Consultative Committee for Space Data Systems

RECOMMENDATION FOR SPACE DATA SYSTEM STANDARDS

CROSS SUPPORT REFERENCE MODEL

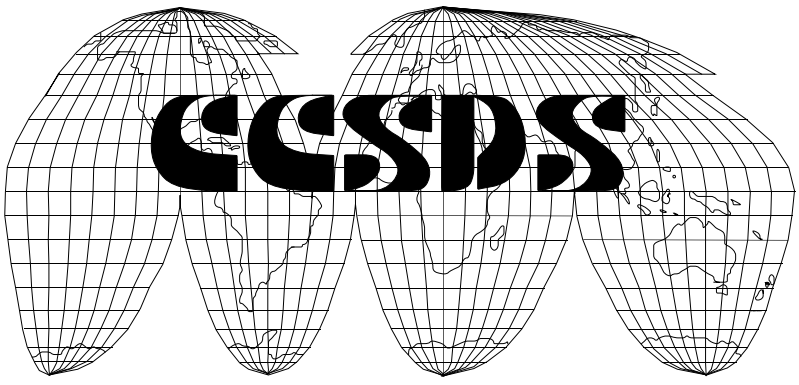
PART 1

SPACE LINK EXTENSION SERVICES

CCSDS 910.4-B-1

BLUE BOOK

May 1996



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FOREWORD

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

This **Recommendation** establishes a common framework and provides a common basis for the specification of data services that extend the space to ground communication services previously defined by CCSDS. It allows implementing organizations within each Agency to proceed coherently with the development of compatible derived Standards for the ground systems that are within their cognizance. Derived Agency Standards may implement only a subset of the optional features allowed by the **Recommendation** and may incorporate features not addressed by the **Recommendation**.

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1 INTRODUCTION

1.1 PURPOSE OF THIS RECOMMENDATION

1.1.1 BASELINE AND REFERENCE FOR SLE SERVICE SPECIFICATIONS

This Recommendation defines a Cross Support reference model which provides a common basis for coordinating the development of CCSDS Recommendations for Space Link Extension (SLE) service specifications and serves as a reference to maintain the consistency of these Recommendations.

1.1.2 RELATIONSHIP TO SPACE LINK RECOMMENDATIONS

1.1.2.1 CCSDS Space Link Recommendations (Advanced Orbiting System (AOS), Packet Telemetry, and Telecommand, references [2]–[7]) define formats and protocols for the transfer of data from/to data sources/sinks on board a space vehicle to/from data sinks/sources on the ground as shown on figure 1-1. These Space Link protocols are designed to work efficiently in the noisy, high-delay environment of space/ground radio links; thus they do not carry information needed to configure and operate the ground systems that link numerous ground stations with the ground sinks and sources of data.

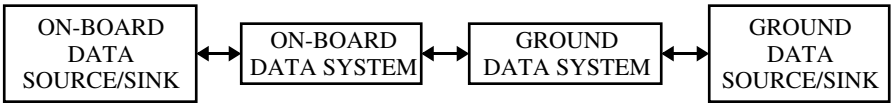


Figure 1-1: CCSDS Space Mission Data System

1.1.2.2 The SLE Recommendations complement the CCSDS Space Link Recommendations with a range of services that are required to configure, operate, and supervise the ground data systems.

1.1.2.3 The SLE Recommendations apply to data systems that are able 1) to receive CCSDS Space Link data structures from a spacecraft via a Space Link, or 2) to send CCSDS Space Link data structures to a spacecraft via a Space Link, or 3) to transfer such CCSDS Space Link data structures between ground-based entities.

1.1.3 SLE SERVICES

SLE services comprise:

a) SLE transfer services, which are concerned with the ground part of the data transfer described in 1.1.2. This transfer is either within the ground data system or between the ground data system and the ground data sources/sinks.

b) SLE management services, which control the scheduling and provision of SLE transfer services by ground systems.

1.1.4 SLE SYSTEMS

Ground systems that provide services that comply with the CCSDS Recommendations for SLE service specifications are called SLE systems.

1.1.5 FRAMEWORK FOR SLE SERVICES

This Recommendation provides the framework for definition of SLE service specifications to be used in support of space missions. This framework comprises:

a) the identification of an SLE system and of its environment;

b) an architectural model of an SLE system including:

   1) a functional view;

   2) a management view;

c) the common characteristics of SLE services and the template for SLE service specifications:

   1) each individual SLE service specification expresses its requirement on supporting telecommunication services in a respective quality-of-service clause;

   2) it is assumed that the provider and user of a given SLE service ensure that appropriate telecommunication facilities are in place;

d) the identification of the SLE transfer services;

NOTE – In d), SLE transfer services are identified; however, the complete service specification will be provided in a separate Recommendation.

1.2 SCOPE

1.2.1 The scope of this Recommendation is the definition of all concepts and terms that establish a common basis for coordinating the development of CCSDS Recommendations for SLE services specifications. In defining these concepts and terms the following assumptions are made:

a) the context is that of a single space mission;

b) within this space mission a single spacecraft is considered;

c) this spacecraft's telemetry and telecommand are compliant with CCSDS Space Link Recommendations;

d) all ground end-users (i.e., data sinks or sources) are affiliated with a single mission management entity.

1.2.2 The following points are not covered by this Recommendation:

1.2.2.1 Although sharing ground systems between multiple space missions or between multiple spacecraft of the same space mission is not explicitly modeled, this Recommendation does not in any way preclude sharing ground systems.

1.2.2.2 Ground systems and/or services that are not directly concerned with the transport of data compliant to CCSDS Space Link Recommendations are not described. Processing data held within the data fields of Source Packet Protocol Data Units (PDUs) described in CCSDS Packet Telemetry, Telecommand, and AOS Recommendations (references [2]–[7]) is outside the scope of this Recommendation.

1.2.2.3 This reference model assumes that ground communications services are used in conjunction with the SLE services to support a space mission, but does not explicitly model these communications services.

1.3 APPLICABILITY

1.3.1 APPLICABILITY OF THIS RECOMMENDATION

This Recommendation serves as a guideline for the development of compatible Agency standards for SLE systems. Systems embraced by this Recommendation include manned and unmanned free-flying spacecraft and space transportation systems. This Recommendation is particularly relevant to the SLE systems that are involved in cross support.

1.3.2 LIMIT OF APPLICABILITY

This Recommendation is neither a specification of, nor a design for, real SLE systems that may be implemented for the control and monitoring of existing or future missions.

1.4 RATIONALE

The primary goal of CCSDS is to increase the level of interoperability among Agencies. This Recommendation furthers that goal by establishing the basis for a set of SLE services to be used in the area where most cross-support activity occurs: between the tracking stations or ground data handling systems of various Agencies and the mission specific components of a mission ground system. Reference [11], *Cross Support Concept — Part 1: Space Link Extension Services*, provides further discussion of the rationale for this Recommendation.

1.5 DOCUMENT STRUCTURE

This Recommendation is organized as follows:

a) Section 1 provides purpose, scope, applicability and rationale of this Recommendation and lists the definitions, conventions, and references used throughout the Recommendation.

b) Section 2 provides the context of cross support, presents the cross-support documentation structure, and shows how this Recommendation fits into that framework. It expands on the scope of this Recommendation to provide an overview of the document.

c) Section 3 defines the SLE system environment, data handled by an SLE system, and introduces SLE services.

d) Section 4 defines an architectural model for the SLE system. This architectural model comprises two views:

   1) A functional view which defines the system concepts, including functions and data, from which the SLE services are derived. In this functional view, the SLE system is decomposed into SLE Functional Groups (SLE-FGs), which implement and augment the ground side of the Space Link protocols described in CCSDS Packet Telemetry, Telecommand, and AOS Recommendations (references [2]-[7]).

   2) A cross-support management view, which defines the management interactions between the entities involved in the provision of SLE services and provides the baseline for the SLE Service Management Specification. In this management view, the SLE system is decomposed into SLE Complexes and the notion of SLE Service Package is introduced.

e) Section 5 defines the common characteristics of SLE services, provides the template for SLE transfer services specifications, and provides an initial description of each SLE service including operations and parameters at the corresponding ports.

f) Annex A expands upon the description, in Section 3, of the data handled in SLE systems.

1.6 DEFINITIONS

1.6.1 DEFINITIONS FROM REFERENCES

This Recommendation uses the Abstract Service Definition Conventions (ASDC) methodology, which provides the means to create a model of a system composed of objects that provide services to one another. This Architecture Model is composed of abstract-objects which have abstract ports, through which they provide abstract-services to other abstract-objects. The definitions below are from reference [10].

1.6.1.1 Definition: Abstract-Object. An abstract-object is a functional entity which interacts with other abstract-objects. Objects are of different types, which determine their function and behavior. These abstract-objects are characterized by their interfaces, which are called abstract-ports, and the operations which can be performed through those ports.

1.6.1.2 Definition: Abstract-Service. ASDC defines an abstract-service as a set of capabilities that one abstract-object offers to another by means of one or more of its abstract-ports. For the purpose of defining SLE Services in this reference model, an abstract-service is considered to be the capability provided by a set of operations that an abstract-object exposes at one or more of its abstract-ports.

1.6.1.3 Definition: Abstract Refinement. A model may be defined as consisting of a few high-level objects. These objects may be decomposed into lower-level, component objects. This decomposition is called abstract refinement.

NOTE – To improve readability, the term “abstract” is used from here onward only when it is necessary to distinguish a feature of the model from its implementation, or to emphasize the use of an ASDC concept or term.

1.6.1.4 Definition: Port Types. Ports that are involved in providing different services are said to be of different types.

1.6.1.5 Definition: Symmetric/Asymmetric Ports. Two ports (of two objects) involved in the provision of a service may be either symmetric ports or asymmetric ports. The ports are symmetric if each offers all of the operations associated with the service. The ports are asymmetric if each offers different operations; in this case, one port is called a consumer, and the other is called a supplier.

1.6.1.6 Definition: Service User/Provider. An object that offers a service to another by means of one or more of its ports is called a service provider (provider). The other object is called a service user (user). An object may be a provider of some services and a user of others.

NOTE – “Provide” is used in the sense of “make available to be used” and does not necessarily imply that the service is being used.

1.6.1.7 Definition: Abstract Binding. When two abstract ports of the same type have an association established between them such that an abstract service can be provided, the two ports are said to be bound. The act of establishing such an association is called abstract binding.

1.6.1.8 Definition: Operation. An operation is a procedure that one object (the invoker) can request of another (the performer) through a port pair bound within the terms of an agreement.

NOTES

1 The relationships among the terms user/provider, supplier/consumer, and invoker/performer are explained in reference [10]. Briefly:

2 The terms user and provider are used to distinguish the roles of two interacting objects. Usually these terms are applied so as to indicate which object (the provider) is performing a function on behalf of the other object (the user). In this Recommendation, when two objects are involved in provision of a service, the object closer to the Space Link is considered to be the provider of the service, and the object further from the Space Link is considered to be the user, regardless of the direction of data flow.

3 The terms consumer and supplier are used to distinguish the roles of two ports, each attached to one of two objects, that are bound. In this Recommendation, these terms indicate direction of transfer of data: *from* the supplier port *to* the consumer port.

4 The terms invoker and performer are used to describe the interaction between two objects, as the operations that constitute the service occur. One object invokes an operation which is performed by the other. For most services, each object, whether consumer or supplier, invokes some operations and performs others.

1.6.2 DEFINITIONS IN THIS DOCUMENT

The definitions provided below are those needed for understanding this Recommendation as a whole. Many other terms are defined throughout this Recommendation.

1.6.2.1 Definition: return data. For the purposes of this Recommendation, Return Data is all data that is sent from the space element to the ground element (e.g., telemetry).

1.6.2.2 Definition: forward data. For the purposes of this Recommendation, forward data is all data that is sent from the ground element to the space element (e.g., telecommand).

1.6.3 CONVENTIONS

1.6.3.1 Style

Within this Recommendation, each formal statement stands in a paragraph by itself and is identified uniquely by a subsection number or by a combination of subsection number and list item number.

1.6.3.2 Notes

Notes are not formally part of this Recommendation. They are isolated from the formal statements and are introduced by the word NOTE.

EXAMPLE

NOTE – This is an example of a note.

1.6.3.3 Usage of Capital Letters

Names of system components, data units, and other elements of the reference model are shown with the first letter of each word capitalized.

1.6.3.4 Types And Instances

As noted in 1.6.1, ASDC allows definition of groups, or classes, of objects that can provide the same services. Such objects are said to be of the same *type*. In this reference model, it is sometimes necessary to distinguish between characteristics that are common to all objects of a type and characteristics of a particular object of a type. Often, this is clear from context, but when necessary to avoid ambiguity the word "instance" is used to emphasize the notion of a single object of a type; the word "type" or the phrase "of a type" is used to refer to all objects of the same class. Generally, "the <type-name>" is used in describing the object-type. Often, characteristics of a class (i.e., objects of a type) are defined by referring to "a (or any, every, each) <type-name>". When specific objects are discussed, they are given names (e.g., X, Y, Mission ABC). This wording is also used with regard to ports, services, and operations defined in the reference model.

1.6.3.5 Drawing Conventions

In figures illustrating this reference model, the following conventions are used.

a) A type of (abstract) object is shown as a round-cornered box. The type-name is shown at the bottom of the box, preceded by the word "Type" and a colon; see figure 1-1a. The initial letter of the type-name is always upper case. The ports and services associated with an object type are also types.

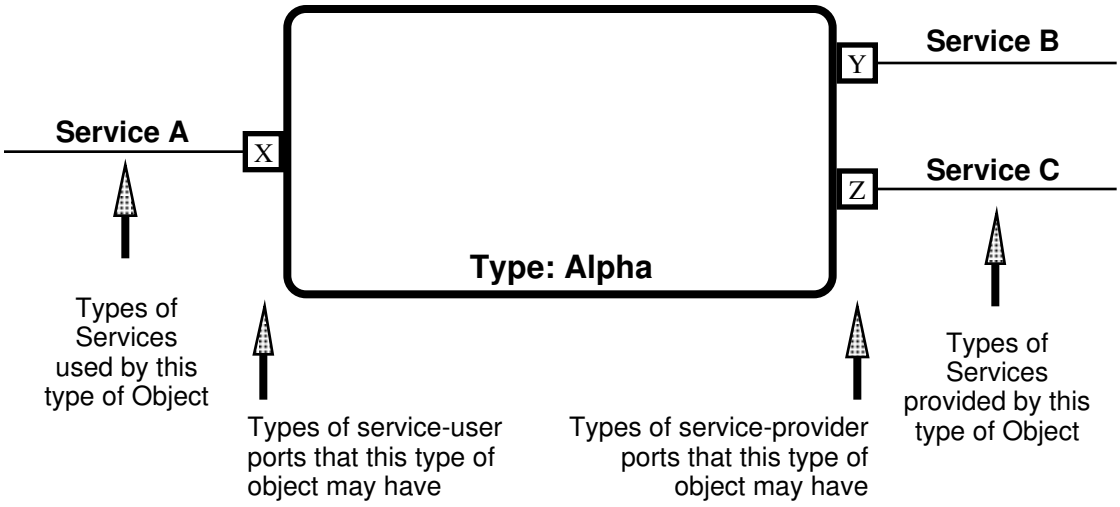


Figure 1-1a: Drawing Conventions for an Object-Type

b) An instance of an object is shown as a round-cornered box. The type-name is again shown at the bottom of the box, but is *not* preceded by the word "Type" and a colon; see figure 1-1b. The ports and services associated with an instance of an object type are also instances.

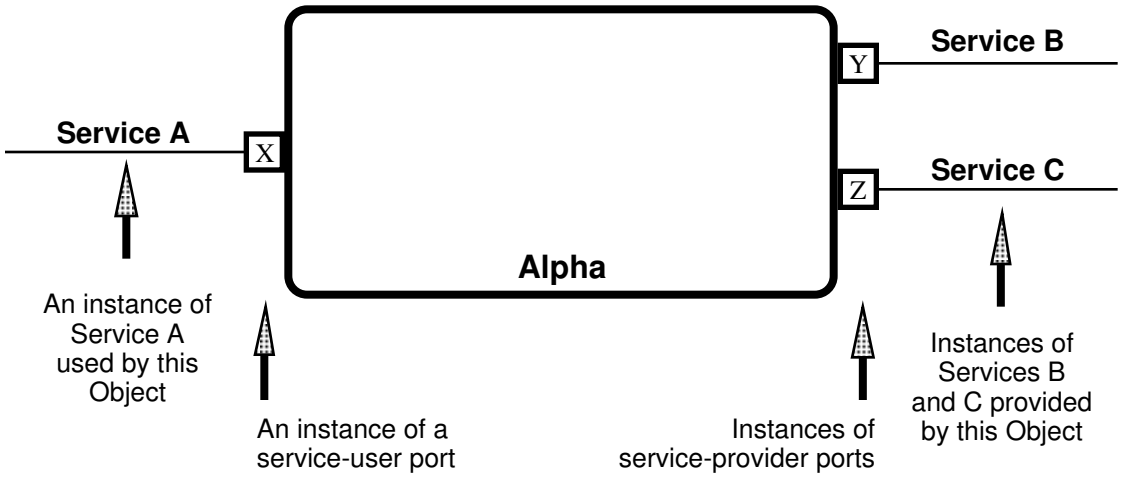


Figure 1-1b: Drawing Conventions for an Object-Instance

c) If a figure shows two or more instances of the same type of object, each is given a name by showing the type-name followed by a colon and the name of the instance. The initial letter of the instance-name is always lower case. See figure 1-1c.

d) Instances of a port type are distinguished by the names of the service instances that are provided at the port. Multiple instances of a single service are permitted. See example instances 1 and 2 of service D in figure 1-1c.

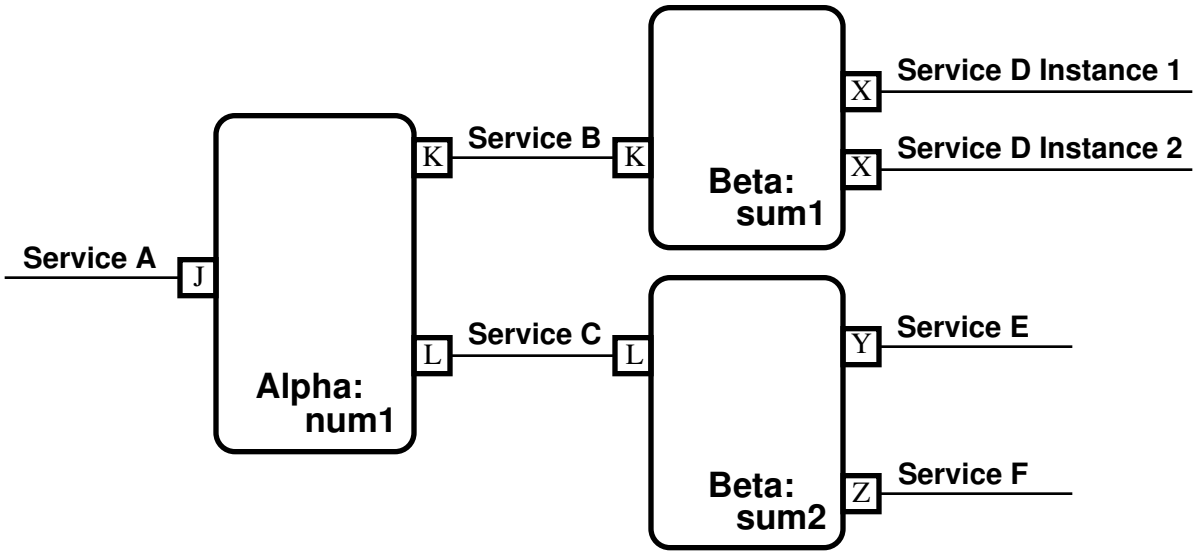


Figure 1-1c: Drawing Conventions for Multiple Object-Instances

1.6.3.6 Object Refinement

In ASDC terms, this document decomposes a system and other objects into component objects. When a port of a component object is exposed as a port of the parent object, it is shown as illustrated by ports G, H, K, and L in figure 1-2.

