list of informative references.
- annex C is informative and provides guidance to the user on selecting link options affecting both the data protocol and coding and synchronization sub-layers.

1.6 CONVENTIONS AND DEFINITIONS

1.6.1 DEFINITIONS

1.6.1.1 Definitions from the Open Systems Interconnection (OSI) Basic Reference Model

This Recommendation makes use of a number of terms defined in reference [1]. The use of those terms in this Recommendation shall be understood in a generic sense; i.e., in the sense that those terms are generally applicable to any of a variety of technologies that provide for the exchange of information between real systems. Those terms are:

- a) blocking;

- b) connection;
- c) Data Link Layer;
- d) entity;
- e) flow control;
- f) Network Layer;
- g) peer entities;
- h) Physical Layer;
- i) protocol control information;
- j) protocol data unit (PDU);
- k) real system;
- l) segmenting;
- m) service;
- n) Service Access Point (SAP);
- o) SAP address;
- p) service data unit(SDU).

1.6.1.2 Definitions from OSI Service Definition Conventions

This Recommendation makes use of a number of terms defined in reference [2]. The use of those terms in this Recommendation shall be understood in a generic sense; i.e., in the sense that those terms are generally applicable to any of a variety of technologies that provide for the exchange of information between real systems. Those terms are:

- a) confirmation;
- b) indication;
- c) primitive;
- d) request;
- e) response;
- f) service provider;
- g) service user.

1.6.1.3 Terms Defined in This Recommendation

For the purposes of this Recommendation, the following definitions also apply. Many other terms that pertain to specific items are defined in the appropriate sections.

aligned: to arrange so that both items start and end in unison. This term is used to describe the relationship of the transfer frame and the forward error correcting (FEC) code block when they start and end in unison.

aperiodic: not *periodic* (see below).

asynchronous: not *synchronous* (see below).

delimited: having a known (and finite) length; applies to data in the context of data handling.

Mission Phase: a period of a mission during which specified communications characteristics are fixed. The transition between two consecutive Mission Phases may cause an interruption of the communications services.

periodic: of or pertaining to a sequence of events in which each event occurs at a fixed time interval (within specified tolerance) after the previous event in the sequence.

Physical Channel: a stream of bits transferred over a space link in a single direction.

space link: a communications link between a spacecraft and its associated ground system or between two spacecraft. A space link consists of one or more Physical Channels in one or both directions.

streaming: the technique of allowing packets to span transfer frame boundaries while sharing the transfer frame data field with more than one packet.

synchronous: of or pertaining to a sequence of events occurring in a fixed time relationship (within specified tolerance) to another sequence of events. Note that 'synchronous' does not necessarily imply 'periodic' or 'constant rate'.

1.6.2 NOMENCLATURE

The following conventions apply throughout this Recommendation:

- a) the words 'shall' and 'must' imply a binding and verifiable specification;
- b) the word 'should' implies an optional, but desirable, specification;
- c) the word 'may' implies an optional specification;
- d) the words 'is', 'are', and 'will' imply statements of fact.

1.6.3 CONVENTIONS

In this document, the following convention is used to identify each bit in an N -bit field. The first bit in the field to be transmitted (i.e., the most left justified when drawing a figure) is defined to be 'Bit 0'; the following bit is defined to be 'Bit 1' and so on up to 'Bit $N-1$ '. When the field is used to express a binary value (such as a counter), the Most Significant Bit (MSB) shall be the first transmitted bit of the field, i.e., 'Bit 0' (see figure 1-1).

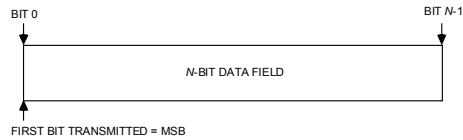


Figure 1-1: Bit Numbering Convention

In accordance with standard data-communications practice, data fields are often grouped into eight-bit 'words' which conform to the above convention. Throughout this Recommendation, such an eight-bit word is called an 'octet'.

The numbering for octets within a data structure starts with zero. By CCSDS convention, all 'spare' bits shall be permanently set to '0'.

1.7 REFERENCES

The following documents contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All documents are subject to revision, and users of this Recommendation are encouraged to investigate the possibility of applying the most recent editions of the documents indicated below. The CCSDS Secretariat maintains a register of currently valid CCSDS Recommendations.

- [1] *Information Technology—Open Systems Interconnection—Basic Reference Model: The Basic Model*. 2nd ed. International Standard, ISO/IEC 7498-1:1994. Geneva: ISO, 1994.
- [2] *Information Technology—Open Systems Interconnection—Basic Reference Model—Conventions for the Definition of OSI Services*. International Standard, ISO/IEC 10731:1994. Geneva: ISO, 1994.
- [3] *TM Synchronization and Channel Coding*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 131.0-B-2. Washington, D.C.: CCSDS, August 2011.
- [4] “Packet Version Number.” Space Assigned Number Authority. http://sanaregistry.org/r/packet_version_number/.
- [5] *CCSDS Global Spacecraft Identification Field Code Assignment Control Procedures*. Issue 5. Recommendation for Space Data System Standards (Blue Book), CCSDS 320.0-B-5. Washington, D.C.: CCSDS, September 2007.
- [6] *Space Packet Protocol*. Issue 1. Recommendation for Space Data System Standards (Blue Book), CCSDS 133.0-B-1. Washington, D.C.: CCSDS, September 2003.
- [7] *Encapsulation Service*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 133.1-B-2. Washington, D.C.: CCSDS, October 2009.
- [8] *Space Data Link Security Protocol*. Issue 3. Draft Recommendation for Space Data System Standards (Red Book), CCSDS 355.0-R-3. Washington, D.C.: CCSDS, October 2013.
- [9] *TM Space Data Link Protocol*. Issue 1. Recommendation for Space Data System Standards (Blue Book), CCSDS 132.0-B-1. Washington, D.C.: CCSDS, September 2003.
- [10] *Proximity-1 Space Link Protocol-Data Link Layer*. Issue 5. Recommendation for Space Data System Standards (Blue Book), CCSDS 211.0-B-5. Washington, D.C.: CCSDS, December 2013.

- [11] *TC Space Data Link Protocol*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 232.0-B-2. Washington, D.C.: CCSDS, September 2010.
- [12] *AOS Space Data Link Protocol*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 732.0-B-2. Washington, D.C.: CCSDS, July 2006.
- [13] *TC Synchronization and Channel Coding*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 231.0-B-2. Washington, D.C.: CCSDS, September 2010.
- [14] *Proximity-1 Space Link Protocol-Coding and Synchronization Sublayer*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 211.2-B-2. Washington, D.C.: CCSDS, December 2013.

NOTE – Informative references are listed in annex B.

2 OVERVIEW

2.1 CONCEPT OF UNIFIED SPACE DATA LINK PROTOCOL

2.1.1 ARCHITECTURE

The Unified Space Data Link Protocol is a Data Link Layer protocol (see reference [1]) to be used by space missions to transfer data across the space link. This protocol has been designed to meet the requirements of space missions for efficient transfer of space application data of various types and characteristics over space-to-ground or space-to-space communications links (hereafter called space links). USLP is an evolutionary development built on the experiences and deployments of TC, TM, Prox-1, and AOS. The intent is to extend older protocols and add new features to support technological innovation. As such, USLP is a convergence of CCSDS protocols anticipating needs in upcoming missions. Its primary goals are to reduce cost and simplify systems engineering by utilizing advances in onboard computational ability, modern security models to include those supported by CCSDS, allow for increased data rates, and use high performance coding option; e.g., LDPC.

Figure [Error! Reference source not found.](#) illustrates the layered model for the space data link layer composed of three protocol sub-layers. The Link Layer sub-layer that connects to the physical layer is the Coding and Synchronization Sub-Layer. This Sub-layer is used to provide the means to delimit and decode the code block providing the desired very low error rate data channel and additionally to delimit the Transfer Frame. The Link Layer Services Sub-layer provides the data structures to transport the data across the link, deliver that data to the required Service Access Port (SAP) and provides accountability and security. The Session Management and Reliable Delivery Protocols reside above the link layer and accept their data units via a designated SAP. The prime purpose of this green book, is to describe a new general purpose Data Link Layer Protocol that operationally resides within the Data Link Services Sub-Layer that will provide the required information for the services for all the CCSDS space links (ground to/from space and space to space links) and to describe the interface to the optional application of forward error correction encoding options within the Link Layer's Coding and Synchronization Sub-layer.

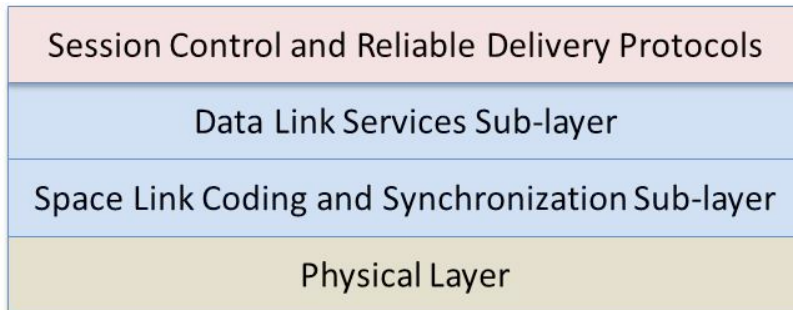


Figure 2-1: CCSDS Space Data Link Layer Protocol stack

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 2-1

2.1.2 PROTOCOL FEATURES

2.1.2.1 Overview of the New Transfer Frame

The proposed Data Link Layer Protocol incorporates a flexible transfer frame structure that can be optimized for the specific needs of each space link type and its constraints, all using the flexible Unified Space Link Protocol (USLP) frame format. This format provides sufficient data visibility within the frame header to enable the receive side link layer frame processing to delimit the frame, separate and route Master and/or Virtual Channel (VC) frames without management details (aside from those required for physical layer operation and forward error correction decoding) nor the security encoding incorporated within them. The tailoring of the frames functionality is accommodated within the transfer frame header and the transfer frame data field header. How one tailors the capabilities of the transfer frame is explained in section 5.

2.1.2.2 Synchronization and Randomization Considerations

When the link management rules specify the use of a forward error correction code then the start of the error correcting code block is delimited by a code block Synchronization Marker (CSM) which is additionally required. In all cases if randomization is also required randomization of the data stream starts immediately after the end of the CSM and terminates at the end of the code block.