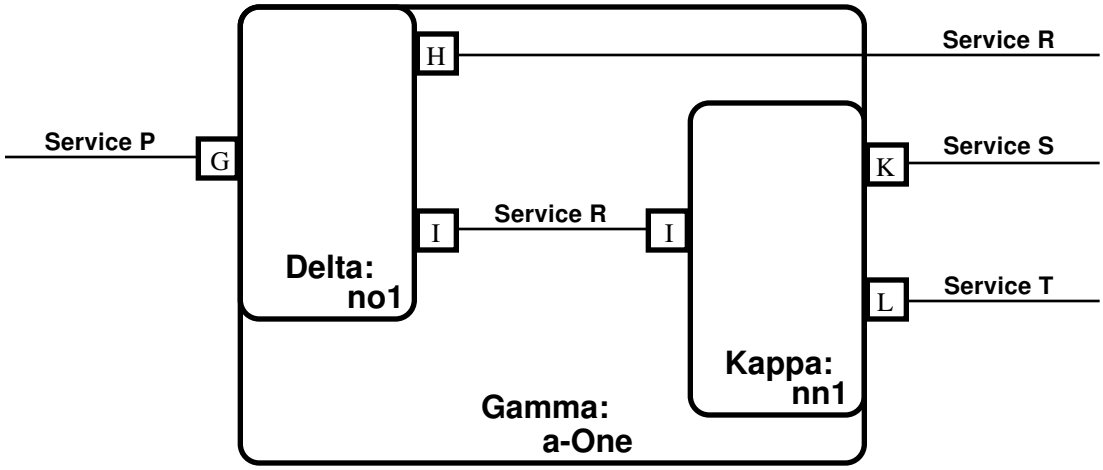


Figure 1-2: Object Refinement

1.7 REFERENCES

The following documents are referenced in the text 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] *Procedures Manual for the Consultative Committee for Space Data Systems*. CCSDS A00.0-Y-6. Yellow Book. Issue 6. Washington, D.C.: CCSDS, May 1994.

[2] *Packet Telemetry*. Recommendation for Space Data System Standards, CCSDS 102.0-B-4. Blue Book. Issue 4. Washington, D.C.: CCSDS, November 1995.

[3] *Telemetry Channel Coding*. Recommendation for Space Data System Standards, CCSDS 101.0-B-3. Blue Book. Issue 3. Washington, D.C.: CCSDS, May 1992.

[4] *Advanced Orbiting Systems, Networks and Data Links: Architectural Specification*. Recommendation for Space Data Systems Standards, CCSDS 701.0-B-2. Blue Book. Issue 2. Washington, D.C.: CCSDS, November 1992.

[5] *Telecommand Part 1 — Channel Service*. Recommendation for Space Data System Standards, CCSDS 201.0-B-2. Blue Book. Issue 2. Washington, D.C.: CCSDS, November 1995.

[6] *Telecommand Part 2 — Data Routing Service*. Recommendation for Space Data System Standards, CCSDS 202.0-B-2. Blue Book. Issue 2. Washington, D.C.: CCSDS, November 1992.

[7] *Telecommand Part 3 — Data Management Service*. Recommendation for Space Data System Standards, CCSDS 203.0-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, January 1987.

[8] *CCSDS Global Spacecraft Identification Field Code Assignment Control Procedures*. Recommendation for Space Data Systems Standards, CCSDS 320.0-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, October 1993.

[9] *CCSDS Publications Manual*. CCSDS A20.0-Y-1. Yellow Book. Issue 1. Washington, D.C.: CCSDS, May 1994.

[10] *Standard Terminology, Conventions, and Methodology (TCM) for Defining Data Services*. Report Concerning Space Data Systems Standards, CCSDS 910.2-G-1. Green Book. Issue 1. Washington, D.C.: CCSDS, November 1994.

[11] *Cross Support Concept — Part 1: Space Link Extension Services*. Report Concerning Space Data Systems Standards, CCSDS 910.3-G-1. Green Book. Issue 1. Washington, D.C.: CCSDS, May 1995.

[12] *Information technology — Text Communication — Message-Oriented Text Interchange Systems (MOTIS) — Part 3: Abstract Service Definition Conventions, Technical Corrigendum 1*. ISO/IEC 10021-3: 1990/Cor. 1: 1992. Geneva: ISO, 1992.

[13] *Information technology — Open Systems Interconnection — Specification of Abstract Syntax Notation One (ASN.1)*. ISO 8824. 2nd ed. Geneva: ISO, 1990.

[14] *Packet Telemetry Services*. Recommendation for Space Data System Standards, CCSDS 103.0-B-1. Blue Book. Issue 1. May 1996.

2 OVERVIEW

2.1 PURPOSE OF THIS SECTION

Section 2 of this Recommendation provides the context for reading this Recommendation. Subsections 2.2 and 2.3 introduce the Cross Support Context and the associated SLE services documentation tree.

2.2 CROSS SUPPORT CONTEXT

The term Cross Support is applied when one Agency uses part of another Agency's resources to complement its own for the purpose of operating a spacecraft.

2.2.1 CROSS SUPPORT SERVICES

Cross Support Services is a generic term that encompasses all services that can be provided by one Agency to support another Agency in operating a spacecraft. On the ground, cross support services are of three kinds:

a) SLE services: defined to extend CCSDS Space Link services as defined in CCSDS Space Link Recommendations (references [2]–[7]);

b) ground communications services: to provide ground communications support, e.g., to relay operational data;

c) ground domain services: which cover all services which handle data related to spacecraft operations but not directly mappable to Space Link data structures defined in CCSDS Space Link Recommendations. Examples of ground domain services are tracking a spacecraft, exchanging spacecraft data bases, mission planning.

2.2.2 CROSS SUPPORT DOCUMENTATION

The cross support documentation is divided according to the kinds of services listed in 2.2.1:

a) Part 1 of the Cross Support Recommendation will address SLE services;[1]

b) Part 2 of the Cross Support Recommendation will address ground communications services;

c) Part 3 of the Cross Support Recommendation will address ground domain services.

[1]CCSDS Panel 3 is, at the time of publication, working only on Part 1.

2.3 SLE SERVICES DOCUMENTATION TREE

This document constitutes the root of the SLE services documentation tree shown in figure 2-1. Directly attached to it are:

a) *Cross Support Concept — Part 1: Space Link Extension Services*: a Report introducing the concepts of cross support and SLE services;

b) SLE Service Management Specification: a Recommendation that defines the service management required for the provision of one or more SLE services;

c) SLE Service Specifications: Recommendation(s) will provide specification of all SLE services.

NOTE – It is anticipated that a similar document approach will be adopted for Part 2 and 3 of this Recommendation (for the ground communications services and ground domain services).

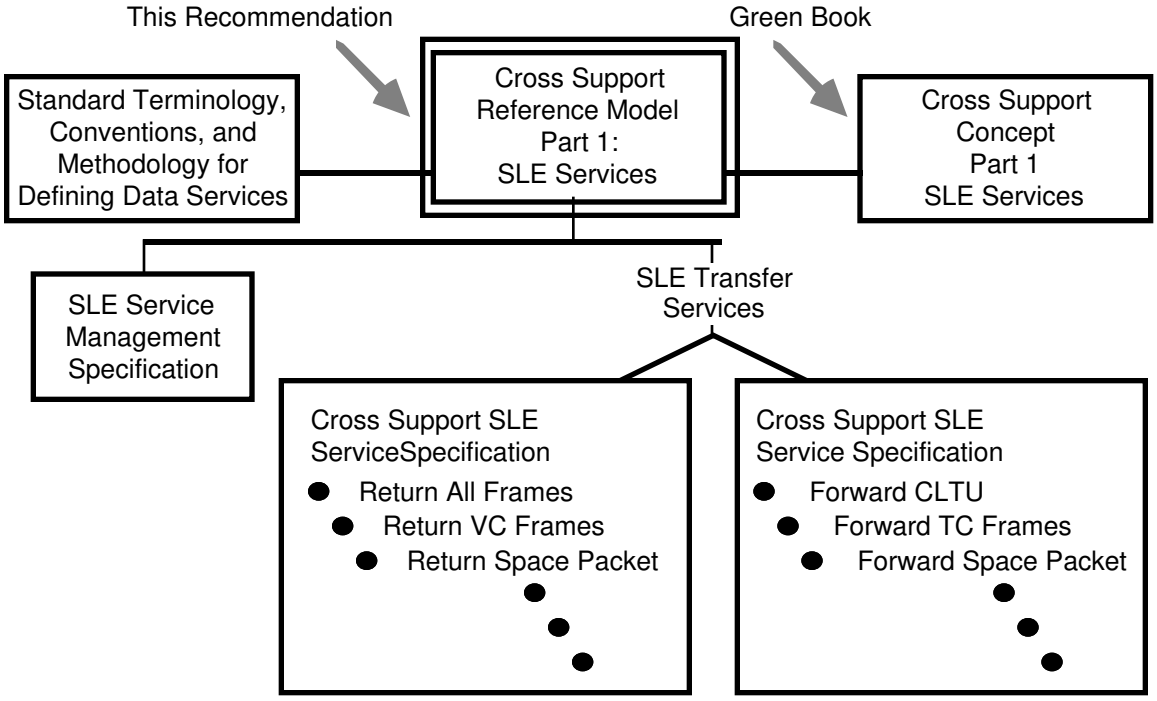


Figure 2-1: SLE Services Documentation Tree

3 SLE SYSTEM ENVIRONMENT, DATA, AND SERVICES

3.1 PURPOSE OF THIS SECTION

Section 3 of this Recommendation defines the SLE system environment, data, and services. It introduces terms and concepts of the SLE System Architectural Model that will be formally defined in Section 4.

3.2 SLE SYSTEM ENVIRONMENT—SPACE MISSION DATA SYSTEM

3.2.1 A Space Mission Data System, as illustrated in figure 3-1, is the set of on-board and ground data systems that support a mission. It consists of a space element and a ground element connected via the Space Link. The space element and ground element exchange return and forward data.

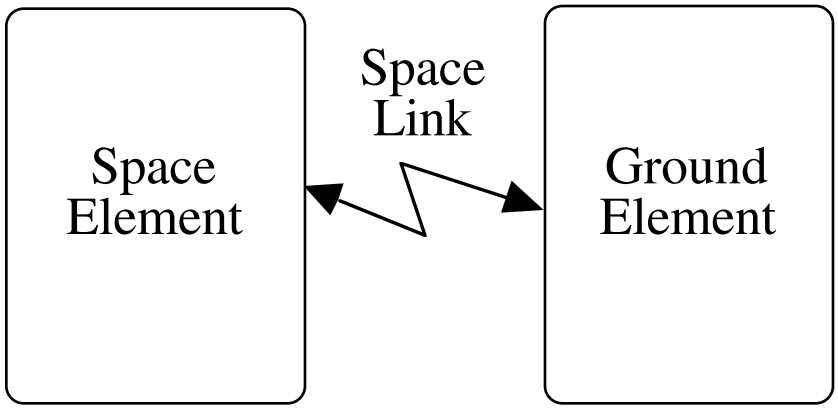


Figure 3-1: Space Mission Data System

NOTE – The Space Mission Data System corresponds to the CCSDS AOS/Packet data system illustrated in figure 1-1.

3.2.2 Definition: Space Element. The space element acts as a source of return data and as a sink for forward data. From the viewpoint of this Recommendation, the space element represents a single spacecraft and comprises the platform and all payloads/instruments of this spacecraft.

NOTES

1 The space vehicles in a multi-spacecraft mission are treated as individual space elements, from the SLE point of view.

2 Platform and payloads/instruments are considered here only for their capability of generating or receiving data. Processing they perform on this data is not within the scope of this Recommendation.

3.2.3 Definition: Physical channel. A physical channel is the capability to transfer a single stream of bits, in a single direction (space to ground or ground to space).

3.2.4 Definition: Space Link. The exchange of forward and return data is performed over a Space Link. A Space Link (SL) consists of one or both of a forward RF carrier channel and/or a return RF carrier channel, each of which may provide one or more physical channels. The simultaneous coexistence of several forward and several return links with a given spacecraft is possible.

3.2.5 Definition: Space Link Session. A Space Link Session is a continuous period during which an SLE system provides the capability to use one or more physical channels on a space link.

3.2.6 Definition: Ground Element. The ground element of a Space Mission Data System includes a Mission Data Operation System (MDOS) and an SLE system. It may also contain other components, but these are not within the scope of this Recommendation. See figure 3-2.

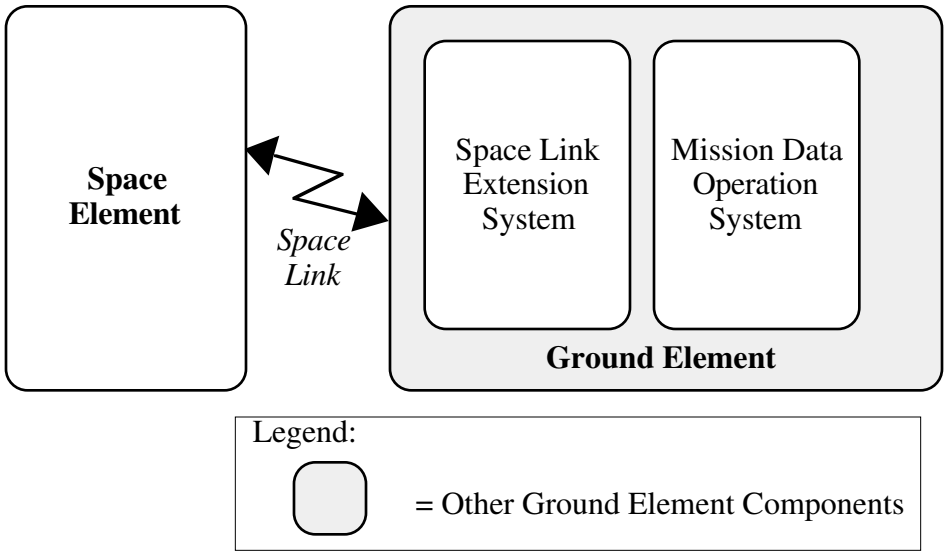


Figure 3-2: Ground Element of a Space Mission Data System

NOTE – The ground element may perform other functions, such as instrument data processing or archiving.

3.2.7 Definition: Space Link Extension System. The Space Link Extension (SLE) System extends the transfer and delivery of forward and return data between a Space Link ground termination point and the MDOS. For a given mission, an SLE system provides its services according to specifications that have been prepared and issued by the respective MDOS.

NOTE – Transfer and delivery involve implementing the ground processing of the protocol described in CCSDS Packet Telemetry, Telecommand, and AOS Recommendations (references [2]–[7]).

3.2.8 Definition: Mission Data Operation System. The Mission Data Operation System (MDOS) acts as a source of forward data and as a sink of return data. For a given SLE system, the MDOS selects SLE services and specifies respective service detail as necessary.

3.2.9 Definition: Mission User Entities (MUEs). Within the MDOS, the MUEs are sources of forward data or sinks of return data. The SLE system provides the forward and return data in the form of transfer services to these MUEs. Several transfer service instances may be provided to a single MUE.

a) Service selection and specification are based on the requirements of the MUEs that are affiliated with the MDOS.

b) In order to cover all requirements, a given MDOS may cooperate with several SLE systems; it is the responsibility of the MDOS to harmonize its cooperation with several SLE systems. (See figure 3-3.) The MDOS contains one SLE Utilization Management and one or more MUEs.

NOTES

1 The MDOS may not be the ultimate source of forward data or sink of return data on the ground element, but from the perspective of this Recommendation it acts as if it is.

2 The MDOS negotiates and manages the services provided by the SLE system for a space mission.

3 This model of an MDOS is not intended to represent physical aspects of a space mission. For example, the MUEs may be distributed geographically or belong to several Agencies.

3.2.10 Definition: SLE Utilization Management. Within the MDOS, the SLE Utilization Management negotiates with the SLE system the provision of transfer services and controls and monitors the provision of these services.

NOTES

1 The SLE Utilization Management (SLE-UM) is responsible only for the management of the MDOS related to the SLE system (and is not responsible for the management of the complete MDOS) or the space element.

2 The SLE-UM coordinates, internally to the MDOS, the provision of the transfer services of forward and return data transfer to the MUEs.

3 The management of the SLE system by the SLE-UM is the subject of a separate management service specification.

3.3 SLE SYSTEM DATA AND SERVICES—DATA EXCHANGE

3.3.1 The MDOS utilizes the SLE to transfer return and forward data to/from the space element. In addition the MDOS and the SLE system exchange management data for the purpose of managing the data transfer. These information exchanges are illustrated in figure 3-3.

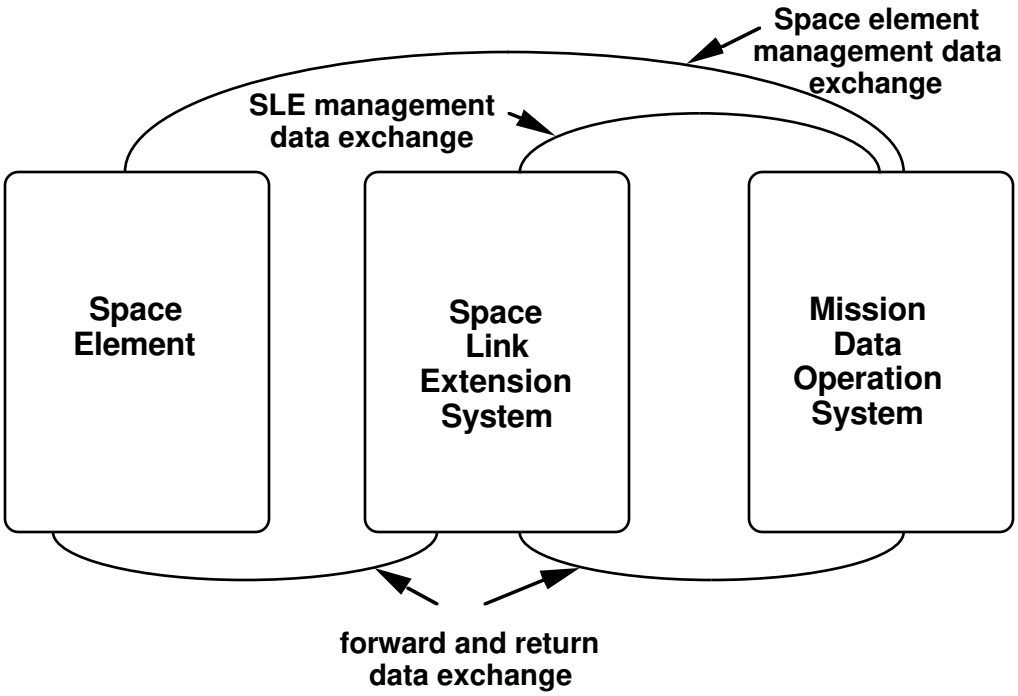


Figure 3-3: Data Exchange

NOTE – The management data exchanged between the space element and the MDOS is illustrated for the sake of completeness; however, it is outside the scope of this Recommendation and will not be further discussed. It is simply part of the total data being forwarded to and returned from the space element. Owing to the lack of a pertinent standard it can not be recognized or interpreted by the SLE system.

3.3.2 Definition: Space Link Data Unit. The SLE system exchanges with the space element streams of Space Link Data Units (SL-DUs). SL-DUs are either Return SL-DUs or Forward SL-DUs.

3.3.3 Definition: Return Space Link Data Unit. A return SL-DU is a data structure defined by the CCSDS Packet Telemetry and AOS Recommendations (references [2]–[4]). The types of return SL-DUs are provided in tables A-1 and A-3 of annex A.

NOTE – Examples of return SL-DUs are: a Space Packet; a telemetry Transfer Frame, as defined in the above references.

3.3.4 Definition: Forward Space Link Data Unit. A Forward SL-DU is a data structure defined by the CCSDS Telecommand or AOS Recommendations (references [4]–[7]). The types of Forward SL-DUs are provided in tables A-2 and A-3 of annex A.

NOTE – Examples of Forward SL-DUs are: a Telecommand Packet; a Telecommand Frame, as defined in the above references.

3.3.5 Definition: Space Link Data Channel. A Space Link data channel is a uniquely identifiable stream of SL-DUs of the same type received from, or sent to, a space element. Annex A explains the relationship between SL-DUs and the Space Link protocols.

NOTE – Examples of Space Link data channels are: a Return Space Packet channel with a specific application identifier; a Return VC Frame channel with a specific virtual channel identifier.

3.3.6 Definition: Space Link Extension Service Data Unit. An SLE Service Data Unit (SLE-SDU) contains an annotated SL-DU and/or control information related to the processing and transfer of SL-DUs by the SLE System.

3.3.7 To extend the Space Link protocols described in CCSDS Packet Telemetry, Telecommand, and AOS Recommendations (references [2]–[7]), the SLE System transfers streams of SL-DUs, encapsulated in SLE-SDUs. The mapping between SL-DU and SLE-SDU is illustrated in figure 3-4a for return data and in figure 3-4b for forward data.

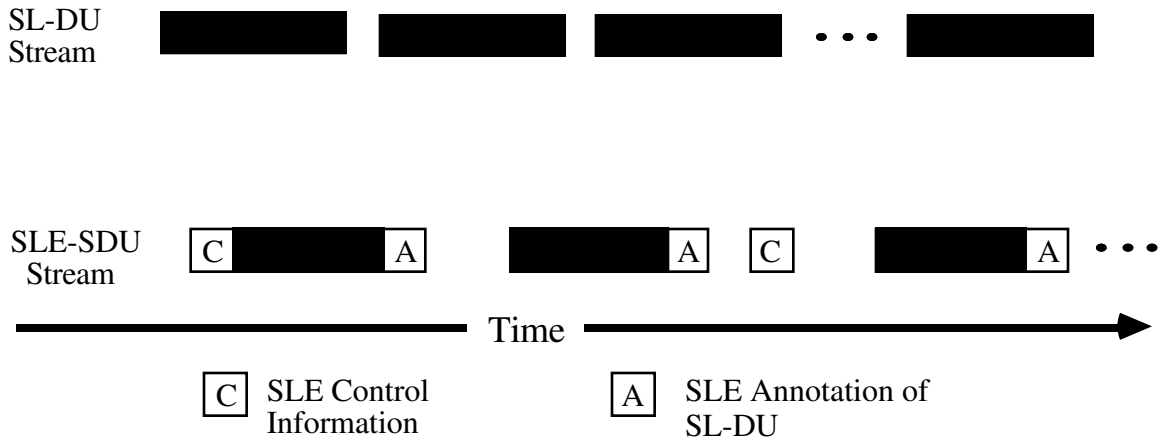


Figure 3-4a: An Illustration of Mapping Return SL-DUs to Return SLE-SDUs

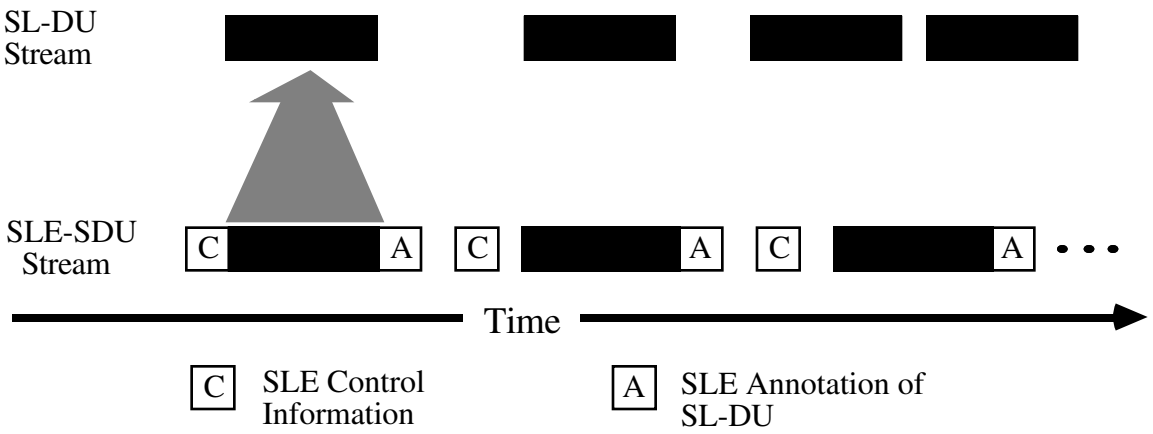


Figure 3-4b: An illustration of Mapping Forward SLE-SDUs to Forward SL-DUs

NOTES

1 Examples of annotation are: ground reception time; quality indication (return data) and requested transmission time, uplink path (forward data). Examples of control are: loss-of-service indication; recovery-of-service indication (return data) and directives related to the Command Operation Procedure (forward data).

2 In the case of return and forward RF signals, the SLE-SDUs are identical to the SL-DUs, i.e., they contain no annotation or control information. They are, nevertheless, referred to as SLE-SDUs in this Recommendation.

3 Figures 3-4a and 3-4b are not meant to specify the order in which SLE control information, SLE annotation of an SL-DU, or the SL-DU appear in an SLE-SDU.

4 Figures 3-4a and 3-4b (like the reference model) do not address the PDUs that may be used to implement the transfer of SLE-SDUs across ground networks.

5 Figure 3-4a illustrates the concept of deriving a stream of Return SLE-SDUs from a stream of Return SL-DUs. The top line shows a stream of SL-DUs. The lower line shows the corresponding stream of SLE-SDUs, where each SL-DU has been "wrapped up" with annotation, and sometimes with control information, and where some control information has been provided in an SLE-SDU that contains no SL-DU. Thus one kind of SLE-SDU is derived from a specific SL-DU, while another kind of SLE SDU provides supplementary control information that does not pertain to a specific SL-DU.

6 Figure 3-4b above illustrates the concept of deriving a stream of Forward SL-DUs from a stream of Forward SLE-SDUs. The lower line shows a stream of SLE-SDUs, where each SL-DU has been wrapped up with annotation and sometimes with control information. An SLE-SDU also may carry control information alone (i.e., no Space link-DU). Such an SLE-SDU might result in generation of an Space link-DU (e.g., a TC COP directive to send an "Unlock" command to the space element), or might be relevant only within the SLE System (e.g., a TC COP directive to set values of ground-end parameters).

3.3.8 Definition: Space Link Extension Data Channel. An SLE data channel is a uniquely identifiable stream of SLE-SDUs of the same type derived from a Space Link data channel. The types and identification are the same as for space data channels. SLE data channels are the streams of data processed and transferred by an SLE System. The types of Space Link Extension Data Channels are listed in tables A-4 and A-5 of Annex A.

NOTE – Formally speaking, an SLE data channel cannot be transferred by an SLE System. It is the SLE-SDUs belonging to an SLE data channel that are transferred by an SLE System.

3.3.9 The detailed structure and semantics of each component of an SLE-SDU, as well as the rules for their composition into SLE-SDUs, are defined in the pertinent SLE service specifications.

3.4 SPACE LINK EXTENSION SERVICES

SLE services are provided by an SLE system to an MDOS. SLE services comprise:

a) the SLE transfer services, which transfer SLE data channels from/to the space element to/from the MDOS through the SLE system;

b) the SLE management service, which controls the scheduling and provision of instances of SLE transfer services by the SLE system.

NOTES

1 In the realm of a specific mission, one speaks of instances of SLE service provided by the SLE system and not of SLE services. The distinction between SLE service and instances of SLE service is discussed in sections 4 and 5.

2 In the realm of a specific mission, there may be several instances of SLE management service and of SLE transfer service at any time provided by an SLE system to an MDOS.

3.4.1 OVERVIEW OF SLE TRANSFER SERVICES

a) Each of the SLE transfer services delivers one type of SLE data channel.

b) The following subsections identify the baseline Return SLE transfer services, Forward AOS SLE transfer services, and Forward Telecommand SLE transfer services, respectively. This baseline may be modified in the future through the addition or deletion of SLE services. These service identifications do not address the details of the services. Subsection 4.3.2 of this document provides more detail on each of the services listed below. For each service listed below, its corresponding description in 4.3.2 is identified.

3.4.1.1 Return SLE transfer services

Return SLE transfer services include:

a) Return All Frames (RAF) service, which delivers the RAF SLE data channel resulting from a single physical channel (4.3.2.1.1 a) 1));

b) Return Insert service, which delivers the Return Insert SLE data channel decommutated from a single physical channel (AOS only) (4.3.2.1.1 a) 2));

c) Return Master Channel (MC) Frame service, which delivers a Master Channel (Master SLE data channels) demultiplexed from an RAF channel (4.3.2.1.2 a) 1));

d) Return Master Channel Operational Control Field (MC-OCF) service, which delivers an Operational Control Field SLE data channel decommutated from its associated Master Channel (4.3.2.1.2 a) 2));

e) Return Master Channel Frame Secondary Header (MC-FSH) service, which delivers a Frame Secondary Header SLE data channel decommutated from its associated Master Channel (Packet Telemetry only) (4.3.2.1.2 a) 3));

f) Return Virtual Channel Frame (VC Frame) service, which delivers a Virtual Channel (Virtual SLE data channel) demultiplexed from an MC channel (4.3.2.1.2 a) 4));

g) Return Virtual Channel Operational Control Field (VC-OCF) service, which delivers an Operational Control Field SLE data channel decommutated from its associated Virtual Channel (4.3.2.1.2 a) 5));

h) Return Virtual Channel Frame Secondary Header (VC-FSH) service, which delivers a Frame Secondary Header SLE data channel decommutated from its associated Virtual Channel (Packet Telemetry only) (4.3.2.1.2 a) 6));

i) Return Bitstream service, which delivers a Bitstream SLE data channel decommutated from its associated virtual channel (AOS only) (4.3.2.1.3 a) 1)); and

j) Return Space Packet (RSP) service, which delivers a set of RSP SLE data channels demultiplexed from a Version-1 or Version-2 virtual channel (4.3.2.1.3 a) 2)).

3.4.1.2 Forward AOS SLE Transfer Services

Forward AOS SLE transfer services include:

a) Forward Bitstream service, which receives a Bitstream SLE data channel from the MDOS (4.3.2.2.1 a) 1));

b) Forward VCA service, which receives a VCA SLE data channel from the MDOS (4.3.2.2.1 a) 2));

c) Forward Space Packet service, which receives Forward Space Packet data channels from the MDOS (4.3.2.2.1 a) 3));

d) Forward ProtoVCDU service, which receives a protoVCDU SLE data channel (4.3.2.2.2 a) 1)) (A protoVCDU is a VCDU that does not yet have data in its insert zone and has not yet been coded);

e) Forward Insert service, which receives a Forward AOS Insert SLE data channel (4.3.2.2.2 a) 2)); and

f) Forward C/VCDU service, which receives C/VCDU SLE data channels (4.3.2.2.2 a) 3)).

3.4.1.3 Forward Telecommand SLE Transfer Services

Forward Telecommand SLE transfer services include:

a) Telecommand VCA (TC-VCA) service, which receives a TC-VCA SLE data channel (4.3.2.3.1 a) 1));

b) Forward Space Packet service, which receives Forward Space Packet SLE data channels (4.3.2.3.1 a) 2));

c) Telecommand Frame service which receives Forward Telecommand Frame SLE data channels (4.3.2.3.2 a));

d) Command Link Transmission Unit (CLTU) service which receives Forward CLTU SLE data channels (4.3.2.3.3 a)).

3.4.2 SLE TRANSFER SERVICE DELIVERY MODES

There are two modes of delivery for SLE transfer services: *online* and *offline*.

3.4.2.1 Online Delivery Mode

The online delivery mode is employed to transfer a stream of SLE service data through all or part of the SLE system during the time that the associated Space Link session is active.

3.4.2.1.1 Forward Online Delivery

a) On-line delivery for forward data is provided during a forward space link session, i.e., the period of time when application processes at the sending and receiving ends of the forward link are physically and/or logically interconnected for the purpose of delivering forward link data.

b) The basic quality of on-line delivery is characterized by the types of services available: 1) complete and in-sequence and 2) expedited.

c) The complete and in-sequence service guarantees that the service data are delivered according to routing control instructions (e.g., multiplexing scheme) with the sequence preserved for a given space packet, with no ground-induced errors, with no data omitted and with no data duplicated.

d) The expedited service delivers the service data in the sequence received, with no ground-induced errors but does not guarantee complete delivery (i.e., data may be lost).

e) The on-line delivery of forward data cannot extend beyond the end of the space link session.

3.4.2.1.2 Return Online Delivery

a) The quality of online delivery is characterized by two factors: the *completeness* of data delivery, and the *timeliness* of data delivery.

b) Unless otherwise constrained for timeliness considerations (see item d), below), Return SLE services provide complete delivery, in which the service data are delivered in the sequence received, with no ground-induced errors, and with no data omitted. Completeness is guaranteed, even if the rate at which the data is received by the SLE system is greater than the rate at which it is delivered to the user.

NOTE – Completeness of delivery from a high-rate source to a lower-rate sink is dependent on the availability of sufficient buffering capability in the SLE system. The guarantee of such completeness therefore requires that sufficient resources have been reserved by the SLE system.

c) The online delivery of return data may extend beyond the end of the Space Link session.

NOTE – Complete, in-sequence delivery may result in large delays between the time a data item is received by the SLE system and the time it is delivered to the user. Return online services support this situation by allowing the delivery of the data to the user to extend beyond the end of the Space Link session.

d) The large delays resulting from complete, in-sequence delivery may result in the delivery of data past the point of its usefulness. The SLE online services provide two mechanisms for dealing with timely data (that is, data that are desired or required to be delivered within a certain delay from the time of receipt by the SLE system):

   1) Delay notification: When the delay in delivery exceeds a user-specified notification delay, $T_{delay\text{-}notify}$, the Return SLE service notifies the user. If and when the delay subsequently shortens to be within $T_{delay\text{-}notify}$, the Return service notifies the user that the delay has been recovered.

   2) Data deletion: When the delay in delivery exceeds a user-specified deletion delay, T_{delete}, the return SLE service deletes the outstanding queue of SLE-SDUs for that service and notifies the user of the deletion and the number of SLE-SDUs deleted.

e) The Return SLE services allow the notification and deletion features to be disabled by the service user.

3.4.2.2 Offline Delivery Mode

The offline delivery mode is employed to transfer sets of SLE service data through all or part of the SLE system, and this transfer typically occurs outside the associated Space Link session.

NOTE – It is possible to provide a finer granularity of service delivery than one data set per Space Link session. CCSDS may define such mechanisms in future releases of this Recommendation. However, one data set per Space Link session will always be a legitimate subset of the offline delivery selection criteria.

3.4.2.2.1 Forward Offline Delivery

a) The offline delivery mode is employed to transfer a set of forward SLE service data through all or part of the SLE system. This transfer must be complete before the transmission of that data set to the space element during the associated Space Link session.

b) Offline delivery is provided in the form of a data set containing all SLE-SDUs (that is, SL-DUs, annotation data, control information, and control messages), complete and in sequence, to be transmitted during the Space Link session.

c) The complete and in-sequence service guarantees that the service data are delivered according to the routing control instructions (e.g., multiplexing scheme) with the sequence preserved for a given data set, with no ground-induced errors, with no data omitted, and with no data duplicated.

d) Provisioning for offline delivery includes the reservation of sufficient storage in the SLE system. The reservation of such storage by the MDOS occurs concurrently with the reservation of SLE system resources to receive the source data to be stored.

e) The offline delivery service includes delivery to the space element at a time defined by the associated SLE management.

3.4.2.2.2 Return Offline Delivery

a) The offline delivery mode is employed to transfer a set of return SLE service data through all or part of the SLE system once the acquisition of that data set from the space element is complete. This transfer occurs during or after the associated Space Link session.

b) Offline delivery is provided in the form of a data set containing all SLE-SDUs (that is, SL-DUs, annotation data, control information, and control messages), complete and in sequence, stored during the Space Link session.

c) Provisioning for offline delivery includes the reservation of sufficient storage in the SLE system. The reservation of such storage by the MDOS occurs concurrently with the reservation of SLE system resources to receive the source data to be stored.

d) In general, storage for subsequent offline delivery is reserved by the SLE system in one of two ways:

1) Source data storage: Storage of the full set of source data that is received by the SLE system for the Space Link session. Storage of the source data allows the MDOS to defer the selection of offline data sets until the time at which those data sets are retrieved by the MDOS.

2) User service data storage: Storage of the complete set of service data that has been extracted from the source data that has been received by the SLE system for the Space Link session. Storage of user service data requires that the MDOS establish, concurrent with the reservation of resources needed to receive the source data, the exact service data sets to be subsequently delivered offline.

NOTES

1 From the perspective of the MDOS, source data storage is usually the preferred option, because it allows the user to defer deciding the exact sets of service data to be delivered offline. However, as the ratio of data to be delivered offline to the amount of source data decreases, the relative cost of storing the source data increases for the SLE system. Therefore, real SLE systems may constrain or disregard altogether storing offline data at the source data level.

2 There may be multiple data sets (corresponding to multiple services) extracted from the source data corresponding to a single Space Link session.

3 Even if the MDOS arranges for offline storage in terms of user service data, an implementation of the SLE system may actually implement the storage at the source data level (or even in some intermediate form). The issue relevant to cross support (and therefore to this Recommendation and the specifications of the various SLE services) is the context in which the MDOS and the SLE system arrange for the data to be stored.

e) The MDOS arranges for the offline delivery of stored service data as a separate activity from the reception and capture of the source data.

NOTE – The mechanism for arranging for online and offline service delivery and the associated resources and processing is called the SLE Service Package (see 4.4.1.2).

4 SLE ARCHITECTURE MODEL

4.1 INTRODUCTION TO SLE ARCHITECTURE MODEL

4.1.1 PURPOSE AND SCOPE OF ARCHITECTURE MODEL

4.1.1.1 The purpose of the Architecture Model is to provide the functional and management concepts of the framework for specifications of SLE services. These functional and management concepts are elaborated in the context of the SLE system environment introduced in section 3.

4.1.1.2 This Architecture Model provides an abstract model of an SLE system. This abstract model is refined in two ways: one to provide a functional view of an SLE system, and the second to provide a cross-support view.

4.1.1.3 The functional view, presented in 4.3, defines the functions (and their management) that may be performed by an SLE system, without regard to the way these functions are allocated to various management authorities in real systems. The functional view decomposes the SLE system into elementary functions, called SLE Functional Groups (SLE-FGs), that transfer and deliver return and forward data between the space element and the MUEs.

4.1.1.4 The cross-support view, presented in 4.4, provides the means to model allocation of the functions identified in the functional view to real systems under independent management authorities, which are named SLE Complexes. The cross-support view also describes the management interactions between SLE Complexes and the SLE Utilization Management on behalf of the MDOS.

4.1.1.5 The relationship between the functional and cross-support view is covered in 4.4.2, which discusses how SLE-FGs relate to SLE Complexes.

4.1.2 MODELING TECHNIQUE

a) The functional and cross-support views of the architecture model are based upon the ASDC methodology (reference [12]), which models real systems through functional entities called abstract-objects.

   NOTES

   1 Subsection 1.6.1 summarizes the terms and concepts defined in reference [10] and used here.

   2 Subsection 1.6.3 extends the definitions of 1.6.1 to support specific aspects of the architecture model.

b) A given port has identical structure and behavior independent of the level where it is exposed. Port characteristics at SLE-System level are described in 4.2.3; characteristics at SLE-Complex level are described in 4.4.2.2, 4.4.2.3 and 4.4.2.4; characteristics at SLE-FG level are described in 4.3.1.2 and 4.3.1.3.

4.2 TOP-LEVEL ARCHITECTURE MODEL

4.2.1 ABSTRACT SLE SYSTEM ENVIRONMENT

4.2.1.1 The Space Mission Data System, described in section 3, can be modeled as an abstract-object which is decomposed into a central abstract-object, the SLE system, and two peripheral abstract-objects, the space element and the MDOS. The SLE system interacts with both the space element and the MDOS by means of a number of different ports, as illustrated in figure 4-1.

NOTES

1 It is not within the scope of this Recommendation to describe the functionality of the space element or of the MDOS.

2 The SLE system interacts with the space element and with the MDOS through the ports which it exposes. These ports are described in 4.2.3.

3 In this Recommendation, the MDOS represents the mission-specific ground systems that are directly involved with the day-to-day operations of a mission spacecraft, and specifically, with the transfer of Space Link data to or from the spacecraft via the SLE system. Thus the MDOS includes the sources of forward data (e.g., telecommand packets), and the sinks of return data (e.g., telemetry packets). Although it is modeled as a single entity, in a real ground system the MDOS could comprise many separate systems, including control centers or data processing centers that handle CCSDS SL-DUs. However, other systems that process, catalog, distribute, or archive mission data are not considered in this discussion.