An Attached Synchronization Marker (ASM) is required and is pre-pended to the frame only when the frame is not aligned with the FEC code block. The exact size and bit pattern chosen for the ASM is dependent upon the applicable channel error characteristics and the maximum frame size. The application of the ASM and the Frame Error Control (FEC) field are discussed later in Annex C.

2.1.2.3 Packet Segmentation and Streaming Overview

The current Telecommand Protocol relies on a segmentation process to allow packets larger than a TC frame to be carried within smaller frames, while the TM and AOS protocols provide a similar capability by a process named in this document as “streaming”. In the “streaming” process, packets are allowed to span transfer frame boundaries with the next available packet starting where the preceding one ended. Both segmentation and streaming are selectable within the USLP and signaled in the Transfer Frame Data Field header. The streaming process requires that the Streaming Pointer Field be included in the TFDF header. This is a dual use field. It provides a First Header Pointer for packet resynchronization. Alternatively, this field may be used as a ‘Last Octet Pointer’ required by the VCA service. The First Header Pointer is required to restart the packet delimiting process when one or more frames are lost. The ‘Last Octet Pointer’ is required to delimit a User’s Octet stream when the TFDF data field is larger than the contained User data unit. This streaming process in combination with a more structured Virtual Channel assignment process may be used to

replace the segmentation process defined in Telecommand (TC) and Proximity-1 if fixed length frames are employed. When variable length frames are employed then segmentation (placing portions of the packet into sequenced frames of the same VC) is provided and signaled within the Data Inclusion Rules field in the TFDF header. Each segment is required to fill the data area in the TFDF. The allowable values and use of the Data Inclusion Rules field are provided in Section 5.3.5.1.

We believe the need to utilize segmentation of packets in the future will be reduced, because USLP provides a transfer frame size that is up to 32 times as large as the [maxium transfer frame size in the](#) current data link [protocol](#) recommendations.

2.1.2.4 Optional Space Data Link Security Protocol

The Data Link Protocol Sublayer includes the Space Data Link Security (SDLS) Protocol specified in reference [8]. The SDLS protocol can provide security, such as authentication and confidentiality, for USLP Transfer Frames. Support for the SDLS protocol is an optional feature of the Unified Space Data Link Protocol. The presence of security on a Virtual Channel is managed i.e., there are no fields in the Transfer Frame header that signal this capability.

The security provided by the SDLS protocol can vary between Virtual Channels. So, e.g., there can be some Virtual Channels with security and some without. The type of security can vary from one Virtual Channel to another.

2.1.2.5 Transfer Frame Content Service

The transfer frame master channel or virtual channel frame services deliver the transfer frame data field that contains User supplied data. The TFDF header identifies both the content specific rules for the inclusion of the data and the protocol of the data unit contained. The TFDF header's Data Content ID field will identify whether the data is included using segmentation or streaming rules, providing the information to support segmentation handling and flag the inclusion of a pointer field (used as either as a first header pointer or last valid octet for streaming processing). The segmentation process requires the use of variable length frames and signals the start and end of a SDU. In the streaming process, which is used for fixed length frames, a First Header Pointer points to the beginning of a CCSDS packet within the frame; thus enabling the CCSDS packet service to resynchronize after a frame loss. The Last Valid Octet Pointer is used to delimit User provided octets (VCA Service) carried within the TFDF.

2.1.2.6 Variable Length Frames Option for all Links

The use of variable length frames is currently limited to the TC and Prox-1 specifications for use in Direct from Earth and/or proximity link operations. The use of high performance

jpl 10/6/2014 1:26 PM

Comment [1]: MATT: The working group needs to see if this is true or not. The agencies, within the working group, need to be polled to see if this statement can be left or removed.

Kazz, Greg J (313B) 10/27/2014 4:39 PM

Deleted: [8]

codes and fixed length frames that used the streaming process was limited to Direct to Earth missions. Allowing the use of high performance FEC codes that are not aligned to transfer frame boundaries enables all links to use variable length transfer frames and segmentation if required.

2.1.2.7 Meet the Increasing Frame Processing needs of High Rate Missions

High rate (such as optical comm at Gbit/sec rates) agency missions require more efficient frame processing (both on board and ground) than CCSDS standards currently permit. This requirement implies that the current maximum CCSDS frame size of 2048 octets is too small and therefore must be larger. This implies also that if frames are larger than 2048 octets, then the frame sequence counter must be increased to provide adequate frame accountability.

There are numerous missions in the planning phase that require significantly higher rates, including Earth Science missions planning to use Ka, Ku band, more advanced coding schemes and optical downlinks. It is anticipated that Observatory Class missions in this decade will downlink 28 Mbps by the NASA James Webb Space Telescope (JWST) and 750 Mbps by the ESA Euclid dark matter/energy mission planned to launch in 2020. Part of the problem with today's ground systems is that they are incapable of processing the data received at rates that are above 1 Gbps. Thus operational equipment needs to be developed to handle those very high rates, and these developments need to start soon enough to ensure mission success. NASA's Constellation Program identified performance problems with the ground services utilizing their selected frame size even when uplink rates were lower than 10 Mbps.

Higher data rates create data handling problems for agencies implementing short length frames. As the data rate increases substantially, the greater the need to increase the corresponding frame length. Optical links are projected to have data rate capabilities up to 30 Gbps. This means that with a frame size of 16,000 octets and a downlink rate of 30 Gbps, 2,343,750 frames per second will be transferred placing a significant burden on the operational link layer services.

USLP proposes a maximum frame size of 65536 bytes (i.e. 64×1024), due to the proposed 16 bit field assigned to the frame length. This enhanced frame length capability would provide for frame sizes 32 times larger than the current set of standards. A larger maximum CCSDS frame size would reduce the frame rate for very high data rate missions and the increased size of the VC sequence counter would provide the needed accountability. The variability in frame size would reduce packet segmentation and reconstruction because frame boundaries could stretch to encompass complete packets or user data units (i.e., supporting in particular IP datagrams or Delay Tolerant Networking Bundles). The exceeding low error floor of the LDPC codes along with their exceeding low undetected error rates facilitate the use of large transfer frames that are protected by multiple code words.

2.1.2.8 Increase the Spacecraft ID Name Space

The current number of version 1 and version 2 Spacecraft IDs (SCIDs) is insufficient to meet agencies needs for future Spacecraft ID growth. This implies the need for a larger than current SCID name space. This implies the need for a larger SCID field.

The number of Spacecraft IDs available to future missions is limited and current missions consume 75% of the available Version 1 SCIDs and 63% of the Version 2 SCIDs, according to the CCSDS Secretariat. Currently there are two sets of SCIDs, one for the TC and TM recommendations (Version 1) up to 1024 SCIDs, and one for AOS that supports 256 SCIDs. As a result, if a spacecraft uses the TC-SDLP on the forward link and the AOS-SDLP on the return link, it must be assigned two SCIDs, one for the TC-SDLP (V=1) and the other for the AOS-SDLP (V=2). Another factor that leads to the rapid consumption of SCIDs is multiple assignments per spacecraft. Currently most missions require multiple SCID assignments in order to differentiate the data based upon mission phase (i.e., System Test vs. Mission Operations). Another driver for an increased number of SCIDs is the anticipated increase in agency activities in developing cubesat/microsats and the future expectation of internetworking in space. Note: There are only a handful of Version 3, Proximity-1 SCIDs in use today and there are up to 1024 possible IDs.

2.1.2.9 Support Variable Length Frames on Telemetry, Telecommand and Proximity Links

USLP offers the option of using a variable length transfer frame that is unaligned to the code block on space links in addition to the traditional frame and code block methods defined in reference [3]. Therefore USLP requires a service from the Coding & Synchronization sublayer that by the use of management rules will support two variations: Option 1: fixed length frames aligned with fixed length code blocks per reference [3], and Option 2: variable length frames unaligned to the fixed length code blocks. A third variation that is currently included in the TC synchronization and Channel Coding specification [13] but not recommended for use with high performance FEC coding. Rather Option 2 is recommended as its replacement. The problem with this third variation in reference [13] is that the code block is created from an integer number of code words that must encompass the variable length frame. This results in the CSM not having the same offset with respect to the start of each TC frame. This lack of alignment makes the synchronization process more complicated. Instead we recommend the following process: The C&S sublayer accepts input transfer frames, prepends an ASM, and adds Idle Data as required to create a continuous symbol stream. The C&S sublayer then slices the required number of octets to fill a code block and then encodes that slice of data prepending the created code block with a CSM and outputs this continuous symbol stream to the physical layer.

To support Option 1, the slice of data provided to the Coding & Synchronization sublayer must always be a fixed length frame and begins at the first bit of the transfer frame. Since a CSM is prepended to the code block and the frame fills the code block then no attached synchronization marker (ASM) is required. If the input stream and a transfer frame are not

available for inclusion into the output bit stream, then an Only Idle Data frame must be provided to keep the link synchronous.

To support Option 2: the input bit stream is sliced independent of its contents, but requires that each frame within the bit stream be concatenated with an ASM, because the beginning of the frame is not guaranteed to coincide with the beginning of the code block. In this case, if a frame is not available for transfer then an Idle Data (bytes) are added to the input bit stream to complete the data slice.

The key interface between C&S WG and this proposed USLP Project is the removal of the constraint present in some CCSDS authorized codes that the code block size determines the transfer frame size. Removing this key constraint opens up the possibility of defining new link layer operational modes e.g., links that would allow a mission to choose between the transfer of fixed or variable length frames, along with the insertion of idle data over an optimally encoded CCSDS link.

The prime liabilities of using variable length frames are first that the Insert Zone could not provide an isochronous data delivery service and second that changes are required in the Spacecraft Clock calibration process and its 'Time Correlation Packets'.

2.1.2.10 Support the optional need for low latency command delivery and status reports using the Insert Zone

A variable length frame accommodates the insertion of a Transfer Frame Insert Zone. This Insert Zone could carry real time data or messages carried within the Insert Zone, signaled in the transfer frame header. The aperiodic insertion of real time data on demand is not efficient using a fixed frame approach.

Control directives accommodating changes in the physical layer and coding sublayer compatible with such applications as data rate and/or coding and modulation changes are under consideration.

Moreover, USLP could reduce the latency associated with the transfer of voice data by allowing the insertion of idle bits instead of Only Idle Data frames across synchronous data links. This is particularly important when ground transport has unexpected transient delays that break the timing required for synchronous frame delivery across the ground network. Defining and providing the rationale for all the applications of these new operational modes is within the scope of the USLP project.

The DLR has identified a use case and therefore a potential requirement for the use of the Insert Zone on both the uplink and downlink. The DLR/GSOC is preparing for operation of robotic low-earth orbit missions, with robotic fixtures operated remotely by the ground control center in real-time. For sending commands to the robotic payload and receiving the associated feedback, a protocol is needed that can handle timely real time conditions. As details emerge, further investigations for the potential use of USLP for this mission class will be made.

The size of an instruments output data unit is typically fixed to a time division data capture mechanism within the instrument or a variable sized data unit that is derived by use of an instrument specific compression algorithm. When a spacecraft contains multiple instruments the size of the data units generated in these instruments is usually different. These instrument data units have been transported within frames within CCSDS Space Packets to accommodate this variability in data unit size. The capability of having the frame length span to match the instruments data unit length can facilitate the use of the current SLE RCF service to deliver and account for instrument data in a simplified and direct manner.

2.1.2.11 Support more efficient Synchronous Commanding

We claim there is a requirement to reduce the frame delivery latency due to the elimination of the command front end buffer when uplinking synchronous transfer frames to reduce the need to include Only Idle Data (OID) frames. OID frames would be replaced with Idle octets. This would provide a more efficient Idle mechanism for synchronous commanding.

2.1.2.12 Support Mission Need for more agile use of Coding

We claim there is a Mission Operations Requirement to be more agile to the performance needs of a project over the space link. By having the transfer frame be unaligned from the code block allows Agencies to swap out the block code without affecting the transfer frame. For example, the short LDPC block codes have an exceeding low code word error rate, it is practical to build the transfer frame by using a fixed number of code words to form the code block. This approach allows for the encoding and decoding functions to be built into the Telecom subsystem and tested there with universal support for different missions. Mission developers should consider the option of concatenating a different number of code words to form different sized fixed length frames to match link performance.

2.1.2.13 Support Selective-repeat Commanding

We believe there is an emerging requirement to support selective-repeat based commanding. In the past, an uplink was only accepted by a spacecraft if the entire uplink was valid. This leads to an in-order, no duplicates, sequence approach of COP-1/P delivery for reliable command delivery. A COP-2 protocol was proposed in the 1980s for selective retransmission but the need at that time was limited and the protocol was never codified. But both uplink and downlink rates and volumes have accelerated and the use of selective repeat is growing.

A selective retransmit protocol may become a more likely approach for command reliability in the future. That requirement has driven the development and codification of CFDP, Bundle Protocol (BP), and LTP in order to facilitate the use of selective repeat commanding. CCSDS has a requirement to provide a mechanism to enable it and provide a path to support COP-1/P and selective retransmission protocols for uplink. We envision USLP being backward compatible with COP-1/P but also future looking towards providing the hooks for upper layer protocols to execute selective repeat.

2.1.2.14 Transfer All CCSDS approved SDUs directly across the space link

USLP has a new capability to transfer the SDUs for all CCSDS approved protocols (e.g., Space Packets, IP Datagrams, DTN bundles) directly across the space link without the need to encapsulate them. This is true as long as the SDU or SDU segment fills the TFDF of a frame and conforms to the protocol segmentation rules as required. The advantages to this approach are to integrate the totality of the segmentation and current CCSDS encapsulation directly into the USLP frame content structure. This mechanism provides a homogenous way of transferring all SDUs across CCSDS links that use variable length transfer frames. (CCSDS currently uses IPoC to transfer IP datagrams and Encapsulation Service to transfer other protocol PDUs.)

2.1.3 SUMMARY OF SERVICES

2.1.3.1 General

Six services are provided by the Unified Space Data Link Protocol. Four of them (Packet, Virtual Channel Access, Virtual Channel Operational Control Field, and Virtual Channel Frame) are provided for a Virtual Channel. The two services at the Master Channel level are Master Channel Frame and Transfer Frame Insert.

Table 2-1 summarizes these services and shows their characteristics and the Service Data Units (SDUs) that they transfer.

Table 2-1: Summary of Services Provided by TM Space Data Link Protocol

Service	Service Type	Service Data Unit	SAP Address
Virtual Channel Packet (VCP)	Asynchronous	Packet	GVCID + Packet Version Number or Protocol ID
Virtual Channel Access (VCA)	Asynchronous or Periodic	VCA_SDU	GVCID
Virtual Channel Operational Control Field (VC_OCF)	Synchronous or Periodic	OCF_SDU	GVCID
Virtual Channel Frame (VCF)	Asynchronous or Periodic	Transfer Frame	GVCID
Transfer Frame Insert Zone Field (IZ)	Synchronous or Periodic	OCF_SDU	MCID
Master Channel Frame (MCF)	Asynchronous or Periodic	Transfer Frame	MCID
† In this document, the term ‘Packet Service’ is used as an abbreviation for Virtual Channel Pack.			

- The optional SDLS protocol can provide security features for the SDUs transferred by the MCF, MC_IZ, VCF and VC_OCF services without interfering with those services:
 - encryption, to provide confidentiality by hiding data content;
 - authentication, to confirm the source and integrity of the data.
- Authenticated encryption, to provide confidentiality by hiding data content and to confirm the source and integrity of the data

2.1.3.2 Virtual Channel Packet (VCP) Service

The Packet Service transfers a sequence of variable-length, octet-aligned service data units known as Packets across a space link. The Packet types transferred by this service must be authorized by CCSDS. For the Packet Version Numbers presently authorized by CCSDS, see SANA reference [4]. CCSDS defined packets are the only type of packet that is authorized to use the streaming data process, all other user packet types must conform to the specific protocol identified in the TFDf header and can not use “streaming” unless they utilize the CCSDS Encapsulation Service reference [7]. This service is unidirectional, asynchronous and sequence-preserving. It does not guarantee completeness, nor does it signal gaps in the sequence of service data units delivered to a receiving user.

A user of this service is a protocol entity that sends or receives Packets. Different users (i.e., different Packets versions or types) can share a single Virtual Channel, and if there are multiple users with the same Virtual Channel, the service provider multiplexes packets of different versions and/or PVNs to form the transfer frames to transport user data across the space link.

2.1.3.3 Virtual Channel Access (VCA) Service

The Virtual Channel Access (VCA) Service provides transfer of a sequence of privately formatted service data units across a space link. The service is unidirectional, either asynchronous or periodic, and sequence-preserving. The service does not guarantee completeness but may signal gaps in the sequence of service data units delivered to the receiving user.

For a given service instance, only one user, identified with the GVCID of the Virtual Channel, can use this service on a Virtual Channel. Service data units from different users are not multiplexed together within one Virtual Channel.

2.1.3.4 Virtual Channel Operational Control Field (VC_OCF) Service

The Virtual Channel Operational Control Field (VC_OCF) Service provides synchronous transfer of fixed-length data units, each consisting of four octets, in the Operational Control Field (OCF) of Transfer Frames of a Virtual Channel. The service is unidirectional and sequence-preserving. The transfer is synchronized with the release of transfer frames of a

Virtual Channel. The service does not guarantee completeness, but it may signal gaps in the sequence of service data units delivered to the receiving user.

For a given service instance multiple user can use this service as long as they are associated with the same SCID and the OCF_SDU names the VC associated with the SDU. Service data units from different users may be multiplexed together within one Virtual Channel as long the OCF_SDU names the VCID associated with the SDU.

2.1.3.5 Virtual Channel Frame (VCF) Service

The Virtual Channel Frame (VCF) Service provides transfer of a sequence of variable length Transfer Frames of a Virtual Channel, created by an independent protocol entity, across a space link. The service is unidirectional, either asynchronous or periodic, and sequence preserving. The service does not guarantee completeness, but it may signal gaps in the sequence of service data units delivered to the receiving user.

For a given VC service instance up to 64 users, identified with the GVCID of the Virtual Channel, can use this service. VC Channel Service data units from different users (VC SAPs) are not multiplexed together within one VCID Channel and must have different GVCIDs.

The Virtual Channel Frame Service transfers the independently created transfer frames through a space link. This service is made available to trusted users who are certified during their design process to ensure that the independently created protocol data units do not violate the operational integrity of the space link by following the link management rules.

2.1.3.6 Transfer Frame Insert Zone (IZ) Service

The Transfer Frame Insert Zone Service provides the ability for a specified provider for a Master Channel to insert an Insert_Zone_SDU. The presence of an Insert_Zone_SDU within a transfer Frame is signaled by the Insert Zone Included Flag. Service data units from different users are not multiplexed together within one Master Channel.

2.1.3.7 Master Channel Frame (MCF) Service

The Master Channel Frame (MCF) Service provides transfer of a sequence of variable-length Transfer Frames of a Master Channel, created by an independent protocol entity, identified by the SCID, across a space link. The service is unidirectional, either asynchronous or periodic, and sequence-preserving. The service does not guarantee completeness, but it may signal gaps in the sequence of service data units delivered to a receiving user.

The Master Channel Frame Service transfers the independently created Transfer Frames through the space link, together with Transfer Frames created by the service provider itself. This service is made available to trusted users who are certified during the design process to ensure that the independently created protocol data units do not violate the operational integrity of the space link.

2.1.4 RESTRICTIONS ON SERVICES

There are some restrictions on the services provided on a Physical Channel:

- a) There can be only one value for the sequence counter behavior flag on a Master Channel;
- b) Only CCSDS packets can use the “Streaming Process” as explained in 2.1.4.2;
- c) All packet types can be segmented but the segments from a specific packet type must be contained within the sequence of frames of that VC until that packet is completed.
- d) If the Virtual Channel Frame Service exists on a Virtual Channel, other services shall not exist simultaneously on that same Virtual Channel;
- e) On a given Virtual Channel, the Virtual Channel Packet (VCP) Service shall not exist simultaneously with the Virtual Channel Access Service.

2.2 OVERVIEW OF FUNCTIONS

2.2.1 GENERAL FUNCTIONS

The USLP transfers various service data units supplied by sending users encapsulated in a sequence of protocol data units using services of lower layers. The protocol data units, known as USLP Transfer Frames, maybe of variable length and must be transferred over a Physical Channel at a constant symbol rate.