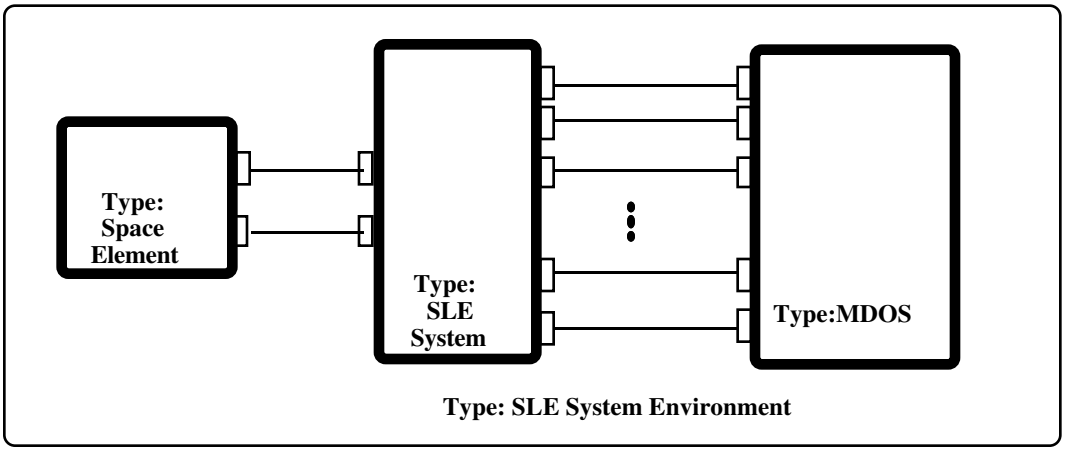


Figure 4-1: Abstract Model of the SLE System Environment

4.2.1.2 Definition: SLE System object. An object of the type SLE system performs the ground part of the data transfer between the space element and the MDOS. This data transfer is an extension of the Space Link data transfer, which is specified in Recommendations (references [2]–[7]).

4.2.2 PROVISION AND PRODUCTION OF SLE TRANSFER SERVICES

4.2.2.1 Definition: SLE Transfer Service Provision. An SLE system is said to *provide* an SLE transfer service when it exposes the operations necessary to obtain the service. Provision of an SLE transfer service implies making available to the service user the capability to obtain the service. Provision involves the interface between the service user and the service provider, and is characterized by what SLE data channels are transferred, when they are transferred, and the quality of service with which they are transferred (e.g., completely, reliably).

4.2.2.2 Definition: SLE Transfer Service Production. In order to provide an SLE transfer service, an SLE system must perform the necessary transformations between the RF carrier channel and the SLE data channels(s) to be transferred to/from the user of the SLE transfer service. Performance of these transformations is called *production* of the SLE transfer service.

4.2.3 PORTS OF AN SLE SYSTEM

An SLE system has Transfer Ports and Management Ports. Through its Transfer Ports it receives or sends one or more space data channels. The service provided by an SLE system at a Transfer Provider Port is called an SLE transfer service. The SLE System Management Ports provide SLE management services, which expose the operations required for negotiation, monitoring and control of the production and provision of SLE transfer services by the MDOS.

a) All SLE services are provided by asymmetric ports.

b) In describing SLE services, ports are designated as consumer (input) or supplier (output) to indicate the direction of space data flow.

c) Although ASDC terminology allows a service to be provided via several ports, each SLE service is defined as being provided at an interface of a single pair of ports, i.e., provided from a single port (instance) of one object to a single port (instance) of another object.

4.2.3.1 Transfer Ports

An SLE system may have multiple Transfer Ports of multiple Transfer Port types. It usually has at least one return RF-signal port and/or one forward RF-signal port. A Transfer Port is either a service-user port, denoted T-U (for Transfer User Port), or a service-provider port, denoted T-P (for Transfer Provider Port), but can not be both.

4.2.3.1.1 Transfer User Port

At a Transfer User Port, an SLE-System uses an SLE transfer service provided by the space element. If the SLE transfer service used is a return SLE transfer service, the port is a consumer of a return space data channel. If the SLE transfer service used is a forward SLE transfer service, the port is a supplier of a space data channel.

4.2.3.1.2 Transfer Provider Port

At a provider port, an SLE-System provides an SLE transfer service. If the SLE transfer service provided is a return SLE transfer service, the port is a supplier of a return space data channel. If the SLE transfer service provided is a forward SLE transfer service, the port is a consumer of a space data channel.

4.2.3.1.3 Transfer Port Type

A Transfer Port type is named for the type of space data channel that it transfers.

4.2.3.2 Management Ports

4.2.3.2.1 An SLE system may have multiple instances of Management Ports. The SLE System Management Port Type is discussed further in the cross-support view of the Architectural Model (4.4).

4.2.3.2.2 Through its Management Ports, an SLE system exchanges management information such as set-up or configuration related to the supervision of the SLE transfer services provided by the SLE system at its Transfer Provider Ports.

NOTE – As described in 1.6.3, the convention in this Recommendation is that for any abstract-object, one service-provider port provides one (and only one) abstract service.

4.3 ARCHITECTURE MODEL—FUNCTIONAL VIEW

4.3.1 FUNCTIONAL VIEW CONCEPTS

4.3.1.1 Functional Decomposition of SLE System

4.3.1.1.1 This reference model functional view is a decomposition, or abstract refinement, of an SLE system that focuses on the functions that provide SLE transfer services. In this view, the SLE data transfer is implemented within the SLE system by abstract-objects called SLE-FGs. Each SLE-FG performs a related set of functions that provide one or more related SLE transfer services.

4.3.1.1.2 Definition: SLE-FG object. An SLE-FG performs the functions that transform SLE-SDUs from an SLE data channel of a given type to produce and provide a related group of SLE transfer services.

4.3.1.1.3 SLE-FGs are of one of eight types of abstract-object, which fall into three categories: return SLE-FGs (listed in table 4-1), forward AOS SLE-FGs (listed in table 4-2), and forward telecommand SLE-FGs (listed in table 4-3). The management, such as set-up and configuration, of SLE-FGs is performed by the SLE system.

NOTES

1 The eight SLE-FG types are described in more detail in 4.3.2. The services provided by the SLE-FGs are described in section 5. The rationale for the breakdown of the SLE system into the eight specific SLE-FG types is provided in annex B.

2 The relationship between the management of SLE-FG and the cross-support view of the SLE System Architectural Model is discussed in 4.4.

Table 4-1: Return SLE Functional Groups

Return Space Link Processing SLE-FG
Return Frame Processing SLE-FG
Return Frame Data Extraction SLE-FG

Table 4-2: Forward AOS SLE-FG

Forward AOS VC Data Insertion SLE-FG
Forward AOS Space Link Processing SLE-FG

Table 4-3: Forward Telecommand SLE-FG

Forward TC VC Data Insert SLE-FG
Forward CLTU Generation SLE-FG
Forward TC Space Link Processing SLE-FG

4.3.1.2 Ports of an SLE-FG

An SLE-FG may have multiple instances of multiple types of Transfer Ports through which it provides one or more SLE transfer services. An SLE-FG has one Function-Management Port through which it exchanges management information such as set-up or configuration relative to the supervision of the SLE transfer services provided by the SLE-FG at its Transfer Provider Ports. An illustration of an SLE-FG is given in figure 4-2.

NOTES

1 As described in 1.6.3, the convention in this Recommendation is that for any abstract-object, one service-provider port provides one (and only one) instance of abstract service.

2 Because the focus of this section is on the functions that produce SLE transfer services, there is no further discussion of service management here. Management of SLE services is discussed in the cross-support view of the architecture model in the SLE Service Management specification and in section 5, Specification of SLE services.

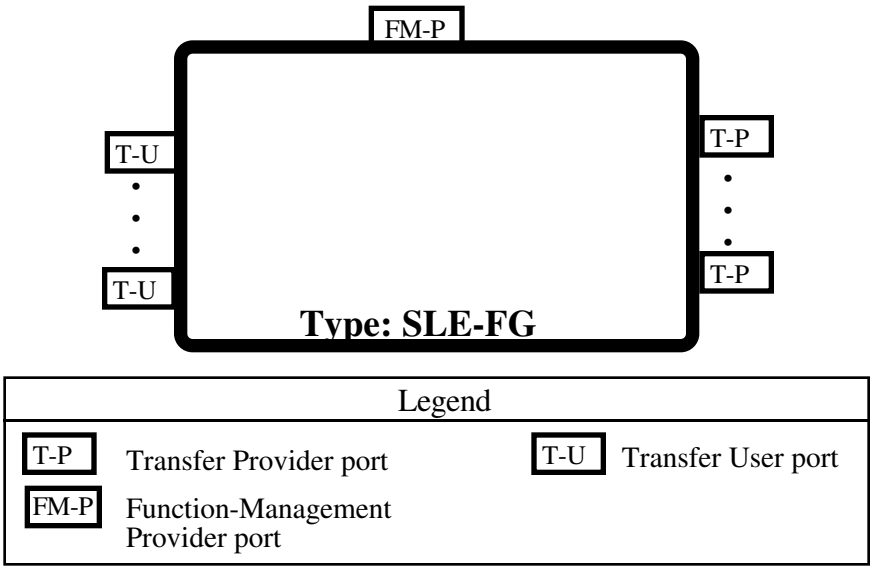


Figure 4-2: Ports of an SLE-FG

4.3.1.2.1 SLE-FG Transfer User Port

At a Transfer User Port, an SLE-FG uses an SLE transfer service provided by another SLE-FG, or by the space element. If the SLE transfer service used is a return SLE transfer service, the port is a consumer of a return space data channel. If the SLE transfer service used is a forward SLE transfer service, the port is a supplier of a space data channel.

4.3.1.2.2 SLE-FG Transfer Provider Port

At a provider port, an SLE-FG provides an SLE transfer service. If the SLE transfer service provided is a return SLE transfer service, the port is a supplier of a return space data channel. If the SLE transfer service provided is a forward SLE transfer service, the port is a consumer of a space data channel.

4.3.1.3 Binding Rules of SLE-FG Transfer Ports

Pairs of (instances of) SLE-FG Transfer Ports may be bound, as illustrated in figure 4-3, in the following ways:

a) a Transfer User Port (of a given type) is bound to a Transfer Provider Port (of the same type) of another SLE-FG, or to the space element;

b) a Transfer Provider Port (of a given type) is bound to a Transfer User Port (of the same type) of another SLE-FG, or of a MUE within the MDOS;

c) each instance of service is provided on a separate pair of (instances of) SLE-FG Transfer Ports.

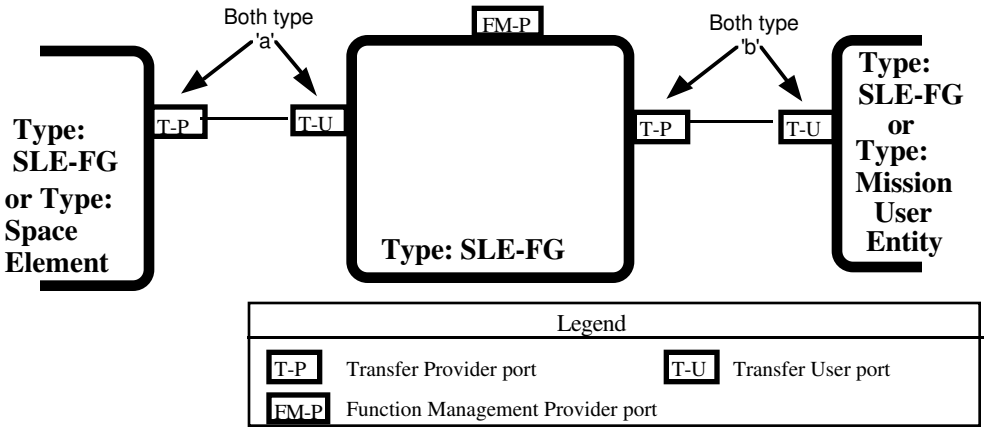


Figure 4-3: Interconnection of SLE-FGs Ports

4.3.2 INTRODUCTION TO SPECIFIC SLE FUNCTIONAL GROUPS

4.3.2.1 RETURN SLE Functional Groups

a) There are three Functional Groups (FGs) that provide return SLE services:

   1) Return Space Link Processing;

   2) Return Frame Processing;

   3) Return Frame Data Extraction.

b) These are illustrated in figure 4-4, below, and are described in the three subsections that follow. In figure 4-4, all services exposed between FGs are available to the MDOS, including the two services used for cross support between FGs (RAF and Return VC Frames).

c) In each subsection, the services provided by that FG are identified, followed by the functions performed by that FG in order to produce those services. Each FG is formally defined as providing all of the services listed and performing all of the functions listed. Real implementations of the FGs may provide all or only a subset of these services, and consequently may perform all or only a subset of the functions identified. The applicable SLE service specifications define the relationship between services implemented and functionality required to produce those services.

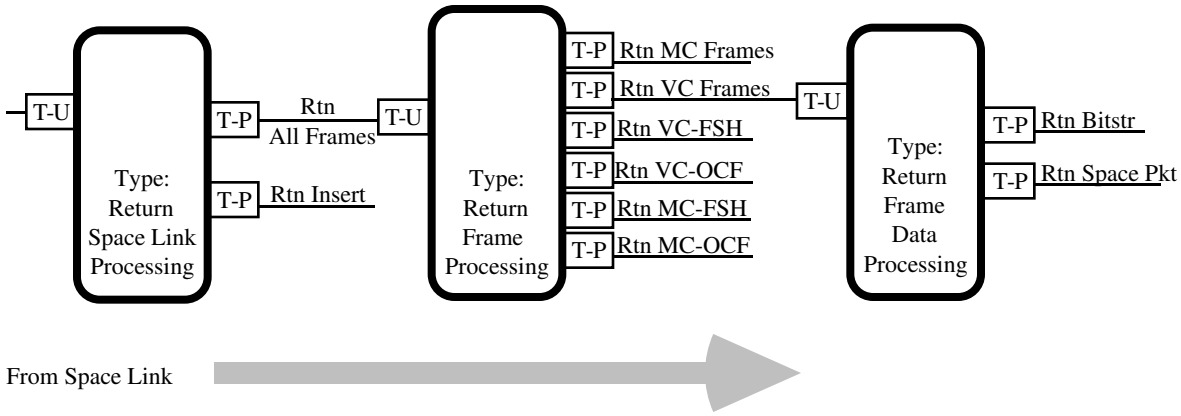


Figure 4-4: Return Functional Groups

4.3.2.1.1 Return Space Link Processing SLE-FG

a) The Return Space Link Processing SLE-FG provides the following services:

1) RAF service, which delivers the RAF SLE data channel resulting from a single physical channel.

2) Return Insert service, which delivers the Return Insert SLE data channel from a single physical channel. Return Insert service is delivered in online mode only.

b) The Return Space Link Processing SLE-FG performs the following functions:

1) utilizes the underlying antenna steering capabilities of the ground element and acquires the RF carrier channel;

2) demodulates the RF carrier channel into one or more physical channels, each of which consists of a digital symbol stream;

3) frame synchronizes and extracts CCSDS frames from each physical channel;

4) error-decodes the frames and corrects the correctable errors: error decoding includes convolutional decoding (optionally applied), bit derandomization (optionally applied), Reed-Solomon decoding (optionally applied) and cyclic redundancy check (CRC) decoding (optionally applied);

NOTES

1 Depending upon the implementation, convolutional decoding may be applied before or after frame synchronization.

2 SLE Return Space Link Processing requires that at any given time, the coding options must be the same for all frames on the physical channel. In some cases, this is more restrictive than the constraints imposed by the corresponding Space Link Recommendations. In particular, Reed-Solomon coding must be present or absent on all of the frames on the physical channel; that is, there cannot be a concurrent mix of some frames with Reed-Solomon coding and some frames without.

5) annotates each frame to form an RAF SLE-SDU;

6) injects the resulting RAF SLE-SDU into the RAF channel associated with the physical channel from which the frame was originally extracted;

NOTE – The RAF channel also contains service control information not carried in the RAF SLE-DUs.

7) for an RAF channel containing a Return Insert Space Link data channel, decommutates the complete insert zone from every frame within the physical channel, annotates each insert zone to form a Return Insert SLE-SDU, and injects the resulting Return Insert SLE-SDUs into the Return Insert SLE data channel identified by the RAF Channel ID;

8) stores sufficient data to subsequently reconstruct the RAF SLE data for delivery through one or more offline SLE service instances;

9) retrieves stored data and reconstructs the RAF SLE data channel for delivery through one or more offline SLE service instances;

10) performs telecommunication functions necessary to supply the Return Space Link Processing SLE data channels (RAF, Return Insert) through both online and offline SLE service instances.

4.3.2.1.2 Return Frame Processing SLE-FG

a) The Return Frame Processing SLE-FG provides the following services:

1) Return Master Channel (MC) Frame service, which delivers one Master Channel (Master SLE data channel) demultiplexed from a particular RAF channel;

2) Return Master Channel Operational Control Field (MC-OCF) service, which delivers one Operational Control Field SLE data channel decommutated from its associated Master Channel;

3) Return Master Channel Frame Secondary Header (MC-FSH) service, which delivers one Frame Secondary Header SLE data channel decommutated from its associated Master Channel;

4) Return Virtual Channel Frame (VC Frame) Service, which delivers one Virtual Channel (Virtual SLE data channel) demultiplexed from a particular MC channel;

5) Return Virtual Channel Operational Control Field (VC-OCF) service, which delivers one Operational Control Field SLE data channel decommutated from its associated Virtual Channel;

6) Return Virtual Channel Frame Secondary Header (VC-FSH) service, which delivers one Frame Secondary Header SLE data channel decommutated from its associated Virtual Channel; and

b) The Return Frame Processing SLE-FG performs the following functions:

1) consumes a single RAF SLE data channel;

2) demultiplexes the RAF channel into its component Master Channels, each identified by its Master Channel ID (MCID = Frame Version Number and SCID), annotates each MC Frame in the Master Channel to form an MC Frame SLE-SDU, and injects the resulting MC Frame SLE-SDUs into the Master Channel SLE data channels;

3) demultiplexes each Master Channel into its component Virtual Channels, each identified by its Global Virtual Channel ID (GVCID = MCID and VCID), annotates each VC Frame in the Virtual Channel to form a VC Frame SLE-SDU, and injects the resulting VC Frame SLE-SDUs into the Virtual Channel SLE data channels;

4) for a Master Channel containing an MC-OCF Space Link data channel, decommutates the OCF field from each MC Frame, annotates the OCF field data to form an MC-OCF SLE-SDU, injects the resulting MC-OCF SLE-SDUs into their respective MC-OCF SLE data channels;

5) for a Master Channel containing an MC-FSH Space Link data channel, decommutates the FSH field from each MC Frame, annotates the FSH field data to form an MC-FSH SLE-SDU, and injects the resulting MC-FSH SLE-SDUs into their respective MC-FSH SLE data channels;

6) for a Virtual Channel containing a VC-OCF Space Link data channel, decommutates the OCF field from each VC Frame, annotates the OCF field data to form a VC-OCF SLE-SDU, and injects the resulting VC-OCF SLE-SDUs into their respective VC-OCF SLE data channels;

7) for a Virtual Channel containing a VC-FSH Space Link data channel, decommutates the FSH field from each VC Frame, annotates the FSH field data to form a VC-FSH SLE-SDU, and injects the resulting VC-FSH SLE-SDUs into their respective VC-FSH SLE data channels;

8) stores sufficient SLE data to support the subsequent reconstruction of one or more space data channels of the following types:

   – Master Channel;
   – Virtual Channel;
   – MC-OCF;
   – MC-FSH;
   – VC-OCF;
   – VC-FSH;

   storage of SLE data may be performed relative to the source RAF SLE data channel or relative to the individual product SLE data channels;

NOTE – Storage of SLE data relative to the source RAF SLE data channel does not require the MDOS to specify the specific channels to be retrieved before the Space Link session occurs, and is therefore more flexible than storage relative to the individual product SLE data channels (which requires the MDOS to identify at or before the execution of the Space Link session the specific SLE data channels that are to be subsequently delivered via offline service instance). However, some implementations may not have sufficient resources to store the equivalent of complete RAF SLE data channels, and may therefore only be able to store the product SLE data.

9) retrieves stored SLE data and reconstructs specified Return Frame Processing SLE data channels (MC Frame, VC Frame, MC-OCF, MC-FSH, VC-OCF, VC-FSH) for delivery through offline SLE service instances;

10) performs telecommunication functions necessary to supply the Return Frame Processing SLE data channels (MC Frame, VC Frame, MC-OCF, MC-FSH, VC-OCF, VC-FSH) through both online and offline SLE service instances.

4.3.2.1.3 Return Frame Data Extraction SLE-FG

a) The Return Frame Data Extraction SLE-FG provides the following services:

1) Return Bitstream service, which delivers one Bitstream SLE data channel decommutated from its associated Version-2 VC Frame channel; and

2) RSP service, which delivers a set of RSP SLE data channels demultiplexed from a single Version-1 or Version-2 VC Frame channel. The RSPs are delivered in the sequence in which they were put into the virtual channel frames by the space element.

NOTE – Version-2 VC Frame channels may carry space packets encapsulating ISO Connectionless Network Protocol (CLNP) PDUs, as defined in the AOS Internet service specification (section 4 of reference [4]). These Internet-Encapsulation space packets are designated by Application Process ID (APID) 2046. The SLE system supports the AOS Internet service through the return and forward Space Packet services: encapsulation, de-encapsulation, and relaying of ISO CLNP PDUs is strictly a function of the MDOS.

b) The Return Frame Data Extraction SLE-FG performs the following functions:

1) The Return Frame Data Extraction SLE-FG consumes VC Frame channels.

2) For a VC Frame channel that carries Bitstream data, the Return Frame Data Extraction SLE-FG extracts the Bitstream PDUs (B-PDUs) from each Version-2 VC Frame SLE-SDU, annotates each B-PDU to form a Bitstream SLE-SDU, and

injects the resulting SLE-SDUs into the Bitstream SLE data channel identified by the GVCID of the parent Virtual Channel.

3) For a VC Frame channel that carries multiplexed packets, the Return Frame Data Extraction SLE-FG demultiplexes CCSDS Packets from the VC Frame SDUs of that data channel.

4) For CCSDS Space Packets, the Return Frame Data Extraction SLE-FG annotates the Space Packets to form RSP SLE-SDUs and injects the resulting RSP SLE-SDUs into their respective RSP SLE data channels. The RSP SLE data channel is identified by its Space Packet Channel ID (SPCID), which is the combination of Frame Version Number, SCID, VCID, and APID. An RSP is defined as being:

   – a CCSDS packet carried by a Packet Telemetry (Version-1) Virtual Channel (reference [2]), or

   – a CCSDS packet carried by an AOS (Version-2) Virtual Channel, with APID in the range (0-2031, 2046) (reference [4]).

   NOTE – In specifying the set of RSPs to be delivered via a single RSP service instance, the user will provide a list of SPCIDs to be delivered.

5) The Return Frame Data Extraction SLE-FG stores sufficient SLE data to support the subsequent reconstruction of one or more Return Bitstream or RSP SLE data channels. Storage of SLE data for the reconstruction of RSP SLE data channels may be performed relative to the source VC Frame channel or relative to the resultant RSP SLE data channels.

NOTE – Storage of SLE data relative to the source VC Frame channel does not require the MDOS to specify the specific RSP channels to be retrieved before the Space Link session occurs, and is therefore more flexible than storage relative to the resultant RSP SLE data channels (which requires the MDOS to identify at or before the execution of the Space Link session the specific RSP SLE data channels that are to be subsequently delivered via offline service instance). However, some implementations may not have sufficient resources to store the equivalent of complete VC Frame channels, and may therefore only be able to store the resultant RSP SLE data.

6) The Return Frame Data Extraction SLE-FG retrieves stored SLE data and reconstructs specified Return Bitstream and RSP SLE data channels for delivery through offline SLE service instances.

7) The Return Frame Data Extraction SLE-FG performs telecommunications functions necessary to supply the Return Bitstream and RSP SLE data channels through both online and offline service instances.

4.3.2.2 FORWARD AOS SLE Functional Groups

a) There are two FGs that provide AOS Forward SLE services:

1) Forward AOS VC Data Insertion;

2) Forward AOS Space Link Processing.

b) These are illustrated in figure 4-5 below, and are described in the two subsections that follow. In figure 4-5, all services exposed between FGs are available to the MDOS, including the protoVCDU service used for cross-support between the two FGs.

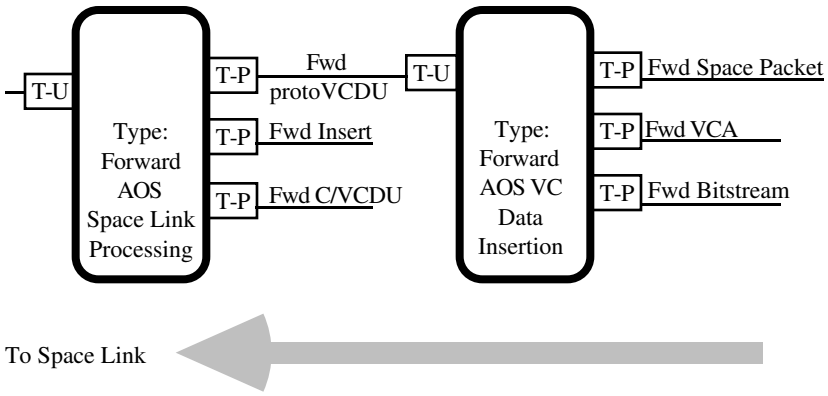


Figure 4-5: AOS Forward Functional Groups

4.3.2.2.1 Forward AOS VC Data Insertion SLE-FG

a) The Forward AOS VC Data Insertion SLE-FG provides the following services:

1) Forward Bitstream service, which receives a Bitstream SLE data channel from the MDOS;

2) Forward VCA service, which receives a VCA SLE data channel from the MDOS; and

3) Forward Space Packet service, which receives Forward Space Packet data channels from the MDOS.

b) The Forward AOS VC Data Insertion SLE-FG performs the following functions:

1) For each Forward Bitstream service instance, the Forward AOS VC Data Insertion SLE-FG consumes one Bitstream SLE data channel, extracts the Bitstream PDU (B-PDU) from each Bitstream SLE-SDU in the data channel, creates a protoVCDU encapsulating the B-PDU, and injects the resulting protoVCDU into the ProtoVCDU SLE data channel. A protoVCDU contains the VCDU primary header (without VCDU Header Error Control) and the VCDU Data Unit Zone.

2) For each Forward VCA service instance, the Forward AOS VC Data Insertion SLE-FG consumes one Forward VC Frame SLE data channel, extracts the VCA-SDU from each VCA SLE-SDU in the data channel, creates a protoVCDU encapsulating the VCA-SDU, and injects the resulting protoVCDU into the protoVCDU SLE data channel.

3) For each Forward Space Packet service instance, the Forward AOS VC Data Insertion SLE-FG consumes one or more Forward Space Packet data channels associated with a single Virtual Channel, extracts the CCSDS packets from the Forward Space Packet SLE-SDUs in each data channel, multiplexes the CCSDS Packets into protoVCDUs, and injects the resulting protoVCDUs into the appropriate protoVCDU SLE data channel.

NOTE – Version-2 VCA SLE data channels may carry space packets encapsulating ISO CLNP PDUs, as defined in the AOS Internet service specification (section 4 of reference [4]). These Internet-Encapsulation space packets are designated by APID 2046. The SLE system supports the AOS Internet service through the Return and Forward Space Packet services: encapsulation, de-encapsulation, and relaying of ISO CLNP PDUs is strictly a function of the MDOS.

4) The Forward AOS VC Data Insertion SLE-FG performs storage and telecommunications functions necessary to supply the protoVCDU SLE data channels to the Forward AOS Insert and Coding FG through both online and offline service instances.

4.3.2.2.2 Forward AOS Space Link Processing SLE-FG

a) The Forward AOS Space Link Processing SLE-FG provides the following services:

1) Forward ProtoVCDU service, which receives a protoVCDU SLE data channel;

2) Forward Insert service, which receives a Forward AOS Insert SLE data channel; and

3) Forward C/VCDU service, which receives C/VCDU SLE data channels.

b) The Forward AOS Space Link Processing SLE-FG performs the following functions:

1) for each Forward protoVCDU service instance, consumes one protoVCDU SLE data channel;

2) for each forward Insert service instance, consumes one forward Insert SLE data channel and extracts the Insert Zones from the forward Insert SLE-SDUs;

3) for each protoVCDU SLE data channel destined for a forward physical channel carrying an Insert channel, synchronously commutates the Insert Zones destined for that physical channel into the protoVCDUs;

4) performs Reed-Solomon and/or CRC error encoding (as required) on each protoVCDU required for that virtual channel and multiplexes the resulting C/VCDU into its respective forward All AOS Frames SLE data channel;

5) if a protoVCDU is not available to carry a received Insert Zone, generates a Fill VCDU to carry the Insert Zone, performs the error encoding required for that Fill virtual channel, and multiplexes the resulting C/VCDU into its respective (fill) forward All AOS Frames SLE data channel;

6) for each forward C/VCDU service instance, consumes forward C/VCDU SLE data channels;

7) multiplexes the C/VCDUs into their respective Forward All AOS Frames SLE data channel;

8) performs bit-randomization (as required), attaches sync markers, and synchronously multiplexes the C/VCDUs in a forward All AOS Frames SLE data channel into a physical channel;

9) as required, convolutionally encodes the stream of bits on the physical channel;

10) utilizes the underlying antenna steering capabilities provided by the ground element;

11) modulates the bit/symbol stream onto an RF carrier channel and radiates the signal to the space element.

4.3.2.3 Forward TC SLE Functional Groups

a) There are three FGs that provide Forward TC SLE services:

1) Forward TC VC Data Insertion;

2) Forward CLTU Generation;

3) Forward TC Space Link Processing.

b) These are illustrated in figure 4-6 below, and are described in the three subsections that follow. In figure 4-6, all services exposed between FGs are available to the MDOS, including the services used for cross support between the FGs (Forward TC Frame and CLTU).

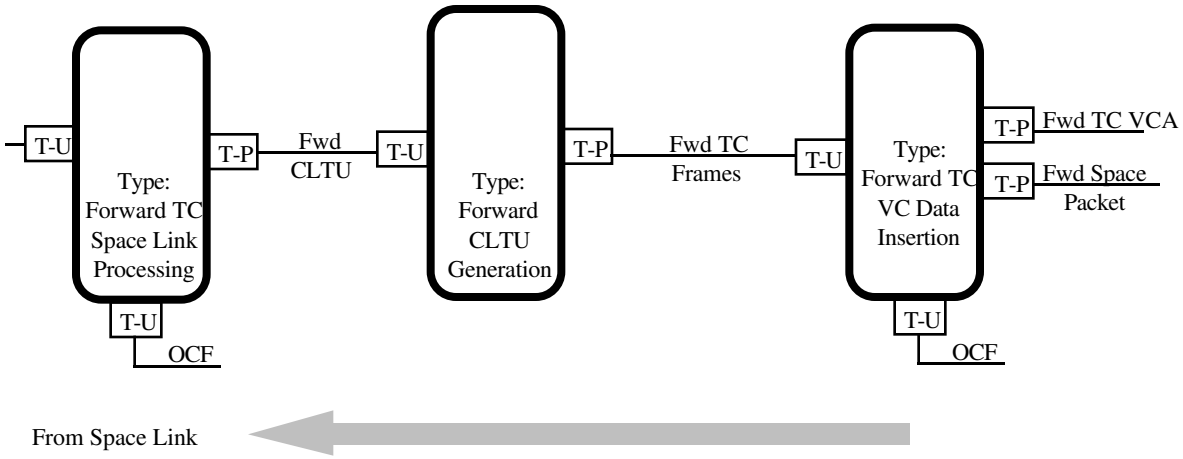


Figure 4-6: Forward Telecommand Functional Groups

4.3.2.3.1 Forward TC VC Data Insertion SLE-FG

a) The Forward TC VC Data Insertion SLE-FG provides the following services:

1) Forward Telecommand VCA (TC-VCA) service, which receives a TC-VCA SLE data channel. A TC-VCA SLE data channel carries user-defined TC Frame Data Units (see 3.2.1 in reference [6]), and control information or annotation including GVCID of the Virtual Channel that is to be used to carry those Forward TC Frame Data Units.

NOTE – The Forward TC-VCA service operates at a virtual-channel level. Any structuring of the data within the TC Frame Data Unit (for example, the use of Multiplexer Access Points to provide segmentation for the user data contained in the TC Frame Data Unit) is part of the MDOS processing and is outside the scope of the Forward TC-VCA service.

2) Forward Space Packet service, which receives forward Space Packet SLE data channels.

b) The Forward TC VC Data Insertion SLE-FG performs the following functions:

1) For each forward TC-VCA service instance, the Forward TC VC Data Insertion SLE-FG consumes one TC-VCA SLE data channel, extracts the TC Frame Data Unit from each TC-VCA SLE-SDU in the data channel, creates a Telecommand Transfer Frame encapsulating the TC Frame Data Unit, and supplies the TC Frame SLE data channel in the form of blocks of one or more TC Transfer Frames. If the Frame is to be sent using the Sequence-controlled service option of the Command Operation Procedure (COP), the Forward TC VC Data Insertion SLE-FG sets the Frame Sequence Count and buffers a copy of the TC Transfer Frame.

2) For each Forward Space Packet service instance, the Forward TC VC Data Insertion SLE-FG consumes one or more Forward Space Packet data channels, extracts the CCSDS packets from the Forward Space Packet SLE-SDUs in each data channel, blocks or segments the CCSDS Packets into Telecommand Transfer Frames, and supplies the TC Frame SLE data channel in the form of blocks of one or more TC Transfer Frames. If the Frame is to be sent using the Sequence-controlled service option of the Command Operation Procedure (COP), the TC VC Data Insertion SLE-FG sets the Frame Sequence Count and buffers a copy of the TC Transfer Frame. Segmented packets cannot be sent without sequence control.

NOTE – If both the Forward TC-VCA and Forward Space Packet services are active in a single virtual channel, only one can be sequence controlled.

3) The Forward TC VC Data Insertion SLE-FG consumes MC-OCF or VC-OCF SLE data channels and extracts the Command Link Control Words (CLCWs). Based on the values in the CLCW, the Forward TC VC Data Insertion SLE-FG retransmits or deletes buffered TC Transfer Frames.

4) The Forward TC VC Data Insertion SLE-FG performs storage and telecommunications functions necessary to supply the TC Frame SLE data channels to the Forward CLTU Generation FG through both online and offline service instances. In addition, it prepares and transmits buffers of TC data containing PDUs from the TC transfer layer (i.e., one or more TC transfer frames).

4.3.2.3.2 Forward CLTU Generation SLE-FG

a) The Forward CLTU Generation SLE-FG provides the Forward Telecommand Frame service, which receives at least one Forward TC Frame SLE data channel.

b) The Forward CLTU Generation SLE-FG performs the following functions:

1) consumes Telecommand Frame SLE data channels supplied as blocks of one or more TC Frames for transmission via a single CLTU;

2) optionally, bit-randomizes the block of TC frames to ensure adequate zero-one transitions;

3) BCH-encodes each block of TC frames into a set of TC Code blocks;

4) forms a CLTU by appending Start and Tail sequences to the TC Code blocks representing the block of TC frames;

5) injects the resulting CLTU into its respective CLTU SLE data channel; and

6) performs the necessary storage and telecommunication functions necessary to supply the CLTU SLE data channel to the Forward TC Space Link Processing FG through both online and offline service instances.

4.3.2.3.3 Forward TC Space Link Processing SLE-FG

a) The Forward TC Space Link Processing SLE-FG provides the Forward CLTU service, which receives one CLTU SLE data channel.

b) The Forward TC Space Link Processing SLE-FG performs the following functions:

1) for each Forward CLTU service instance, consumes a CLTU SLE data channel;

2) consumes MC-OCF or VC-OCF SLE data channels which contain CLCWs; based on the values in the CLCW, the Forward TC Space Link Processing SLE-FG determines whether the physical channel is available;

3) generates Acquisition and Idle Sequences on the asynchronous physical channel in accordance with the Physical Link Operations Procedure (PLOP) in effect;

4) injects the CLTUs into the asynchronous physical channel;

5) utilizes the underlying antenna steering capabilities provided by the ground element;

6) modulates the resulting stream of bits to RF and radiates the signal to the space element.

4.4 ARCHITECTURE MODEL—CROSS-SUPPORT VIEW

4.4.1 CROSS-SUPPORT VIEW CONCEPTS

a) Real SLE systems are often made up of several physical systems that interoperate to provide SLE services to a space mission. These physical systems may be independently operated by different Agencies or by different organizational elements within an Agency. In the cross-support view, each such physical system is modeled as an SLE Complex.

b) **Definition: SLE Complex**. An SLE Complex is a set of SLE-FGs under a single management authority. At the time of cross support, an SLE complex has a single established relationship between the SLE system and the MDOS.

c) From a mission cross-support view, the SLE system is composed of one or more SLE Complexes as illustrated in figure 4-7.

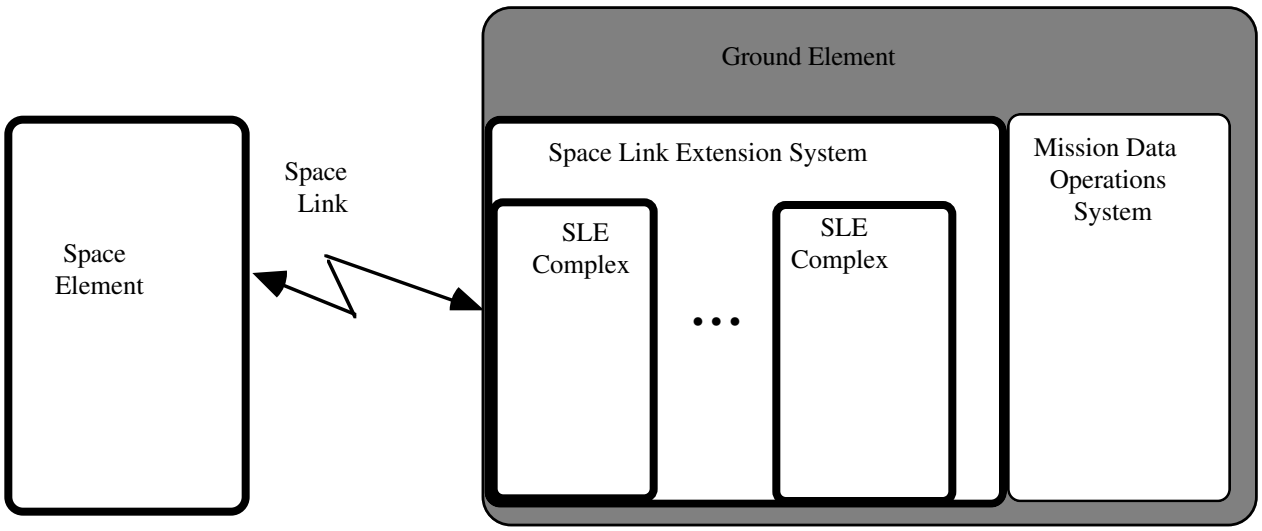


Figure 4-7: SLE Complexes

NOTES

1 From the management perspective of the MDOS, the SLE system appears to be decomposed into several (non-overlapping) SLE Complexes.

2 An SLE Complex is a representation of a real system, as viewed by the MDOS of a space mission. However, issues related to the sharing of real systems shared by multiple missions are beyond the scope of this reference model.

3 None of the entities described above are intended to imply particular implementations or particular physical or administrative affiliations.

4.4.1.1 SLE Utilization Management

All SLE Complexes within an SLE system interface to a single entity within the MDOS called the SLE Utilization Management, as illustrated in figure 4-8. The SLE Utilization Management arranges for forward and return SLE transfer services data with the SLE Complexes and monitors the transfer process. The SLE Utilization Management is part of the Mission Management Entity, which coordinates the activities of the Space and ground elements on behalf of a mission.

NOTES

1 The SLE Utilization Management is an abstraction of the entities within a real ground system that are involved in managing real SLE Complexes for a particular mission. This Recommendation does not make any assumptions about how this SLE Utilization Management is implemented in real systems.

2 The SLE Utilization Management is identified to acknowledge that the Mission Management Entity has many aspects that are outside the scope of SLE.