The protocol entity performs the following protocol functions:

- a) generation and processing of protocol control information (i.e., headers and trailers) to perform data identification, loss detection, and error detection;
- b) streaming and blocking of service data units to transfer variable-length service data units in fixed-length protocol data units;
- c) multiplexing/demultiplexing and commutation/decommutation in order for various service users to share a single Physical Channel;
- d) generation and removal of idle data to transfer protocol data units at a constant rate.
- e) segmenting and blocking of service data units to transfer variable-length service data units in variable-length protocol data units;

If the protocol entity supports the optional SDLS protocol, then it uses the functions of SDLS to apply the configured security features.

The security protocol entity does not perform the following protocol functions:

- a) connection establishment and release;
- b) flow control;
- c) retransmission of protocol data units;
- d) management or configuration of the SDLS protocol.

2.2.2 INTERNAL ORGANIZATION OF PROTOCOL ENTITY

Figures 2-1 and 2-2 show the internal organization of the protocol entity of the sending and receiving ends, respectively. Data flow from top to bottom in figure 2-1, and from bottom to top in figure 2-2. These figures identify data-handling functions performed by the protocol entity and show logical relationships among these functions. The figures are not intended to imply any hardware or software configuration in a real system. Depending on the services actually used for a real system, not all of the functions may be present in the protocol entity.

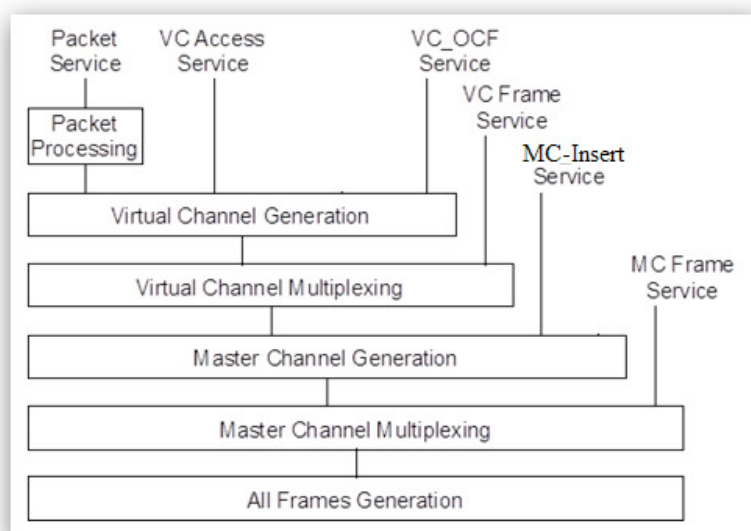


Figure 2-1: Internal Organization of Protocol Entity (Sending End)

Kazz, Greg J (313B) 10/27/2014 4:39 PM

Deleted: 2-5

Kazz, Greg J (313B) 10/27/2014 4:39 PM

Deleted: 2-6

Kazz, Greg J (313B) 10/27/2014 4:39 PM

Deleted: 2-5

Kazz, Greg J (313B) 10/27/2014 4:39 PM

Deleted: 2-6

Kazz, Greg J (313B) 10/27/2014 4:39 PM

Deleted: 5

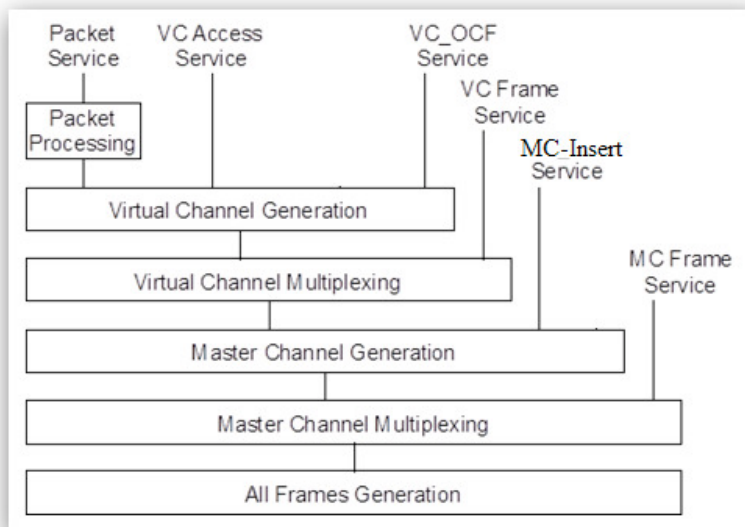


Figure 2-2: Internal Organization of Protocol Entity (Receiving End)

By extracting multiplexing/demultiplexing and commutation/decommutation functions from figures 2-1, and 2-2, the relationship among various data units can be shown as figure 2-3, which is known as the Channel Tree of the USLP Space Data Link Protocol.

In figure 2-3, multiplexing (shown with a triangle) is a function of mixing, according to an algorithm established by the project, multiple streams of data units, each with a different identifier, to generate a single stream of data units. Commutation (shown with a box) is a function of concatenating, according to the formatting rule specified by the protocol definition, multiple data units, each from a different service, in a single protocol data unit sharing the same identifier.

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 6

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 2-5

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 2-6

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 2-7

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 2-7

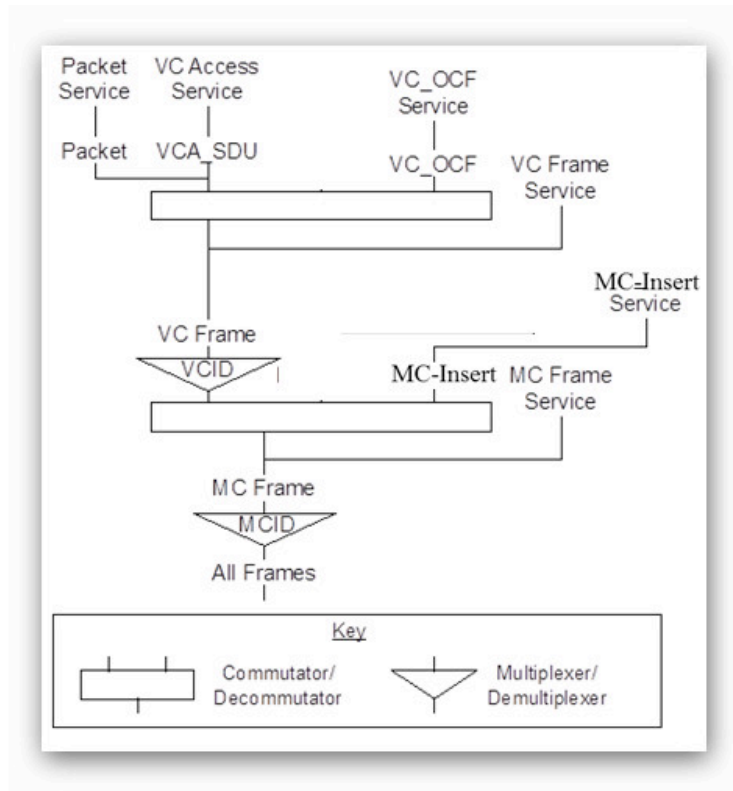


Figure 2-3: USLP Space Data Link Protocol Channel Tree

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 7

2.3 SERVICES ASSUMED FROM LOWER LAYERS

2.3.1 SERVICES ASSUMED FROM THE SYNCHRONIZATION AND CHANNEL CODING SUBLAYER

USLP requires a service from the Coding & Synchronization sublayer to accept variable length frames at the sending end and delivers (validated) variable length frames at the receiving end. Such a service should utilize one of the three techniques documented in Annex C. The required physical channel management rules along with the frame and code block alignment option rule will be communicated to the C&S sublayer via a set of managed parameters (see Managed Parameter specification in section 4.) Some key interface parameters between the C&S sublayer and the data link protocol sublayer deal with the removal of the constraint present in some CCSDS authorized codes that the codeblock size is fixed or variable and whether the frame and code block are aligned. Removing the key transfer frame and code block alignment constraint opens up the possibility of defining new

link layer operational modes e.g., links that would allow a mission to choose between the transfer of fixed or variable length frames, along with the insertion of idle data over an optimally encoded CCSDS link.

As described in 2.1.1, both the TM and the TC Synchronization and Channel Coding Recommendations (reference [3] and [13]) must be used with the Unified Space Data Link Protocol as the Synchronization and Channel Coding Sublayer specifications. The functions provided by the TM and TC Synchronization and Channel Coding Recommendation are as follows:

- a) error control encoding and decoding functions (optional);
- b) bit transition generation and removal functions (optional);
- c) delimiting and synchronizing functions.

The Synchronization and Channel Coding Sublayer, then, transfers contiguous, variable-length, delimited protocol data units as a contiguous stream of symbols over a space link using the services of the underlying Physical Layer.

2.3.2 REQUIREMENTS TO LOWER LAYERS

The coding options of the TM Channel Coding and Synchronization Recommendation and the performance of the RF link provided by the Physical Layer shall be chosen according to the following criteria:

- a) the probability of misidentifying the SCID and VCID shall be less than a mission-specified value;
- b) the probability of not correctly extracting Packets from Transfer Frames using the First Header Pointer and the Packet Length Field in support of streaming shall be less than a mission-specified value.

In order to assure correct decoding at the receiving end, the same coding options must be applied to all Transfer Frames of a Physical Channel.

Note: We recommend the use of fixed length code blocks. It is possible to change the code block size by allowing a different number of code words to be specified for inclusion between CSMs. However these changes should only be allowed to be made when different data rates are applied. This process can easily be accomplished because the FEC decoder is constant no matter how many code words are contained in a code block and the portion of the symbol stream contained can be delivered immediately and thus reduce latency.

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: [3]

3 USLP OVERVIEW OF MISSION SERVICES

3.1 USER APPLICATIONS

The USLP Recommendation supports single space vehicles, or constellations of space vehicles, which simultaneously execute a wide spectrum of applications in near-earth orbit, geostationary orbit, or deep space. The USLP can be tailored to support observational science, experimental science, manned and robotic platforms/vehicles, launch services and the transfer of engineering data for the operational control of the space vehicle (“core”) systems.

3.2 OBSERVATIONAL SCIENCE

Observational science is primarily performed from unpressurized platforms in orbits around the Earth or other planetary bodies. Examples include astronomy, space physics, and Earth observation.

Typically, the lifetime of observational payload investigations is in the order of years. The user equipment is relatively stable in terms of location and functionality and usually requires minimal on-orbit human interaction during the life of a mission. There is therefore a relatively static association between a space instrument and its ground processing facility.

Since transmitted data rates are often high, the observational user requires streamlined techniques for acquiring, buffering and delivering large volumes of data from space to ground, with protocols optimized so as to reduce requirements for onboard processing resources and communications bandwidth. The data taking process usually is performed during much of the trajectory path but communications is often limited to preplanned periods. The process therefore typically requires the acquired data to be buffered until it can be down linked during a communications session. Because of the need to share limited onboard resources between multiple users (i.e. instruments), observational operations may require extensive preplanning and scheduling. Uplink data delivery requirements are significant lower than the downlink rate requirements. A large degree of protocol flexibility, such as the capability to change addresses dynamically, is therefore unnecessary.

3.3 EXPERIMENTAL SCIENCE

Experimental science, such as materials processing and the effects of space on human physiology, is conducted primarily in pressurized space vehicles since a high degree of flight crew interaction may be required.

In contrast to observational science, experimental science investigations are often scheduled for only a limited time duration. General purpose “laboratory” equipment that has been used in one experiment may be almost immediately reconfigured for use in another. A crew member may control an experiment from workstations at different locations, possibly assisted by an investigator on earth. Hence, source-destination data communications pairs

may be only temporarily associated with any particular experiment, and these associations will typically exist only for relatively short sessions. The level of human interaction is high in terms of monitor and control of the experiment and much of the information that is generated will be evaluated on board. Thus, the volume of data that is transmitted to and from the ground may be relatively low.

Experimental users have needs that are quite similar to those of users of a local area network facility located on the ground. In particular, they need data communications protocols which provide routing flexibility by supporting global source and destination addressing, and which support a rich repertoire of upper-layer data handling services.

3.4 ROBOTIC PLATFORMS/VEHICLES

The links that support robotic platforms/vehicles typically operate in short windows of time based on the available geometry between the robotic platforms/vehicles and the other terminus of the link. These links can be end-to-end or rely on a relay system to forward the data between the robotic platform/vehicle and its Earth based control entity. The link characteristics can be significantly different but the end-to-end services would likely be the same. The USLP is designed to accommodate the differences in link characteristics primarily by allowing the frame and the link layer coding to be independent. This frees the framing from the constraints of link's coding implementations.

Disassociating the frame from the code block also provides the opportunity to provide a frame relay service. In this mode the communications hub can receive frames and relay them toward their destination based on a managed path for frames using their spacecraft id and the value in the destination/source flag.

3.5 MANNED PLATFORMS/VEHICLES

Communications links to support manned mission are typically 24/7. The required links include emergency control and voice delivery, science data telemetry, instrument and vehicle remote control, human text type services, health and safety data and video. The data for these services, as currently being designed for the NASA manned program, utilizes Internet network packets and services. The USLP is designed to efficiently transfer these network packets, contained within CCSDS Encapsulation Service Packets, between Internet routers on the ground and in space. It is anticipated that during normal operations link data rates can be in the multi-megabit range for selected data. It is also anticipated that Operations Control Centers would provide some form of link layer security for the user data that is under its purview and it is desired to limit the number of Keys required. Security for other users may use the security algorithm but may control their own keys. In total the desire might be to limit the number of different security associations to limit the key management complexity.

The use of the USLP allows the manned missions to use the same data link protocol for all of its links. It will also provide a more efficient platform for transferring IP Datagrams and DTN Bundles. The USLP also provides mechanisms to reduce latencies.

3.6 LAUNCH VEHICLES

The data rates supporting launch vehicles are typically limited in both directions. Timeliness of data delivery is the critical factor in both the return and forward links. The NGLP has a few features that are designed to support these requirements. The capability to send variable length frames and capitalize on using a transfer frame Insert Zone for critical messaging keeps latency to a minimum. The separation of the frame from the code block allows the frame size to vary while the code word size is maintained. This functionality is also useful for decent and landing telemetry links for telemetering critical event information with minimum latency.

3.7 CORE OPERATIONS

The core infrastructure operates and maintains the space vehicle systems that support the payload users. Core user requirements share attributes that are common to all space vehicle applications. Since the safety of the space mission (as well as often the safety of human lives) is involved, reliability concerns may strongly influence the selection of services that are used for transmission of core data.

A high degree of interaction is required in order to perform adaptive command and control (similar to experimental users), yet fairly large quantities of systems monitoring data must be repetitively and continuously returned to static locations on Earth in order to support long-term analysis of engineering performance (similar to observational users). Core users are therefore likely to use both the Internet service and the Path service for message exchange. For piloted missions, synchronized digitized audio and video must also be integrated with message traffic between ground controllers and onboard crew; the Path service can often satisfy these needs, but for some applications special CCSDS point-to-point space link data-transfer mechanisms have been provided.

3.8 SPACE NETWORKING ENVIRONMENT

Space/ground data transmission requires use of high capital-investment tracking facilities that must be shared not only by multiple users, but also by multiple space missions. Onboard resources are almost invariably subject to constraints of power, weight, volume, and the high costs of flight-qualifying hardware and software.

All of these considerations point to the need for robust space data handling services which are optimized for efficiency and low utilization of onboard resources. Because of the intermittent nature of the space/ground link transmission contacts, onboard data storage and replay must be accommodated. Removing the artifacts of transmission across the space link often requires considerable value-added processing prior to delivery of data to end users.

4 MANAGED PARAMETERS

NOTES

- 1 In order to conserve bandwidth on the space link, some parameters associated with the USLP are handled by management rather than by inline communications protocol. The managed parameters are those which tend to be static for long periods of time, and whose change generally signifies a major reconfiguration of the protocol entities associated with a particular mission. Through the use of a management system, management conveys the required information to the protocol entities.
- 2 In this section, the managed parameters used by the USLP are listed for each of the Channels and for Packet transfer. These parameters are defined in an abstract sense and are not intended to imply any particular implementation of a management system.

4.1 MANAGED PARAMETERS FOR A PHYSICAL CHANNEL

Table 4-1, lists the managed parameters associated with a Physical Channel.

Table 4-1: Managed Parameters for a Physical Channel

Managed Parameter	Allowed Values
Physical Channel Name	Character String
Coding used	CCSDS Telemetry [3] or Telecommand [13] Sync & Channel Coding specs
Frame and Code block alignment	Fixed or Variable
Transfer Frame Version Number	6
Valid Spacecraft IDs	Set of Integers, SCID SANA Registry
MC Multiplexing Scheme	Mission Specific
Presence of Frame Error Control	Present, Absent

Kazz, Greg J (313B) 10/27/2014 4:39 PM

Deleted: 5-1

4.2 MANAGED PARAMETERS FOR A MASTER CHANNEL

Table 4-2 lists the managed parameters associated with a Master Channel.

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 5-2

Table 4-2: Managed Parameters for a Master Channel

Managed Parameter	Allowed Values
Spacecraft ID	Integer, SCID SANA Registry
Valid VCIDs	Set of Integers (from 0 to 7)
VC Multiplexing Scheme	Mission Specific
Presence of TF_IZ	Fixed or Signaled
NOTE – The value of the Transfer Frame Version Number is the same for all Transfer Frames on a Physical Channel.	

4.3 MANAGED PARAMETERS FOR A VIRTUAL CHANNEL

Table 4-3 lists the managed parameters associated with a Virtual Channel.

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 5-3

Table 4-3: Managed Parameters for a Virtual Channel

Managed Parameter	Allowed Values
VCID	0, 1, ..., 63
Data Field Content	Packets, VCA_SDU
Presence of Space Data Link Security Header	Present / Absent
Presence of Space Data Link Security Trailer	Present / Absent
Length of Space Data Link Security Header (octets)	Integer
Length of Space Data Link Security Trailer (octets)	Integer
NOTE – The value of the Transfer Frame Version Number is the same for all Transfer Frames on a Physical Channel.	

4.4 MANAGED PARAMETERS FOR PACKET TRANSFER

Table 4-4 lists the managed parameters associated with a Virtual Channel used for the Virtual Channel Packet Service.

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: 5-4

Table 4-4: Managed Parameters for Packet Transfer

Managed Parameter	Allowed Values
Valid Packet Version Numbers	Set of Integers selected from reference [4]
Maximum Packet Length (octets)	Integer
Protocol ID	SANA Registry - http://sanaregistry.org/r/protocol_id/protocol_id.html
Whether incomplete Packets are required to be delivered to the user at the receiving end	Required, Not required

5 **EXAMPLE** PROTOCOL SPECIFICATION AND RATIONALE

5.1 OVERVIEW

The proposed Data Link Layer Protocol incorporates a flexible transfer frame structure that can be optimized for the specific needs of each space link type and its constraints, all using the flexible Unified Space Link Protocol (USLP) frame format. This format provides sufficient data visibility within the frame header to enable the receive side link layer frame processing to delimit the frame, separate and route Master and/or Virtual Channel (VC) frames without management details (aside from those required for physical layer operation and forward error correction decoding) nor the security encoding incorporated within them. The tailoring of the frame functionality is accommodated within the transfer frame header. The contents and structure of the Transfer Frame Data Field is identified within the Transfer Frame Data Field header. The details of the tailoring capabilities of the transfer frame will be explained in this chapter below.

In order to provide missions with enhanced operability by augmenting the services provided within the TC and Proximity-1 Protocols, the USLP has provided a new sequence counter behavior flag that divides the VCID space into two groups of 32 Virtual Channels each. USLP enables each of these VC groups to share the same sequence counter to provide a continuity check for the specific group. The first group is defined for VCIDs 0 to 31. The second group is defined for VCIDs 32-63. For each group the sequence counter increments by one when a VC of that particular group is transported. This capability enables a single VC group to provide reliable delivery of the various SDUs sharing that VC group using the “Go-Back-N” protocol as currently used in Telecommand (using MAPs) and Proximity Links (Port IDs). The other VC group may be used to deliver SDUs that are supported by a selective repeat protocol.