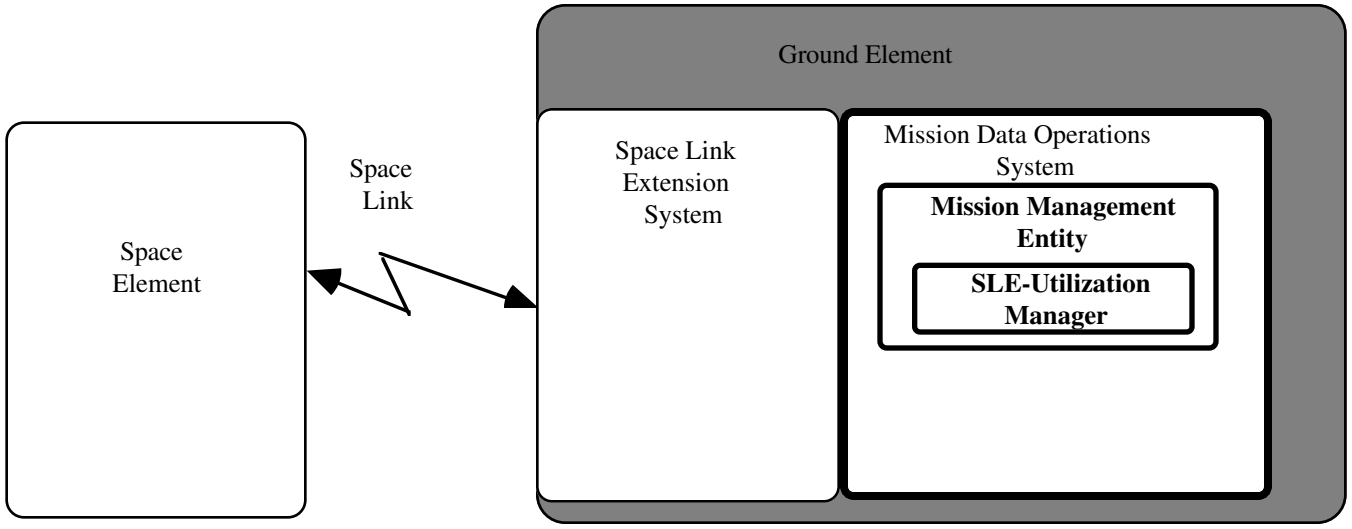


Figure 4-8: Mission and SLE Utilization Management

NOTE – None of the entities described above are intended to imply particular implementations or particular physical or administrative affiliations.

4.4.1.2 SLE Service Package

4.4.1.2.1 Definition: SLE Transfer Service Instance. An SLE transfer service instance is the provision by an SLE Complex of the capability to transfer one or more SLE data channels of a given type, all of which are related to the same Space Link Session.

4.4.1.2.2 Definition: SLE Service Package. An SLE Service Package is the set of instances of SLE transfer services, together with the specification of the characteristics of the production of those SLE Service Instances, that are provided by one SLE Complex to one or more SLE transfer service users. The on-line SLE transfer services are restricted to one Space Link Session.

4.4.1.2.3 An SLE Service Package may contain multiple SLE service instances of multiple SLE services. SLE Utilization Management and the SLE Complex prepare the mutually agreed SLE Service Package(s) to be supported by the SLE Complex. The SLE Service Package contains a schedule for the execution of the production of the SLE data channels, and for the provision of the SLE transfer service instances.

NOTES

1 SLE Service User above is either another SLE Complex (belonging to the same SLE system) or a MUE.

2 "Provide" is used in the sense of "make available to be used" and does not necessarily imply that the service is being used.

3 In cases where the SLE system comprises two or more SLE complexes, an SLE Service Package specifies the characteristics of only part of the production of the SLE transfer services that are provided to the MDOS, namely, that subset of the production that is performed by the SLE Complex that provides the SLE Service Package. The remaining production is specified in other SLE Service Packages, and is performed by other SLE Complexes.

4 Management, i.e., negotiation, scheduling, and control, of SLE Service Packages is further discussed in the SLE Service Management specification.

4.4.2 MODEL OF SLE COMPLEX

4.4.2.1 SLE Complex Objects

4.4.2.1.1 Definition: SLE Complex abstract-object type. An SLE Complex comprises one or more instances of SLE-FGs, of one or more SLE-FG types. An SLE Complex also contains a management entity, called the SLE Complex Management, which coordinates the activities of the SLE-FGs pertaining to the SLE Complex on behalf of the SLE Utilization Management. An SLE Complex is illustrated in figure 4-9.

4.4.2.1.2 Definition: SLE Complex Management abstract-object type. An SLE Complex Management negotiates the provision of SLE Service Packages with the SLE Utilization Management and controls and monitors the production and provision of SLE transfer service instances by the SLE-FGs belonging to the SLE Complex. An SLE Complex Management exchanges, with the SLE Utilization Management, set-up and configuration parameters required for the provision of the SLE transfer service instances. An SLE Complex Management distributes these parameters to the SLE-FGs and coordinates their activities for the provision of the SLE transfer service instances. An SLE Complex Management collects from the SLE-FGs reporting information, consolidates it, and forwards it to the SLE Utilization Management.

NOTE – The interactions between the SLE Complex Management and the SLE Utilization Management are discussed in the SLE Service Management specification.

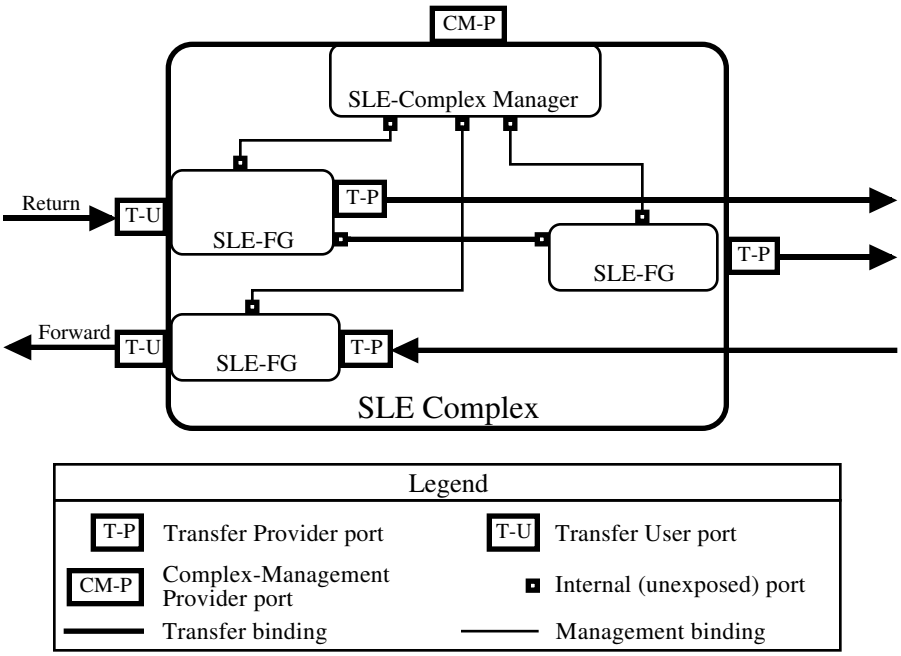


Figure 4-9: An Example of SLE Complex Ports

NOTE – The SLE Complex shown in figure 4-9 is assumed to interface with other SLE Complexes or the Space Link to its left, and with other SLE Complexes or the MDOS to its right. The SLE Complex can receive return data (through a user port on the left) and can send that return data toward the MDOS, potentially via other SLE Complexes (through a provider port on the right). It can receive forward data (through a provider port on the right), and can send that forward data toward the spacecraft, potentially via other SLE Complexes (through a user port on the left).

4.4.2.2 Ports of an SLE Complex

The SLE Complex exposes two or more Transfer Ports (possibly of different types, but at least one user port and one provider port) and a single Complex Management Port. The Ports of an SLE Complex are illustrated in figure 4-9, above.

4.4.2.2.1 Ports of an SLE Complex Management

4.4.2.2.1.1 The SLE Complex Management and the SLE Utilization Management function of the MDOS share a single Complex Management association via a Complex Management port pair. At the Complex Management Port, the SLE Complex Management exposes management operations as required for negotiation, provision, monitoring and control of the SLE transfer services being provided by the SLE Complex.

NOTE – Because an SLE Complex is a virtual entity dedicated to a single space mission, by definition it has only a single instance of a Complex Management port. However, an SLE Complex is realized by a "real" system (i.e., a "real SLE Complex") that may provide SLE services to multiple space missions. In such cases, the management entity for the "real SLE Complex" exposes a dedicated Complex Management port for each space mission supported.

4.4.2.2.1.2 The SLE Complex Management also exposes (within the SLE Complex) one or more FG Management Ports. The SLE Complex Management FG Management Ports are of the same type as the SLE-FG Management Ports and match, by pair, the SLE Complex's SLE-FG Management Ports.

4.4.2.2.1.3 The Ports of an SLE Complex Management are illustrated in figure 4-9, above.

NOTE – At an SLE Complex Management Port, an SLE Complex exposes operations that can be invoked by SLE Utilization Management to exchange management information. Incoming management information carries information that influences the behavior of the SLE Complex. Outgoing management information carries information that reflects the status of the FGs.

4.4.2.2.2 Transfer Ports of an SLE Complex

The SLE Complex Transfer Ports are defined as being the collection of the SLE Complex's SLE-FG Transfer Ports.

NOTE – Not all SLE-FG Transfer Ports of an SLE Complex need be exposed as SLE Complex Transfer Ports. For instance, if an SLE-UM has negotiated an SLE RtnSpacePkt service (based on an RF signal input) with an SLE Complex, within the SLE Complex several SLE-FGs are cascaded, but only the RF signal and RtnSpacePkt Transfer Port are exposed externally to the SLE Complex.

4.4.2.2.3 Binding Rules for SLE Complex Ports

SLE Complex ports may be bound as illustrated in figures 4-10 and 4-11, in the following ways:

a) a user port (of a given type) is bound to a provider port (of the same type) of another SLE Complex, or to the space element via the Space Link;

b) a provider port (of a given type) is bound to a user port (of the same type) of another SLE Complex, or of a MUE within the MDOS;

c) a single SLE Complex Management port is bound to a single management port of an SLE Utilization Management.

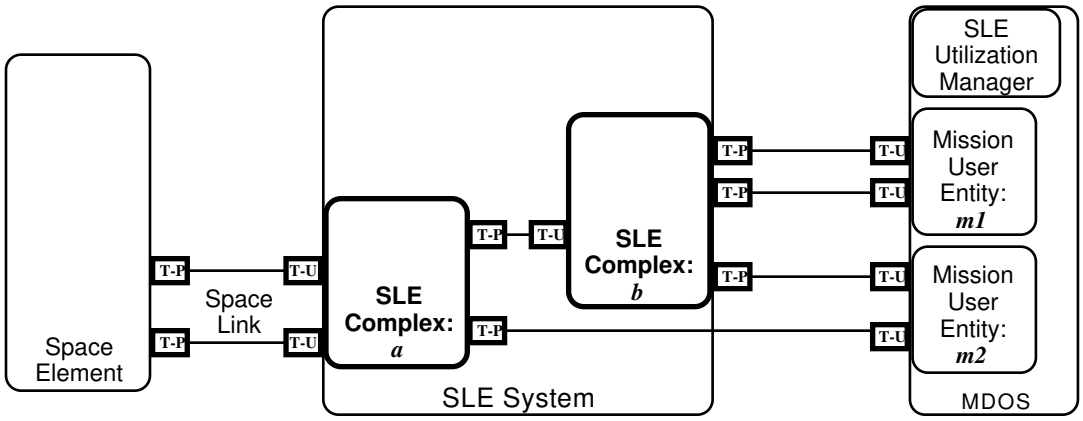


Figure 4-10: Binding SLE Complex Transfer Ports

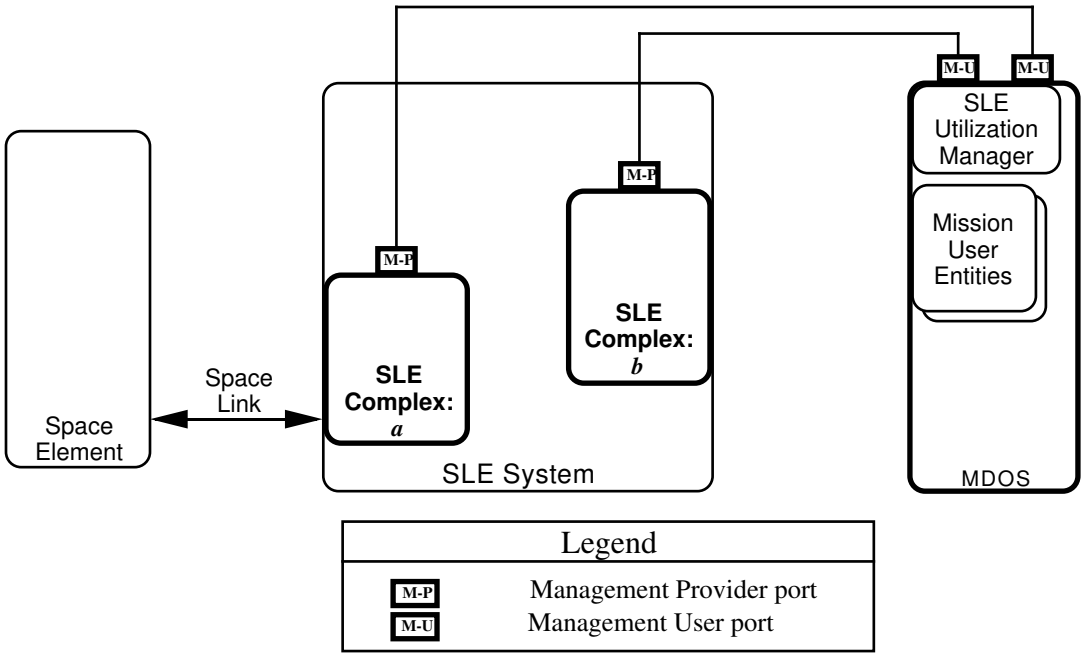


Figure 4-11: Binding of SLE Complex Management Ports

4.4.3 SLE SERVICE AGREEMENT

An SLE Service Agreement specifies the SLE transfer and management services to be provided to the MDOS by an SLE Complex, and the conditions under which those SLE transfer services will be provided. There is only one SLE Service Agreement in effect between a particular SLE Complex and a particular mission (represented by an MDOS) at any one time, but there could be more than one SLE Service Agreement over the lifetime of the mission.

NOTE – Figure 4-12 shows an example of a mission supported by two SLE Complexes. The MDOS thus has two SLE Service Agreements, one with each of the supporting complexes. Through its management ports, the SLE Utilization Management negotiates SLE service packages with each of the SLE Complexes.

The SLE Complex management of each SLE Complex has two roles:

a) negotiates the provision of SLE service packages with the SLE Utilization Management; and

b) sets up, monitors, and controls the production of the services specified in the SLE service packages.

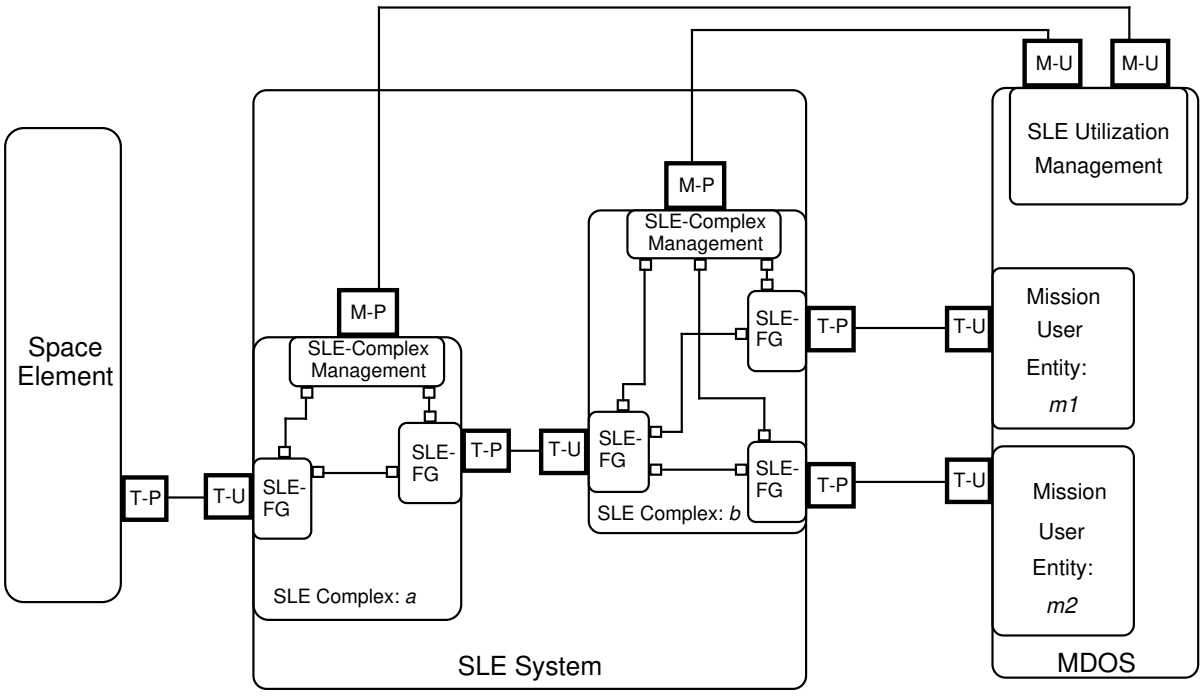


Figure 4-12: Composite Example of SLE Management

5 SPECIFICATION OF SLE SERVICES

5.1 PURPOSE AND ORGANIZATION

5.1.1 This section provides direction for specification of the individual SLE services, within the framework of the architecture model presented in section 4, in which SLE FGs and SLE Complexes are modeled as ASDC (abstract) objects. The provision of SLE services is formally described in terms of the *abstract ports* (*ports*) exposed by these objects and the *abstract operations* (*operations*) invoked at those ports.

5.1.2 Subsection 5.2 defines an ASDC model of an SLE service, including identification of the types of operations that underlie SLE services.

5.1.3 Subsection 5.3 provides a template for writing SLE transfer service specifications. These specifications will be provided in separate Recommendations.

5.1.4 Subsection 5.4 identifies the ports and operations associated with the SLE transfer services and defines the SLE Objects that contain them.

5.1.5 Subsection 5.5 identifies the ports and operations associated with the SLE management service and defines the SLE Objects that contain them.

5.1.6 Subsection 5.6 defines the *production* of each SLE transfer service. As stated earlier, an SLE transfer service is produced by one or more FGs and involves multiple Transfer ports and one or more Management ports. The production of an SLE transfer service may or may not be carried out by a single SLE complex: it is an abstract specification of the elements required to bring the service to fruition.

5.2 ABSTRACT MODEL OF SLE SERVICE

5.2.1 SLE SERVICE DESCRIPTION

5.2.1.1 An SLE service is modeled as an ASDC abstract service. Thus an SLE service is described by the set of operations that can be invoked and performed through a pair of ports that constitute an interface between two objects. As noted in 1.6.1, the pair of ports must be bound, and to be bound, they must be of the same type. See figure 5-1.

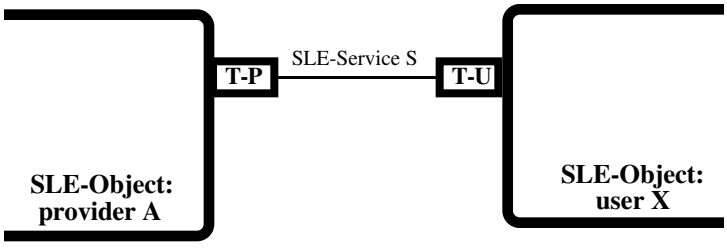


Figure 5-1: Abstract Model of an SLE Service

5.2.1.2 The types of operations that can be exposed at SLE Transfer ports and SLE management ports are defined below.

5.2.2 TRANSFER PORT OPERATION TYPES

5.2.2.1 Transfer port operations allow an SLE object to transfer space data channels at its transfer ports. These operations also allow in-line control of the transfer process, including authorization, authentication, or in-line status request/response.

5.2.2.2 The following types of operations may be invoked at the transfer ports of an SLE object:

a) Transfer_Data: transfers an SLE-SDU containing Space Link data between the user and the provider of the SLE transfer service.

b) Transfer_Set: initializes or updates service data attributes and configuration options pertinent to that user's service instance. A Transfer_Set operation is invoked by the SLE service user and performed by the SLE service provider.

c) Transfer_Get: retrieves service status and service configuration information regarding an individual service instance. A Transfer_Get operation is invoked by the SLE service user and performed by the SLE service provider.

d) Transfer_Notification: reports status (e.g., periodic or event) and accounting information associated with the individual service instance carried by the Transfer port. A Transfer_Notification operation is invoked by the SLE service provider.