The current Telecommand Protocol relies on a segmentation process to allow large packets to be carried within small frames, while the TM and AOS protocols provide this capability by a process named in this document as “streaming”. In the “streaming” process, a sequence of packets is allowed to flow continuously across transfer frame boundaries. The streaming process has been incorporated within USLP for use on all links to provide this functionality. The USLP protocol also supports transfer of variable length frames that can support delivery of user SDUs using segmentation if necessary.

5.2 USE OF SDLS PROTOCOL

If SDLS as defined in reference [8], is required over the USLP, then the SDLS protocol shall be used.

NOTE – The Space Data Link Security Protocol provides a security header and trailer along with associated procedures that may be used with the USLP to provide data authentication and data confidentiality at the Data Link Layer.

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: [8]

5.3 USLP TRANSFER FRAME

5.3.1 OVERVIEW

The Transfer Frame contains up to 7 fields: Transfer Frame Header, TF Insert Zone, Optional Security Header/Trailer, Transfer Frame Data Field, Operational Control Field and the Error Control Field. The Transfer frame Header is the only mandatory field in the entire transfer frame. It contains the frame length field providing the link the capability of transporting variable length frames whenever there is no management restriction requiring only fixed length frames. The Transfer Frame Insert Zone, the Operational Control Field, the Virtual Channel Sequence Counter (in TF header) and the Transfer Frame Error Control Fields are all optional and their presence is signaled in the TF header. The size of the Virtual Channel Sequence Counter and the Transfer Frame Error Control Field are identified in the Transfer Frame header.

Transfer Frame Header	Transfer Frame Insert Zone	VC Security Header	Transfer Frame Data Field (TFDF_PDU)	VC Security Trailer	Transfer Frame Operational Control Field	Transfer Frame Error Control Field
6-13 Octets Mandatory	Variable Optional	Variable Optional	Variable Optional	Variable Optional	4 Octets Optional	Variable Optional

Figure 5-1: USLP Transfer Frame

5.3.2 TRANSFER FRAME PRIMARY HEADER IN A FRAME

The Transfer Frame Header is the only mandatory field in the frame and it contains a frame length field providing the capability for the Transfer Frame to be of variable length making it compatible for all data links. The frame structure is backward compatible for each link type supporting all currently provided services (as described in Section 2). The forward error correcting coding, frequency and modulation along with the frame and code block alignment choice are management controlled items for setting up a link connection. The Transfer Frame Header contains eleven fields and the order that they appear is shown in Figure 5-2 below.

Transfer Frame Version Number	Spacecraft ID	Source or Destination ID	Unspecified	Virtual Channel ID	Frame Length	Insert Zone Included Flag	FECF Size	OCF Flag	Sequence Counter Behavior Flag	Sequence Counter Length	Sequence Counter Value
3 bits	13 bits	1 bit	1 bit	6 Bits	16 Bits	1 bit	2 bits	1 bit	1 bit	3 bits	0-56 Bits

Figure 5-2: USLP Transfer Frame Header

5.3.2.1 TRANSFER FRAME VERSION NUMBER (TFVN)

The Transfer Frame Version Number identifies the format of the transfer frame. By examining the TFCN SANA registry, one can determine the space data link protocol associated with a given TFCN. This field is 3 bits long. The original field specified in references [9-12] has been extended by one bit to allow for one future version number. The USLP Transfer Frame uses the last remaining value available in the 2 bit Transfer Frame Version Number field i.e., '11' and appends "0" to it to complete the 3 bit version number ('110').

5.3.2.2 SPACECRAFT ID (SCID)

The value contained in the SCID identifies the Master Channel for that transfer frame. The Spacecraft ID field has been extended from the current 8 bits (Version 2) or 10 bits (Version 1 and 3) to 13 bits (Version 4) to accommodate a larger population of spacecraft expected (up to 8192), especially due to the advent of Cube and Micro Satellites and landed data gathering sensor platforms.

5.3.2.3 SOURCE OR DESTINATION ID (S/D ID)

The Source-or-Destination Identifier is used to interpret the value of the SCID field. A S/D ID of "0" (source) identifies the spacecraft that created this frame. A S/D ID of '1' (destination) identifies the intended recipient of this frame.

The behavior of the recipient of this frame with respect to the values of the SCID field and Source-or-Destination Identifier is described below:

When the value contained within the Source-or-Destination Identifier field is "0" then the recipient may accept this frame if allowed by mission management. This methodology allows the sender to broadcast the data to one or more recipient entities while identifying its self.

When the value contained within the Source-or-Destination Identifier field is "1" then the recipient only accepts this frame if its assigned SCID equals the value of the SCID contained within the frame or its function is to relay that frame toward the identified recipient. The methodology is used to transfer data exclusively to the designated recipient spacecraft.

5.3.2.4 UNDEFINED FIELD – 1 BIT SPARE

This spare bit is reserved for future CCSDS use.

5.3.2.5 VIRTUAL CHANNEL ID

The VCID field is 6 bits in length and provides the capability to create up to 64 virtual

channels. VCs are used to multiplex different types of data across the master channel. The selection of the VCID is dependent upon the value of the VC SEQUENCE COUNTER BEHAVIOR FLAG. See Section 5.3.2.10.

NOTES

- 1 If only one Virtual Channel is required for selection of the receiving process as in the Proximity protocol, the remaining bits can be used to identify internal routing addresses or specific rule sets [i.e. control commands not requiring sequence control (not bypass)].
- 2 A Virtual Channel used for transmission of Idle Transfer Frames is indicated by setting these bits to the reserved value of 'all ones' (i.e., 63).
- 3 There are no restrictions on the selection of Virtual Channel Identifiers except the rules described above. In particular, Virtual Channels are not required to be numbered consecutively.

5.3.2.6 TRANSFER FRAME LENGTH

The Transfer Frame Length Field is 16 bits in length providing the capability to create a maximum frame of 65,536 octets long. Thus a range of frame lengths from very small [i.e., an emergency command containing 1 octet of payload data can be as small as 7 octets (6 octet TF Header, no Insert Zone, No Security Header/Trailer, no Sequence Count Field, no OCF and no FECF)] to very large transfer frames can reduce operational frame handling complexities at high rates.

5.3.2.7 INSERT ZONE INCLUDED FLAG

If the value in the field is "0", then no Transfer Frame (TF) Insert Zone Field is contained. When the value contained within this field is a "1", it signals that a TF Insert Zone Field is contained within the transfer frame. The TF Insert Zone may be included to provide a data transfer zone in the frame in addition to the Frame Data Field. The contents of the TF Insert Zone would be provided to the frame generation process by the TF Insert Service. Previous to the USLP, the TF Insert Zone was only included in the AOS protocol [12] and it was required to occur in every frame of that Master Channel. The service in AOS was defined to provide for the transfer of isochronous data only and required the presence of an Insert Zone to be managed, its length fixed, and be present in all frames in a physical channel. The USLP does not impose this constraint allowing the presence of an Insert Zone to be signaled and its size identified in the Insert Zone's mandatory header. See Section 2.1.1.2 Transfer Frame Insert Zone. The use of the Insert Zone is mission dependent and may also be used to provide the same service obtainable using the VC Secondary Header in the TM frame if desired.

5.3.2.8 FRAME ERROR CONTROL FIELD (FECF) SIZE FIELD

This field is 2 bits and provides the information about the size of the FECF. The acceptable values are: 1) '00' indicates there is no FECF field, 2) '01' indicates that the FECF is 16 bits in length and uses the 16 bit CRC code documented in the reference [11]) '10' indicates that the FECF is 24 bits in length (a CCSDS algorithm has not been standardized for this length

field), and 4) '11' indicates the FECF is 32 bits in length and is the CRC documented in the Proximity-1 reference [14]. If an FECF is contained in the frame, then the Master Channel process will know that it is to verify the frame's contents and recognize the algorithm to use for that process.

5.3.2.9 OPERATION CONTROL DATA FIELD (OCF) INCLUDED FLAG

If the value in the field is "0" then no OCF field is contained. When the value contained within this field is a "1", it signals that an OCF field is contained within the transfer frame. The OCF field is used to support the frame GO-Back-N Protocols used in support of DFE and Proximity-1 protocols. The OCF can optionally be used for other signaling services that have yet to be codified.

5.3.2.10 SEQUENCE COUNTER BEHAVIOR FLAG

This flag specifies the type of behavior that the VC Channel Sequence Counter Field exhibits for either a group of VIDs or for an individual VID. There are two distinct ways in which the VC Sequence Counter Field increments based upon the value of this flag.

This flag specifies the type of behavior that the VC Channel Sequence Counter Field exhibits for either a group of VIDs or for an individual VID. There are two distinct ways in which the VC Sequence Counter Field increments based upon the value of this flag.

When Behavior Flag is '0' (false), then each VC (0 through 63) has a separately assigned Sequence Counter that is incremented for each frame in that given VC. Note: This behavior is mainly used for telemetry applications.

When Behavior Flag is '1' (true), then each VC (0 through 31) has a separately assigned Sequence Counter that is incremented for each frame in that VC created but VCs 32-64 share a single Sequence Counter that is incremented when a frame in that VC group (VCs 31-63) is created. This behavior is primarily use for command applications.

5.3.2.11 SEQUENCE COUNTER SIZE

The value contained within this field identifies the size of the Virtual Channel Sequence Count. This 3 bit field allows the size of the Transfer Frame Sequence Counter to vary from 0 to 7 octets in length. Emergency and control commanding that traditionally uses the bypass options in their respective protocols do not require any sequence count and this feature allows for a minimum frame size. The very high rate links that utilize the sequence counts for both accounting and ordering of received frames especially when received from multiple ground stations can set the sequence size to the size that they require. For Virtual Channels that are not sequence controlled and carry data that utilize selective retransmission, the sequence counter value may be inconsequential and thus the counter size field could be set to zero.

5.3.2.12 SEQUENCE COUNTER FIELD

The Sequence Counter field is the only field within the Transfer Frame Primary Header with a variable length. The size of this field is determined by the value contained within the VC Sequence Count Size Field. The Sequence Counter field size can vary from 0 to 7 bytes in length. The maximum count would be approximately 7.2×10^{16} . This field would be larger than currently obtainable using the AOS Space Data Link Protocol [12] or as small as desired for control commanding, messaging or emergency telemetry modes. The sequence counter field provides the means to determine sequence continuity for either a VC or VC Group dependent upon the value contained within the Sequence Counter Behavior Flag.

5.3.3 TRANSFER FRAME INSERT ZONE

The Transfer Frame Insert Zone, if used, must be signaled by the Transfer Frame Insert Zone Flag within the Transfer Frame header for each frame of the Master Channel within which it appears. In order to comply with the requirement to make MC services data driven, it is necessary to include a specified Insert Zone Header within the Insert Zone itself.

The ability to provide a synchronous data insert using the TF Insert Zone requires that transfer frames be of a fixed size and occur at a fixed interval. Currently AOS [12] requires each transfer frame in the Master Channel to be of fixed length and the size of the TF Insert Zone is fixed and no additional idle bits between frames is accommodated. This exact optional implementation can be accomplished using the USLP assuming the same constraints are applied for the MC.

The TF Insert zone could be used to carry real time data/data messages if the frame size is allowed to vary to accommodate the variability of the TF Insert zone. This approach could be utilized for low latency messaging for Launch, decent and landing, and tele-robotics.

5.3.3.1 Transfer Frame Insert Zone Header

A Transfer Frame Insert Zone header is required to determine the length of the Transfer Frame Insert Zone. A single octet is required as the first octet in the Insert Zone which contains the value of the length of the Insert Zone.

- 5.3.3.1.1** The first byte of the TF Insert Zone contains the Length of the Insert Zone in Octets. This constrains the length of the TF Insert Zone to 256 bytes.

5.3.4 SECURITY HEADER

If present, the Security Header shall follow, without gap, the Transfer Frame Secondary Header if a Transfer Frame Secondary Header is present, or the Transfer Frame Primary Header if a Transfer Frame Secondary Header is not present.

NOTES

- 1 The presence of the Security Header is a managed parameter of the Virtual Channel.
- 2 The requirements for the length and contents of the Security Header are specified in reference [8].
- 3 The length of the Security Header is an integral number of octets and is a managed parameter of the Virtual Channel. See Section 4.3.

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: [8]

5.3.5 TRANSFER FRAME DATA FIELD

The Transfer Frame Data Field contains the data contents of a Virtual Channel. The contents of this field are managed by the Virtual Channel user that is identified in the Transfer Frame Header. The TFDF consists of a header and data. The Size and content of the TFDF Header are dependent on how it is used. It may consist of up to three fields: Data Inclusion Rules, Protocol ID (including a Protocol ID Extension), and Streaming Data Pointer. The TFDF header is provided to enable the receiver of the frame to process the frame contents without knowledge of the management rules for the VC. The services that may be performed uniquely are: IP datagram extraction and delivery, DTN bundle and fragment extraction and delivery. The functions for extraction of and reassembly of CCSDS Space Packets and VCA data are provided but delivery of those entities require user management data. See Figure 5-3 below.

Mandatory Fields		Optional	Optional
Data Inclusion Rules	Protocol ID	Protocol ID Extension	Streaming Data Pointer
3 bits	5 bits	8 bits	16 bits

Figure 5-3: Transfer Frame Data Field Header

5.3.5.1 Data Inclusion Rules

This field identifies the type of SDU data contained and the data packing rules for inclusion in the Transfer Frame Data Field (TFDF). The options are:

- '000' = one or more complete CCSDS packets in this TFDF (no segmentation)
- '001' = Spare for CCSDS use
- '010' = CCSDS Packets using streaming rules
- '011' = Idle Data
- '100' = SDU is a continuation segment that neither starts or ends in this TFDF
- '101' = SDU is segmented and ends in this TFDF but does not start in this TFDF
- '110' = SDU is segmented and starts in this TFDF but does not end in this TFDF
- '111' = a complete single user SDU that starts and ends in this TFDF

5.3.5.2 Protocol ID and Optional Protocol ID Extension Fields

This field identifies the Protocol of the User data. This field is either 5 bits or 13 bits in length. Optionally when the five bits following the Data Inclusion Rules are set to "11111" then an additional octet is appended to the five bit field to provide an extra 256 Protocol SDUs for identification. The Protocol IDs currently recognized by CCSDS for transmission over the CCSDS space link are:

'00000' = CCSDS Space Packet

'00001' = IP Datagram

'00010' = DTN Bundle

'00011' = User Octets

'11111' = Signals the use of the Protocol ID Extension field which is 1 octet in length and immediately follows the Protocol ID field

Note: This extension provides for the optional inclusion of another 256 Protocols that can be assigned.

All unused Protocol IDs are under the control of CCSDS and managed by SANA.

5.3.5.3 Streaming Data Pointer

This field is required only when transporting streaming data. It provides the mechanism that allows packet delimiting to be reinitialized when frame loss occurs and for determining where either the last valid packet header (VCP service) or the last valid octet (VCA service) is located in the TFDF. The values are: Not required, First Header Packet Pointer, Last Valid Octet in TFDF, TBD.

5.3.5.4 Transfer Frame Data Field Content

This field contains the user data units that are transported by the transfer frame. When fixed length frames are used then the data content in the TFDF is restricted to streaming CCSDS Packets or User Octets (VCA_SDUs). When variable length frames are used then the segmentation of packets is accommodated with the delimiting flags provided in the Data Inclusions Rules Field in the TFDF Header.

5.3.6 SECURITY TRAILER

If present, the Security Trailer shall follow, without gap, the Transfer Frame Data Field.

NOTES

- 1 The presence of the Security Trailer is a managed parameter of the Virtual Channel.
- 2 The requirements for the length and contents of the Security Trailer are specified in reference [8].
- 3 The length of the Security Trailer is an integral number of octets and is a managed parameter of the Virtual Channel. See Section 4.3.

Kazz, Greg J (313B) 10/27/2014 4:39 PM
Deleted: [8]

5.3.7 OPERATIONAL CONTROL FIELD

The presence of this optional OCF is signaled in the transfer frame header. When the COP is in use, this field contains the Command Link Control Word (CLCW)/Proximity-1 Link Control Word (PLCW).

5.3.8 FRAME ERROR CONTROL FIELD

The presence of this field is conditional. Its presence and size are signaled by the FECF Size Field. The function of this field is to carry the data generated by the frame validity Control algorithm designated for use on this specific Transfer Frame. The size of FEC field also identifies the algorithm used to create the data.

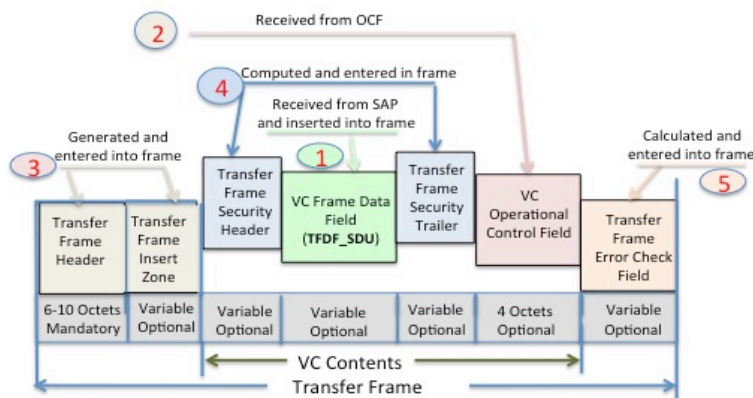
5.4 SENDING END PROTOCOL PROCEDURES

5.4.1 TRANSFER FRAME ASSEMBLY PROCESS

See Figure 5-4, Transfer Frame Assembly Process below. The total length of all the included fields plus the frame header will be identified in the length field in the Transfer Frame header. The size, content type and data structuring rules for the contents in the TFDF are signaled within the TFDF header. The order for inclusion of the data fields within the frames is provided by three assembly processes as follows: 1) the Virtual Channel Assembly process

accepts the optional Transfer Frame Data Field (TFDF) and inserts it into the frame being assembled along with 2) the optional VC Operational Control Field as supplied by the Frame Acceptance and Reporting Mechanism (FARM) and additionally includes the areas that will be filled by the Link Security Protocol process, 3) the Master Channel Assembly process provides the mandatory Transfer Frame header (since the length of the frame can now be calculated) along with the optional Transfer Frame Insert Zone 4) the optional Space Link Security Protocol Service can then calculate and provide the Security Header and Security Trailer that uses the assigned Security Association and inserts the data into the reserved portions of the transfer frame and optionally lastly 5) the inclusion of the Frame Error Control field (FECF) is managed thus its inclusion in the frame is anticipated by the Master Channel Assembly Process (for determining the length of the frame). The CRC is calculated based on all the fields already placed in the frame using the predefined CRC algorithm defined for the link.

Transfer Frame Assembly



Note:

The number within the circles identifies the order of inclusion in the frame formation process

Figure 5-4: Transfer Frame Assembly Process

ANNEX A**ACRONYMS**

(This annex **is not** part of the Recommendation)

AOS	Advanced Orbiting Systems
APID	Application Process Identifier
ASM	Attached Synchronization Marker
CCSDS	Consultative Committee for Space Data Systems
CLCW	Communications Link Control Word
COP	Command Operations Procedure
C&S	Coding and Synchronization (Working Group in CCSDS)
CSM	Codeword Synchronization Marker
DLR	Zentrum fuer Deutsche Luft und Raumfahrt
FEC	Forward Error Correcting
FECF	Frame Error Control Field
GSOC	German Space Operations Center
GVCID	Global Virtual Channel Identifier
IZ	Insert Zone
LDPC	Low Density Parity Check
MC	Master Channel
MCF	Master Channel Frame
MCID	Master Channel Identifier
MSB	Most Significant Bit
USLP	Unified Space Link Protocol
OCF	Operational Control Field
OID	Only Idle Data

OSI	Open Systems Interconnection
PDU	Protocol Data Unit
PVN	Packet Version Number
SAP	Service Access Point
SANA	Space Assigned Numbers Authority
SCID	Spacecraft Identifier
SDLS	Space Data Link Security
SDU	Service Data Unit
TC	Telecommand
TFDF	Transfer Frame Data Field
TM	Telemetry
TFVN	Transfer Frame Version Number
VC	Virtual Channel
VCA	Virtual Channel Access
VCF	Virtual Channel Frame
VCID	Virtual Channel Identifier
VCP	Virtual Channel Packet