5.3 SLE SERVICE SPECIFICATION

5.3.1 Each SLE service is defined in an SLE service specification. An SLE service specification includes the specification of

a) the list of operations that may be performed in providing the SLE service:

   1) the parameters of each operation are named and described;

   2) the format and content of the data units transferred are defined;

   3) these operations are defined in accordance with ASDC (reference [12]), in ASN.1 (reference [13]);

b) the behavior of the SLE system in reaction to these operations;

c) the identification of the prerequisite space data channel for production of the SLE service;

d) the quality of service requirements on the underlying supporting communications services;

e) the SLE service initialization or configuration parameters used to set up the service.

5.3.2 The style and format of an SLE service specification shall conform to the CCSDS Publications Manual (reference [9]).

5.4 SLE TRANSFER SERVICE PORTS

5.4.1 PURPOSE AND ORGANIZATION

5.4.1.1 This subsection (5.4) identifies the formal elements (ports and operations) associated with the SLE transfer services named in 3.4, and allocates those ports and operations to the SLE FGs named in 4.3.2. Identification of these elements provides the common framework upon which the individual SLE transfer service specifications are to be built.

5.4.1.2 Each SLE service is provided via a Transfer port pair for that service. In accordance with the ASDC (reference [12]), which have been adopted and extended for this reference model, one port is associated with the user of the service, and the other port is associated with the provider. In the SLE RM, these Transfer ports are asymmetric; that is, in each pair, one port assumes the role of consumer, and the other, the role of supplier. The operations invoked by the object containing the consumer port are different from those that are invoked by the object containing the supplier port.

5.4.1.3 Subsection 5.4.2 addresses the Transfer ports associated with the provision of the Return SLE services. Subsection 5.4.3 addresses the Transfer ports associated with the provision of the Forward SLE services. In each of these subsections,

– the SLE services are associated with the Transfer port types that support them;

– the relationship between the consumer/supplier roles and User/Provider roles is established;

– the SLE Object types that contain each of the port types are identified;

– the operation types are named; and

– the relationship between port roles and invocation of operation types is defined.

5.4.1.4 There are two SLE Transfer port types that are not directly associated with SLE services, the Return RF Carrier port type and the Forward RF Carrier port type. For these ports, the notion of “user” and “provider” do not have meaning (or, at least, not the meaning that is associated with the ports at which the SLE services are provided). Subsection 5.4.4 briefly describes these port types.

5.4.2 RETURN TRANSFER PORTS

5.4.2.1 For the Return SLE Transfer ports, the SLE-FG that provides the service (Service Provider) assumes the role of *supplier* and the SLE Object (SLE-FG or MUE) that uses the service (Service User) assumes the role of *consumer*.

5.4.2.2 Table 5-1 identifies the Return SLE Transfer port types, the SLE service that is associated with each of them, the SLE-FG that provides the service, and the SLE Object(s) (SLE-FG and/or MUE) that use the service.

Table 5-1: Return SLE Transfer Ports, SLE Services, Provider SLE-FGs, and User SLE Objects

SLE Port Type Name	Associated SLE Service	Provider SLE-FG (Supplier)	User SLE Object(s) (Consumer)
Rtn-AF-Transfer	Return All Frames (RAF)	Return Space Link Processing	Return Frame Processing, MUE
Rtn-Insert-Transfer	Return Insert	Return Space Link Processing	MUE
Rtn-MCF-Transfer	Return Master Channel Frames	Return Frame Processing	MUE
Rtn-VCF-Transfer	Return Virtual Channel Frames	Return Frame Processing	MUE
Rtn-MCFSH-Transfer	Return Master Channel Frame Secondary Header	Return Frame Processing	MUE
Rtn-MCOCF-Transfer	Return Master Channel Operational Control Field	Return Frame Processing	Forward TC VC Data Insertion, Forward TC Space Link Processing, MUE
Rtn-VCFSH-Transfer	Return Virtual Channel Frame Secondary Header	Return Frame Processing	MUE
Rtn-VCOCF-Transfer	Return Virtual Channel Operational Control Field	Return Frame Processing	Forward TC VC Data Insertion, Forward TC Space Link Processing, MUE
Rtn-Bit-Transfer	Return Bitstream	Return Frame Data Extraction	MUE
Rtn-SP-Transfer	Return Space Packet	Return Frame Data Extraction	MUE

5.4.2.3 For the Service Provider Return SLE Transfer ports:

a) the supplier (Service Provider) invokes the Transfer_Data and Transfer_Notification operation types;

b) the names of the port-type-specific Transfer_Data operation types are formed by appending “Data” to the name of the port type, e.g., “Rtn-Bit-TransferData”;

c) the names of the port-type-specific Transfer_Notification operation types are formed by appending "Notification" to the name of the port type, e.g., "Rtn-Bit-TransferNotification."

5.4.2.4 For the Service User Return SLE Transfer ports:

a) the consumer (Service User) invokes the Transfer_Set and Transfer_Get operation types;

b) the names of the port-type-specific Transfer_Set operation types are formed by appending "Set" to the name of the port type, e.g., "Rtn-Bit-TransferSet";

c) the names of the port-type-specific Transfer_Get operation types are formed by appending "Get" to the name of the port type, e.g., "Rtn-Bit-TransferGet."

5.4.3 FORWARD TRANSFER PORTS

5.4.3.1 For the Forward SLE Transfer ports, the SLE-FG that provides the service (Service Provider) assumes the role of *consumer* and the SLE Object (SLE-FG or MUE) that uses the service (Service User) assumes the role of *supplier*.

5.4.3.2 Table 5-2 identifies the Forward SLE Transfer port types, the SLE service that is associated with each of them, the SLE-FG that provides the service, and the SLE Object(s) (SLE-FG and/or MUE) that use the service.

5.4.3.3 For the Service User Forward SLE Transfer ports:

a) the supplier (Service User) invokes the Transfer_Data, Transfer_Set, and Transfer_Get operation types;

b) the names of the port-type-specific Transfer_Data operation types are formed by appending "Data" to the name of the port type, e.g., "Fwd-Bit-TransferData";

c) the names of the port-type-specific Transfer_Set operation types are formed by appending "Set" to the name of the port type, e.g., "Fwd-Bit-TransferSet";

d) the names of the port-type-specific Transfer_Get operation types are formed by appending "Get" to the name of the port type, e.g., "Fwd-Bit-TransferGet."

Table 5-2: Forward SLE Transfer Ports, SLE Services, Provider SLE-FGs, and User SLE Objects

SLE Port Type Name	Associated SLE Service	Provider SLE-FG (Consumer)	User SLE Object(s) (Supplier)
Fwd-C/VCDU-Transfer	Forward C/VCDU	Forward AOS Space Link Processing	MUE
CLTU-Transfer	Forward CLTU	Forward TC Space Link Processing	Forward CLTU Generation, MUE
Fwd-ProtoVCDU-Transfer	Forward ProtoVCDU	Forward AOS Space Link Processing	Forward AOS VC Data Insertion, MUE
Fwd-Insert-Transfer	Forward Insert	Forward AOS Space Link Processing	MUE
TCFrame-Transfer	Forward Telecommand Frame	Forward CLTU Generation	Forward TC VC Data Insertion, MUE
TCVCA-Transfer	Forward Telecommand Virtual Channel Access	Forward TC VC Data Insertion	MUE
Fwd-VCA-Transfer	Forward Virtual Channel Access	Forward AOS VC Data Insertion	MUE
Fwd-Bit-Transfer	Forward Bitstream	Forward AOS VC Data Insertion	MUE
Fwd-SP-Transfer	Forward Space Packet	Forward AOS VC Data Insertion, Forward TC VC Data Insertion	MUE

NOTE – The Forward TC VC Data Insertion and Forward TC Space Link Processing FGs also expose Rtn-MCOCF or Rtn-VCOCF consumer ports, as described in Table 5-1.

5.4.3.4 For the Service Provider Forward SLE Transfer ports:

a) the consumer (Service Provider) invokes the Transfer_Notification operation type;

b) the names of the port-type-specific Transfer_Notification operation types are formed by appending "Notification" to the name of the port type, e.g., "Fwd-Bit-TransferNotification."

5.4.4 RF CARRIER TRANSFER PORTS

5.4.4.1 In addition to the port types directly associated with the provision of SLE transfer services, the two RF Carrier port types serve as the interfaces with the space element.

5.4.4.2 The Return RF Carrier Transfer port type (Rtn-RF-Transfer) transfers the RF carrier signal from the space element (in the supplier role) to the SLE system (in the consumer role). This port type has one operation, Rtn-RF-TransferData, which is invoked by the supplier and performed by the consumer.

5.4.4.3 The Forward RF Carrier Transfer port type (Fwd-RF-Transfer) transfers the RF carrier signal from the SLE system (in the supplier role) to the space element (in the consumer role). This port type has one operation, Fwd-RF-TransferData, which is invoked by the supplier and performed by the consumer.

5.5 SLE MANAGEMENT SERVICE PORTS

5.5.1 This subsection (5.5) identifies the relationships between the various SLE management ports. The SLE-FG assumes the role of *supplier* and the Complex Management assumes the role of *consumer*.

NOTE – As described in 4.4.3, the SLE-UM is actually the consumer, but this is realized via the SLE Complex Management port.

5.5.2 Each SLE-FG has one management port associated with it. Through that management port, the production of the services provided by that SLE-FG are configured and monitored by the Complex Management . Table 5-3 identifies the SLE management ports and the SLE-FGs that contain them.

Table 5-3: SLE Management Ports and Supplier SLE-FGs

SLE Management Port Name	SLE-FG Assuming the Supplier Role
Rtn-SpLinkProc-Mgmt	Return Space Link Processing
Rtn-FrameProc-Mgmt	Return Frame Processing
Rtn-FrameData-Mgmt	Return Frame Data Extraction
Fwd-AOSSpLinkProc-Mgmt	Forward AOS Space Link Processing
Fwd-AOSData-Mgmt	Forward AOS VC Data Insertion
TCSpLinkProc-Mgmt	TC Space Link Processing
CLTUGen-Mgmt	CLTU Generation
TCData-Mgmt	TC VC Data Insertion

5.5.3 For the Service Provider SLE management ports:

a) the supplier invokes the Management_Notification operation type;

b) the names of the port-type-specific Management_Notification operation types are formed by appending “Notification” to the name of the port type, e.g., “Rtn-SpLinkProc-MgmtNotification.”

5.5.4 For the Service User SLE management ports:

a) the consumer invokes the Management_Set and Management_Get operation types:

b) the names of the port-type-specific Management_Set operation types are formed by appending "Set" to the name of the port type, e.g., "Rtn-SpLinkProc-MgmtSet";

c) the names of the port-type-specific Management_Get operation types are formed by appending "Get" to the name of the port type, e.g., "Rtn-SpLinkProc-MgmtGet."

5.6 SLE TRANSFER SERVICE PRODUCTIONS

In this subsection, the formal elements involved with the production of each SLE transfer service are identified. For each SLE transfer service, the SLE-FGs that participate in the production of that service are identified. For each SLE-FG, the port types and their roles (consumer/supplier) are indicated. The SLE services were illustrated in figures 4-4, 4-5, and 4-6.

5.6.1 SLE RETURN TRANSFER SERVICES

5.6.1.1 Return All Frames Service

a) The production of the Return All Frames (RAF) service involves the Return Space Link Processing SLE-FG.

b) Return Space Link Processing SLE-FG ports:

   1) consumer Rtn-RF-Transfer and supplier Rtn-AF-Transfer ports;

   2) supplier Rtn-SpLinkProc-Mgmt port.

5.6.1.2 Return Insert Service

a) The production of the Return Insert service involves the Return Space Link Processing SLE-FG.

b) Return Space Link Processing SLE-FG ports:

   1) consumer Rtn-RF-Transfer and supplier Rtn-Insert-Transfer ports;

   2) supplier Rtn-SpLinkProc-Mgmt port.

5.6.1.3 Return Master Channel Frame (MCF) Service

a) The production of the Return MCF service involves the Return Space Link Processing SLE-FG and the Return Frame Processing SLE-FG.

b) Return Space Link Processing SLE-FG ports:

   1) consumer Rtn-RF-Transfer and supplier Rtn-AF-Transfer ports;

   2) supplier Rtn-SpLinkProc-Mgmt port.

c) Return Frame Processing SLE-FG ports:

   1) consumer Rtn-AF-Transfer and supplier Rtn-MCF-Transfer ports;

   2) supplier Rtn-FrameProc-Mgmt port.

5.6.1.4 Return Virtual Channel Frame (VCF) Service

a) The production of the Return VCF service involves the Return Space Link Processing SLE-FG and the Return Frame Processing SLE-FG.

b) Return Space Link Processing SLE-FG:

   1) consumer Rtn-RF-Transfer and supplier Rtn-AF-Transfer ports;

   2) supplier Rtn-SpLinkProc-Mgmt port.

c) Return Frame Processing SLE-FG:

   1) consumer Rtn-AF-Transfer and supplier Rtn-VCF-Transfer ports;

   2) supplier Rtn-FrameProc-Mgmt port.

5.6.1.5 Master Channel Frame Secondary Header (MC-FSH) Service

a) The production of the MC-FSH service involves the Return Space Link Processing SLE-FG and the Return Frame Processing SLE-FG.

b) Return Space Link Processing SLE-FG:

   1) consumer Rtn-RF-Transfer and supplier Rtn-AF-Transfer ports;

   2) supplier Rtn-SpLinkProc-Mgmt port.

c) Return Frame Processing SLE-FG:

   1) consumer Rtn-AF-Transfer and supplier Rtn-MCFSH-Transfer ports;

   2) supplier Rtn-FrameProc-Mgmt port.

5.6.1.6 Return Master Channel Operational Control Field (MC-OCF) Service

a) The production of the Return MC-OCF service involves the Return Space Link Processing SLE-FG and the Return Frame Processing SLE-FG.

b) Return Space Link Processing SLE-FG:

   1) consumer Rtn-RF-Transfer and supplier Rtn-AF-Transfer ports;

   2) supplier Rtn-SpLinkProc-Mgmt port.

c) Return Frame Processing SLE-FG:

   1) consumer Rtn-AF-Transfer and supplier Rtn-MCOCF-Transfer ports;

   2) supplier Rtn-FrameProc-Mgmt port.

5.6.1.7 Return Virtual Channel Frame Secondary Header (VC-FSH) Service

a) The production of the Return VC-FSH service involves the Return Space Link Processing SLE-FG and the Return Frame Processing SLE-FG.

b) Return Space Link Processing SLE-FG:

   1) consumer Rtn-RF-Transfer and supplier Rtn-AF-Transfer ports;

   2) supplier Rtn-SpLinkProc-Mgmt port.

c) Return Frame Processing SLE-FG:

   1) consumer Rtn-AF-Transfer and supplier Rtn-VCFSH-Transfer ports;

   2) supplier Rtn-FrameProc-Mgmt port.

5.6.1.8 Return Virtual Channel Operational Control Field (VC-OCF) Service

a) The production of the Return VC-OCF service involves the Return Space Link Processing SLE-FG and the Return Frame Processing SLE-FG.

b) Return Space Link Processing SLE-FG:

   1) consumer Rtn-RF-Transfer and supplier Rtn-AF-Transfer ports;

   2) supplier Rtn-SpLinkProc-Mgmt port.

c) Return Frame Processing SLE-FG:

   1) consumer Rtn-AF-Transfer and supplier Rtn-VCOCF-Transfer ports;

   2) supplier Rtn-FrameProc-Mgmt port.

5.6.1.9 Return Bitstream Service

a) The production of the Return Bitstream service involves the Return Space Link Processing SLE-FG, the Return Frame Processing SLE-FG, and the Return Frame Data Extraction SLE-FG.

b) Return Space Link Processing SLE-FG:

   1) consumer Rtn-RF-Transfer and supplier Rtn-AF-Transfer ports;

   2) supplier Rtn-SpLinkProc-Mgmt port.

c) Return Frame Processing SLE-FG:

   1) consumer Rtn-AF-Transfer and supplier Rtn-VCF-Transfer ports;

   2) supplier Rtn-FrameProc-Mgmt port.

d) Return Frame Data Extraction SLE-FG:

   1) consumer Rtn-VCF-Transfer and supplier Rtn-Bit-Transfer ports;

   2) supplier Rtn-FrameData-Mgmt port.

5.6.1.10 Return Space Packet Service

a) The production of the RSP service involves the Return Space Link Processing SLE-FG, the Return Frame Processing SLE-FG, and the Return Frame Data Extraction SLE-FG.

b) Return Space Link Processing SLE-FG:

   1) consumer Rtn-RF-Transfer and supplier Rtn-AF-Transfer ports;

   2) supplier Rtn-SpLinkProc-Mgmt port.

c) Return Frame Processing SLE-FG:

   1) consumer Rtn-AF-Transfer and supplier Rtn-VCF-Transfer ports;

   2) supplier Rtn-FrameProc-Mgmt port.

d) Return Frame Data Extraction SLE-FG:

   1) consumer Rtn-VCF-Transfer and supplier Rtn-SP-Transfer ports;

   2) supplier Rtn-FrameData-Mgmt port.

5.6.2 SLE FORWARD TRANSFER SERVICES

5.6.2.1 Forward C/VCDU Service

a) The production of the Forward C/VCDU service involves the Forward AOS Space Link Processing SLE-FG.

b) Forward Space Link Processing SLE-FG ports:

1) supplier Fwd-RF-Transfer and consumer Fwd-C/VCDU-Transfer ports;

2) supplier Fwd-AOSSpLinkProc-Mgmt port.

5.6.2.2 Forward CLTU Service

a) The production of the Forward CLTU service involves the TC Space Link Processing SLE-FG.

b) TC Space Link Processing SLE-FG ports:

1) supplier Fwd-RF-Transfer and consumer CLTU-Transfer ports;

2) supplier TCSpLinkProc-Mgmt port;

3) consumer Rtn-MCOCF-Transfer or consumer Rtn-VCOCF-Transfer ports.

5.6.2.3 Forward ProtoVCDU Service

a) The production of the Forward ProtoVCDU service involves the Forward AOS Space Link Processing SLE-FG.

b) Forward Space Link Processing SLE-FG ports:

1) supplier Fwd-RF-Transfer and consumer Fwd-ProtoVCDU-Transfer ports;

2) supplier Fwd-AOSSpLinkProc-Mgmt port.

5.6.2.4 Forward Insert Service

a) The production of the Forward Insert service involves the Forward AOS Space Link Processing SLE-FG.

b) Forward Space Link Processing SLE-FG ports:

1) supplier Fwd-RF-Transfer and consumer Fwd-Insert-Transfer ports;

2) supplier Fwd-AOSSpLinkProc-Mgmt port.

5.6.2.5 Forward Telecommand (TC) Frame Service

a) The production of the Forward TC Frame service involves the TC Space Link Processing SLE-FG and the CLTU Generation SLE-FG.

b) TC Space Link Processing SLE-FG ports:

   1) supplier Fwd-RF-Transfer and consumer CLTU-Transfer ports;

   2) supplier TCSpLinkProc-Mgmt port.

c) CLTU Generation SLE-FG ports:

   1) supplier Fwd-CLTU-Transfer and consumer TCFrame-Transfer ports;

   2) supplier CLTUGen-Mgmt port.

5.6.2.6 Forward Telecommand Virtual Channel Access (TC-VCA) Service

a) The production of the Forward TC-VCA service involves the TC Space Link Processing SLE-FG, the CLTU Generation SLE-FG, and the TC VC Data Insertion SLE-FG.

b) TC Space Link Processing SLE-FG ports:

   1) supplier Fwd-RF-Transfer and consumer CLTU-Transfer ports;

   2) supplier TCSpLinkProc-Mgmt port.

c) CLTU Generation SLE-FG ports:

   1) supplier Fwd-CLTU-Transfer and consumer TCFrame-Transfer ports;

   2) supplier CLTUGen-Mgmt port.

d) TC VC Data Insertion SLE-FG ports:

   1) supplier Fwd-TCFrame-Transfer and consumer TCVCA-Transfer ports;

   2) supplier TCData-Mgmt port;

   3) consumer Rtn-MCOCF-Transfer or consumer Rtn-VCOCF-Transfer ports.