ANNEX B**INFORMATIVE REFERENCES**

(This annex **is not** part of the Recommendation)

- [B1] *Overview of Space Communications Protocols*. Issue 3. Report Concerning Space Data System Standards (Green Book), CCSDS 130.0-G-3. Washington, D.C.: CCSDS, July 2014.
- [B2] *Space Data Link Protocols-Summary of Concept and Rationale*. Issue 2. Report Concerning Space Data System Standards (Green Book), CCSDS 130.2-G-2. Washington, D.C.: CCSDS, November 2012.
- [B3] *Proximity-1 Space Link Protocol-Rationale, Architecture, and Scenarios*. Issue 2. Report Concerning Space Data System Standards (Green Book), CCSDS 210.0-G-2. Washington, D.C.: CCSDS, December 2013.
- [B4] *Next Generation Uplink*. Issue 1. Report Concerning Space Data System Standards (Green Book), CCSDS 230.0-G-1. Washington, D.C.: CCSDS, July 2014.
- [B5] *TC Synchronization and Channel Coding-Summary of Concepts and Rationale*. Issue 2. Report Concerning Space Data System Standards (Green Book), CCSDS 230.1-G-2. Washington, D.C.: CCSDS, November 2012.
- [B6] *TM Synchronization and Channel Coding-Summary of Concepts and Rationale*. Issue 2. Report Concerning Space Data System Standards (Green Book), CCSDS 130.1-G-2. Washington, D.C.: CCSDS, November 2012.
- [B7] *Telecommand Summary of Concept and Rationale*. Issue 6. Report Concerning Space Data System Standards (Green Book), CCSDS 200.0-G-6. Washington, D.C.: CCSDS, January 1987.
- [B8] *Advanced Orbiting Systems, Networks and Data Links: Summary of Concept, Rationale and Performance*. Issue 3. Report Concerning Space Data System Standards (Green Book), CCSDS 700.0-G-3. Washington, D.C.: CCSDS, November 1992.

NOTE – Normative references are listed in 1.7.

ANNEX C

RELATIONSHIP OF THE TRANSFER FRAME TO THE CODE BLOCK

(This annex **is not** part of the Recommendation)

C1 GENERAL

The USLP requires that the link layer bit stream be continuous and unbroken but it allows management to establish rules for a physical link that is either constrained to have the start of a transfer frame and the start of the code block align together (frame length dependent upon the code block size) or alternatively to allow the transfer frame to be unaligned to code block boundaries. When randomization is applied to the link it must be synchronized to the beginning of the code block. There are code block synchronization issues when using high performance codes that operate with a high physical layer bit error rate. This problem is simplified when the code blocks are of fixed length so that the code block synchronization occurs at a fixed interval. Thus the use of Idle Data between code blocks is limited for use only when not using high performance codes.

C2 LINK OPTIONS

The USLP is compatible with all of the CCSDS coding options. The simplest options involve the choice of operating the link without coding (uncoded) or using the CCSDS Convolutional Code in the Physical Layer. If certain types of CCSDS codes are used, the Coding & Synchronization sublayer provides a service with two user options both at the sending and receiving interfaces with the USLP. In option 1, the bit stream input to the C&S sublayer as well as the bit stream output from the C&S sublayer is managed so that the first bit of the transfer frame aligns with the first bit of the code block. This alignment is then maintained for every frame transferred. In option 2, the bit stream input to the C&S sublayer is sliced to provide a data block that will fit within the data portion of the code block. The output bit stream from the C&S sublayer is formed from the decoded input data code blocks. The frames in the output data were not aligned with the code block, thus an ASM attached to the frame is required to delimit the start of the frame. The pros and cons for choosing these options are discussed below.

C2.1 UNCODED OR CONVOLUTIONALLY ENCODED OPTIONS

When the PLTU is transported on a link that has an inadequate undetected error rate, the transfer frame must contain the optional Frame Error Control Field and the PLTU must contain an Attached Synchronization Marker (ASM) that is compatible with the bit error rate of the underlying channel. The FECF is required to insure that the probability of accepting a received frame that contains transmission errors is within the mission requirement. The FEC used will be dependent upon the link characteristics. e.g., the Proximity link uses a 32 bit CRC to check for erred bits because the symbol error rate may be substantially lower than

required for reliable bit recognition due to slant range conditions and or multicast from nearby surfaces. Traditionally the transmission of variable length PLTUs allows transfer frames to be inserted into the transmitted bitstream as desired or available. Thus in order to maintain a continuous bit stream Idle Data may need to be inserted between PLTUs when required.

C2.2 TRANSFER FRAME ALIGNED WITH THE CODE BLOCK

When the start of the transfer frame and the start of the Code block are required to align then only the code word sync marker (CSM) is used for synchronization in the symbol domain. The ASM is not used nor required for transfer frame synchronization. The CCSDS link layer protocols TC, TM, AOS require that the transfer frame be aligned to the Code block. The AOS and TM specifications require the transfer frame to be of fixed length corresponding to the size of the code block. The TC specification requires that the start of the transfer frame aligns with the start of the code block. However since the transfer frame is of variable length, the code block can scale to contain the transfer frame. In the TC case a series of codewords are concatenated to contain the transfer frame but fill bits may be required to be appended to the CLTU to totally fill the contents of the code block. Here a problem emerges as to how to determine where the code block and the randomization processes end. When multiple code words are concatenated to form the code block it is required to determine how many code words are included in the code block. This can be automatically accomplished by the forward error decoding process by concatenating a non-decodable code word to the last code word that encompasses the frame. Another delimiting method would be to read the frame length field obtained from the first code word in the PLTU and use that value to determine the number of code words in the code block.

C2.3 TRANSFER FRAME UNALIGNED WITH THE CODE BLOCK

When the code block and PLTUs are unaligned, then the code blocks are required to be continuous and delimited only by the CSM. In this mode, the CSM delimits the beginning of the code block and the derandomization process while the fixed length of the code block delimits the end of the decoding and derandomization processes. The start of the transfer frame is located using the ASM and the frame length field in the transfer frame header determines where the frame ends. Whenever a code word error is detected, the decoding and derandomization processes are terminated, the CSM search is initiated and any partial frame data acquired is discarded. The search for the transfer frame contained in the output bit stream from the FEC decoder is reinitiated to search for the ASM. Note that since the transfer frame and Code block lengths are independent of one another and the output from the C&S sublayer is assumed to be essentially error free (given the low undetected error rate of the CCSDS coding sublayer) then the probability of obtaining frame synchronization and the value of the acquired frame length field value has a high probability of being valid. The decoupling of the frame length from the code block size makes it possible to efficiently accommodate the transfer of variable length frames on a link that is maximizing its coding effectiveness by utilizing fixed length code blocks. Since the bit error rate of the bit stream output from the forward error decoders is assumed to be virtually error free the

synchronization process to find the start of the frame is simplified. Therefore the user may insert Idle Data between user data frames as desired as long as a synchronous Insert Zone is not required on the link.

ANNEX D

USLP USE CASES

D1 DIRECT FROM EARTH LINKS (ROBOTIC AND MANNED MISSIONS)

The USLP frame can be structured to resemble the Telecommand frame [11]. We recommend that the BCH Forward Error Correction code be replaced by a short length LDPC code with the frame unaligned to the code block. (The CCSDS C&S Working Group is developing an CCSDS Orange book on these codes.) The variable length frame would use the sequence counter behavior that separates the VCs into two groups (1 providing a counter for use by a Go-Back-N protocol and the other used for protocol control frames and data deliveries that use a selective repeat protocol at a higher layer like CFDP). The transfer frames may carry all types of data packets delivering for example IP datagrams directly to an IP router for network delivery and operations. Very large data packets, CFDP files or DTN bundles can be delivered within a single transfer frame or may be segmented for transfer. The frame sequence counter can be of any size but only the least significant byte need be included in the transfer frame and OCF fields. No sequence counter octets need be included in control commands or by-pass frames. The FECF may be included if extra assurance of correct delivery is required especially if an uncoded link is utilized. The number of code word that are concatenated to form the code block could be fixed for a mission or could be allowed to change based on the data rate. This would primarily only have the effect of reducing the overhead on the link but would allow a single code word decoder to be used.

D2 DIRECT TO EARTH LINKS

The USLP transfer frame can be structured to provide for telemetry for all sorts of missions even those that have unique instrument characteristics and delivery requirements. The AOS or TM frame format can be functionally replicated using fixed length frames that are aligned to the code block and use streaming data processes. The sequence counter behavior would be set to provide an independent counter for each VC. The size of the sequence counter can be individually set for each VC. The requirement for a FECF is limited and probably need not be included except where desired to minimize the undetected error rate.

The ability to have the frames non- aligned to the code block allows the Earth based receivers to be fully tested independently of the mission data. This process can support either fixed or variable length frames. When variable length frames are allowed then the Insert Zone can be used to deliver low latency reports by being included in high rate long data frames. When variable length frames are used then a number of options can be used to simplify mission accounting and delivery. The frame can be tailored to the individual need of an instrument on a VC. The length could accommodate an instruments fixed time division mechanism for data acquisition or the variability of an instrument unique data compression process while at all times providing the spacecraft control process to inject messages in the Insert Zone.

D3 SPACE TO SPACE LINKS

The USLP transfer frame may be structured to resemble the Proximity-1 frame [10]. It is recommended that the Convolutional Forward Error Correction code may be replaced by a short length LDPC code with the frame unaligned to the code block. (The CCSDS C&S Working Group is developing an CCSDS Orange book on these codes.) The variable length frame would use the sequence counter behavior that separates the VCs into two groups (1 providing a counter for use by a Go-Back-N protocol and the other used for control frames and data deliveries that use a selective repeat protocol at a higher layer like CFDP). The transfer frames may carry all types of data packets delivering for example IP datagrams directly to an IP router for network delivery and operations. Very large data packets, CFDP files or DTN bundles may be delivered within a single transfer frame or may be segmented for transfer. The frame sequence counter can be of any size but only the least significant byte need be included in the frames and OCF fields. No sequence counter octets need be included in control commands or by-pass frames. The FECF can be included if extra assurance of correct delivery is required especially if an uncoded link is utilized. All Proximity-1 control commands and processes can be supported. The OCF need not be sent in its own frame but can be delivered within a data frame if desired to improve link efficiency.