5.6.2.7 Forward Virtual Channel Access (VCA) Service

a) The production of the Forward VCA service involves the Forward AOS Space Link Processing SLE-FG and the Forward AOS VC Data Insertion SLE-FG.

b) Forward Space Link Processing SLE-FG ports:

1) supplier Fwd-RF-Transfer and consumer Fwd-ProtoVCDU-Transfer ports;

2) supplier Fwd-AOSSpLinkProc-Mgmt port.

c) AOS VC Data Insertion SLE-FG ports:

1) supplier Fwd-ProtoVCDU-Transfer and consumer Fwd-VCA-Transfer ports;

2) supplier AOSData-Mgmt port.

5.6.2.8 Forward Bitstream Service

a) The production of the Forward Bitstream service involves the Forward AOS Space Link Processing SLE-FG and the Forward AOS VC Data Insertion SLE-FG.

b) Forward Space Link Processing SLE-FG ports:

1) supplier Fwd-RF-Transfer and consumer Fwd-ProtoVCDU-Transfer ports;

2) supplier Fwd-AOSSpLinkProc-Mgmt port.

c) AOS VC Data Insertion SLE-FG ports:

1) supplier Fwd-ProtoVCDU-Transfer and consumer Fwd-Bit-Transfer ports;

2) supplier AOSData-Mgmt port.

5.6.2.9 Forward Space Packet Service

The production of the Forward Space packet service is accomplished using one of two profiles: the AOS profile or the TC profile.

5.6.2.9.1 Forward Space Packet Service: AOS Profile

a) The production of the AOS-profile Forward Space packet service involves the Forward AOS Space Link Processing SLE-FG and the Forward AOS VC Data Insertion SLE-FG.

b) Forward Space Link Processing SLE-FG ports:

1) supplier Fwd-RF-Transfer and consumer Fwd-ProtoVCDU-Transfer ports;

2) supplier Fwd-AOSSpLinkProc-Mgmt port.

c) AOS VC Data Insertion SLE-FG ports:

1) supplier Fwd-ProtoVCDU-Transfer and consumer Fwd-SP-Transfer ports;

2) supplier AOSData-Mgmt port.

5.6.2.9.2 Forward Space Packet Service: TC Profile

a) The production of the TC-VCA service involves the TC Space Link Processing SLE-FG, the CLTU Generation SLE-FG, and the TC VC Data Insertion SLE-FG.

b) TC Space Link Processing SLE-FG ports:

   1) supplier Fwd-RF-Transfer and consumer CLTU-Transfer ports;

   2) supplier TCSpLinkProc-Mgmt port.

c) CLTU Generation SLE-FG ports:

   1) supplier Fwd-CLTU-Transfer and consumer TCFrame-Transfer ports;

   2) supplier CLTUGen-Mgmt port.

d) TC VC Data Insertion SLE-FG ports:

   1) supplier Fwd-TCFrame-Transfer and consumer Fwd-SP-Transfer ports;

   2) supplier TCData-Mgmt port.

ANNEX A

SPACE LINK EXTENSION DATA STRUCTURES

(This annex **is** part of the Recommendation)

A1 INTRODUCTION

This annex identifies the various data structures associated with the SLE services. These data structures exist at two levels. At the lower level, the data structures are the *space data units* that are exchanged between the space element and the SLE system, between the various components of the SLE system, and between SLE system and the MDOS. At the higher level, the data structures are the *space data channel*. Subsection A2 lists the data units associated with the SLE services. Subsection A3 describes the space data channel tree concepts and identifies the specific space data channel trees pertinent to the production of SLE services.

A2 SPACE DATA UNITS

A major function of the SLE services is to perform the transformations between the SL-DU*s* (that is, those that are exchanged between the space element and the SLE system) and the *SLE data units* (those that are exchanged between the various components of the SLE system, and between the SLE system and the MDOS). SLE data units can be further delineated into *SLE service data units* and *SLE PDUs*. Subsections A2.1, A2.2, and A2.3 describe the SL-DUs, SLE service data units, and SLE PDUs, respectively, and how they relate to each other.

A2.1 SPACE LINK DATA UNITS

A2.1.1 The SL-DUs are the data elements that are common to the Space Link *PDUs* defined in the Telecommand, Packet Telemetry, and Advanced Orbiting System (AOS) Recommendations (references [2]–[7]), and the SLE data units defined for the various SLE services. The SL-DUs are derived from the SL-PDUs, which means that in some cases they are equivalent to the SL-PDUs, and in other cases they are formed from one or more subfields of the SL-PDUs, because some SL-PDUs carry data that translates into different types of SLE services.

A2.1.2 Table A-1 lists the Packet Telemetry SL-DU types. Table A-2 lists the Telecommand SL-DU types. Table A-3 lists the AOS SL-DU types. Each SL-DU type description identifies the relationship with the appropriate SL-PDU. Only the most closely related (or highest-layer) SL-PDU is identified. That is, if an SL-DU is one or more fields of a defined SL-PDU, the field(s) of the SL-PDU are identified. If the SL-DU has a one-to-one correspondence with a defined SL-PDU, only that corresponding SL-PDU is named, even though the corresponding SL-PDU is itself “derived” from a lower-layer SL-PDU.

A2.2 SLE SERVICE DATA UNITS

A2.2.1 The SLE Service Data Units (SLE-SDUs) are the service-user-oriented data units exchanged between components of the SLE system, and between the SLE system and the MDOS. That is, the SLE-SDUs contain the information directly derived from (or related to) the SL-DUs and the quality of Space Link over which those SL-DUs are transferred.

Table A-1: Packet Telemetry SL-DUs

SL-DU Type	SL-PDU Derivation (from references [2], [3], and [8])
Packet Telemetry (PT) Transfer Frame (Version 1 Frame)	PT Transfer Frame
Frame Secondary Header (FSH)	FSH field of PT Transfer Frame
Operational Control Field (OCF)	OCF field of PT Transfer Frame
Privately Defined Data (PDD)	Private Data Delivery Status Flag, First Header Pointer, and Spacecraft Application Data fields of PT Transfer Frame
Source Packet	CCSDS Source Packet

Table A-2: Telecommand SL-DUs

SL-DU Type	SL-PDU Derivation (from references [5], [6], and [7])
Command Link Transmission Unit (CLTU)	CLTU
Telecommand (TC) Transfer Frame (Version 1 Frame)	TC Transfer Frame
TC Frame Data Unit	TC Frame Data Unit
TC Segment	TC Segment
CCSDS Packet	TC Packet

A2.2.2 There are two kinds of SLE-SDUs: data-bearing SLE-SDUs and service control SLE-SDUs.

A2.2.3 The data-bearing SLE-SDUs contain:

a) data that have been extracted from, or are to be injected into, SL-DUs;

b) annotation data applicable to a specific SL-DU that aids in the processing of the data contained in that SL-DU; and

c) channel status information that reports upon changes in the condition of the SLE data channels that carry the SLE-SDUs. The SLE data channels are described in A3. Normally, the condition of the SLE data channel does not change frequently, or at least not as frequently as the appearance of each data-bearing SLE-SDU, so valid channel status information may or may not be present in any given data-bearing SLE-SDU.

Table A-3: AOS SL-DUs

SL-DU Type	SL-PDU Derivation (from references [3] and [4])
(Coded) Virtual Channel Data Unit (C/VCDU) (Version 2 Frame)	C/VCDU
Insert Zone	VCDU Insert Zone field of C/VCDU
ProtoVCDU	Frame Version Number, VCDU Identifier, Virtual Channel Data Unit Counter, Signaling, and VCDU Data Unit Zone fields of the C/VCDU
Operational Control Field (OCF)	Operational Control Field of the C/VCDU
VCA-SDU	VCDU Data Zone of the C/VCDU
Bitstream PDU	Bitstream PDU
CCSDS Packet	CCSDS Packet
Internet-Encapsulation Packet	CCSDS Packet with reserved APID
ISO CLNP Packet	ISO CLNP Packet

A2.2.4 Channel status SLE-SDUs carry channel status information when there are no data-bearing SLE-SDUs immediately available to carry the status information.

A2.3 SLE PROTOCOL DATA UNITS

A2.3.1 In order to transfer the SLE-SDUs between components of the SLE system, and between the SLE system and the MDOS, the SLE systems and MDOS employ service protocols. These protocols ensure that the SLE-SDUs are delivered with the quality of service required by the service user. These service protocols involve the exchange of SLE-PDUs.

A2.3.2 There are two kinds of SLE-PDUs: data-bearing SLE-PDUs that encapsulate SLE-SDUs (along with other protocol control information), and stand-alone protocol control messages. Whereas the annotation and channel status information appended to the SL-DUs in the SLE-SDUs are valid across multiple Provider/User associations, the protocol control information is local to a single Provider/User association.

A2.3.3 The content and construction of the SLE-PDUs is outside the scope of this reference model, and is addressed in the individual SLE service specifications.

A3 SPACE DATA CHANNELS

A3.1 TYPES OF SPACE DATA CHANNELS

A3.1.1 A *space data channel* is a stream of space data units of the same type, associated with each other by a single, unique identifier. In several cases, different space data channel types carry the same space data unit; the differentiation between channel types comes strictly from the different ways in which those data units are identified.

A3.1.2 There are two sets of space data channels, the *SL data channels* and the *SLE data channels*. The SL data channels carry the SL-DUs between the SLE system and the space element. The SLE data channels carry the SLE-SDUs between the components of the SLE system, and between the SLE system and the MDOS. The types of SL data channels are the same as the types of SLE data channels: the difference lies in the fact that the SLE data channels contain annotation and other channel status information in addition to the "raw" SL-DUs found on the SL data channels. Therefore, the remainder of this section deals with the SLE data channels.

A3.1.3 *Space data channel trees* are the hierarchical structures that relate the various space data channels to one another. There are two channel trees that are used to organize SLE data channels (and also SL data channels), the Return SLE data channel tree and the Forward SLE data channel tree. Subsections A3.2 and A3.3 describe the Return and Forward SLE data channels and their associated channel trees, respectively.

A3.2 RETURN SPACE DATA CHANNELS

A3.2.1 Table A-4 defines the Return SLE data channels by SL-DUs, unique identification, and, for data channels that are provided through SLE services, the identity of those SLE services.

NOTES

1 The PDD SDUs, which are the SL-DUs associated with the Packet Telemetry PDD service (reference [14]), are not exposed in the SLE data channel trees. Rather, they are carried by Virtual Channels which are delivered via instances of VC Frame service. Exposure of the Packet Telemetry PDD service, if it is used by a particular project, occurs only within the Space Element and the MDOS.

2 The VCA-SDUs, which are the SL-DUs associated with the AOS VCA service (reference [4]), are not exposed in the SLE data channel trees. Rather, they are carried by Virtual Channels which are delivered via instances of VC Frame service. Exposure of the AOS VCA service, if it is used by a particular project, occurs only within the Space Element and the MDOS.

3 The ISO CLNP packets, which are the SL-DUs associated with the AOS Internet service (reference [4]), are not exposed in the SLE data channel trees. Rather, they are encapsulated in a special class of Space Packets (APID = 2046), which in turn are treated by the SLE system as any other Space Packets. Exposure of the AOS Internet service, if it is used by a particular project, occurs only within the space element and the MDOS.

The base (or most primitive) return SLE data channel is the Return Space Link, which is the return portion of the space link. The return space link is a special kind of SLE data channel, in that its structure is dependent on the coding and modulation techniques used by a particular space mission. Therefore, it may provide a variety of space link formats, frequencies, number of carriers and subcarriers, etc. Thus for each space mission a link-unique portion of the channel tree must be defined to: (a) specify the acquisition production steps necessary for the SLE Complex to produce the physical channels, and (b) provide identifiers for the physical channels (physical channel IDs) for the purpose of cross-support management (see the SLE Service Management specification).

NOTE – The physical channel is the most primitive return SLE data channel from which the remainder of the return channel tree can be unambiguously derived. However, the physical channel does not carry SL-DUs as defined in the AOS or Packet Telemetry Blue Books. This is because this channel exists below the layers addressed in the AOS and Packet Telemetry books. Indeed, at the physical layer at which this channel exists, there are no proper “data units,” but only the base elements of which data units are composed: bits and/or symbols. Thus the “SL-DUs” associated with this channel are not really data units.

Table A-4: Return SLE Data Channels

SLE Data Channel	SL-DU	Unique ID	SLE Service
Return Space Link	not standardized as part of SLE	not standardized as part of SLE	
physical channel	baseband stream of symbols	physical channel ID	
Return All Frames (RAF) channel	PT Transfer Frame and/or C/VCDU	RAF channel ID	RAF
Insert channel (Version 2 master channels only)	Insert Zone	RAF channel ID	Insert
Master Channel	PT Transfer Frame and/or C/VCDU	MCID (Frame Version Number and SCID)	Master Channel
MC-OCF channel: (Version 1 master channels only)	OCF	MCID	MC-OCF
MC-FSH channel (Version 1 master channels only)	FSH	MCID	MC-FSH
Virtual Channel	PT Transfer Frame and/or C/VCDU	GVCID (MCID and VCID)	Virtual Channel
VC-OCF channel	OCF	GVCID	VC-OCF
VC-FSH channel (Version 1 master channels only)	FSH	GVCID	VC-FSH
Return Bitstream channel (Version 2 virtual channels only)	Bitstream PDU	GVCID	Return Bitstream
Return Space Packet channel	CCSDS Packet	GVCID and APID: for V1 GVCIDs, APID = (0-2046); for V2 GVCIDs, APID = (0-2031, 2046)	Return Space Packet

A3.2.2 Figure A-1 illustrates the Return SLE Channel Tree, showing the tree relationships among the various structural elements of the CCSDS AOS and Packet Telemetry return links. It is important to note that the channel tree illustrates the possible kinds of channels and their interrelationships - any given mission can (and probably will) implement only a subset of the overall channel tree.

NOTE – Figure A-1 shows a single demultiplexer (see A.3.2.3.2, below) between the return space link and the physical channel(s). In a real space link acquisition function, there may be several intermediate “channels” between the space link and the physical channels (e.g., various subcarriers). However, their number and type will depend on the exact nature of the particular space link acquisition function, and they are not defined as part of the “standard” return SLE data channel tree.

A3.2.3 Figure A-1 uses five symbols (illustrated in the key below the tree diagram): the decommutator, the demultiplexer, the OR symbol, the frame synchronization symbol, and the tap-off.

A3.2.3.1 The *decommutator* symbol represents the process in which different types of data elements (e.g., Frame Secondary Header and Ops Control fields) are removed from SL-DUs.

A3.2.3.2 The *demultiplexer* symbol represents the process by which different data channels of the same type (e.g., transfer frames of different virtual channels) are separated. The way to read the demultiplexers and decommutators is that the numerical index tells you how many of that type of output are possible, but each output line should be read as "one of" in the context of the following demultiplexer/decommutator. So, for example, there are "1 to n" (one or more) Master Channels, *each of which* demultiplexes into "1 to n" Virtual channels. Each line that comes out of a decommutator represents a different kind of channel.

A3.2.3.3 The *OR* symbol (curly brace ({)) is used to identify an OR condition: the channel to the left of the symbol may consist of any of the subtree types identified to the right of the symbol.

A3.2.3.4 The *frame synchronization* symbol (a circular symbol (○)) is used to differentiate the physical channel (which contains all symbols on the physical channel prior to frame synchronization) from the RAF channel (which contains only frames which have been successfully frame-synchronized).

A3.2.3.5 The *tap-off* symbol (⊥) is used for channels that are copied out of a channel, but the original channel still exists (i.e., all the fields of the data units are preserved). An example of a tap-off is the copying of all frames from an AOS RAF channel so that the Insert channel may be decommutated. The original RAF channel (which contains the embedded Insert data) is still unaffected.

A3.3 FORWARD SPACE DATA CHANNEL TREE

A3.3.1 Table A-5 defines the Forward SLE data channels by SL-DUs, unique identification, and, for data channels that are provided through SLE services, the identity of those SLE services.

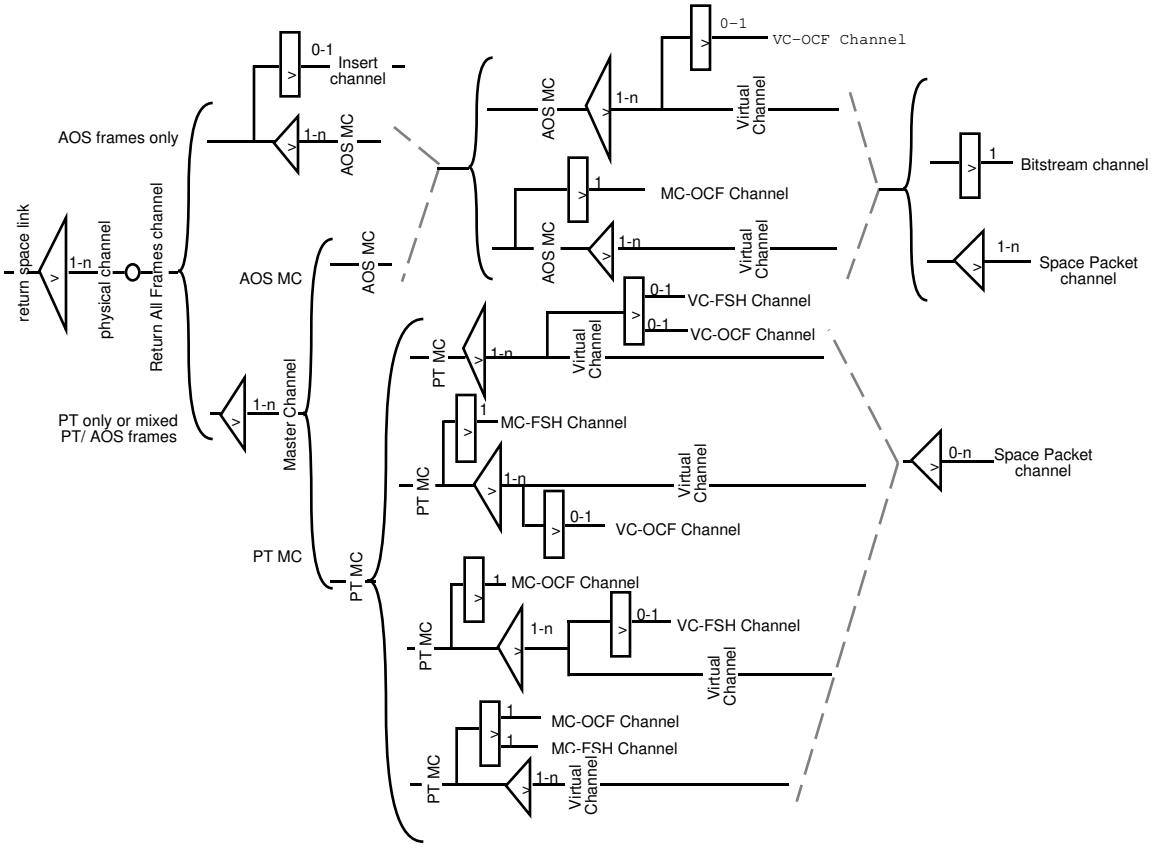
NOTE – The ISO CLNP packets, which are the SL-DUs associated with the AOS Internet service (reference [4]), are not exposed in the SLE data channel trees. Rather, they are encapsulated in a special class of Space Packets (APID = 2046), which in turn are treated by the SLE system as any other Space Packets. Exposure of the AOS Internet service, if it is used by a particular project, occurs only within the space element and the MDOS.

The base (or most primitive) forward SLE data channel is the Forward Space Link, which is the forward portion of the space link. The forward space link is a special kind of SLE data channel, in that its structure is dependent on the coding and modulation techniques used by a particular space mission. Therefore, it may provide a variety of space link formats, frequencies, number of carriers and subcarriers, etc. Thus for each space mission a link-unique portion of the channel tree must be defined to: (a) specify the acquisition production steps necessary for the SLE Complex to produce the physical channels, and (b) provide identifiers for the physical channels (physical channel IDs) for the purpose of cross-support management (see the SLE Service Management specification).

NOTE – The physical channel is the most primitive forward SLE data channel from which the remainder of the forward channel tree can be unambiguously derived. However, the physical channel does not carry SL-DUs as defined in the AOS or Telecommand Blue Books. This is because this channel exists below the layers addressed in the AOS and Telecommand books. Indeed, at the physical layer at which this channel exists, there are no proper "data units," but only the base elements of which data units are composed: bits and/or symbols. Thus the "SL-DUs" associated with this channel are not really data units.

A3.3.2 Figure A-2 illustrates the Forward SLE Channel Tree, showing the tree relationships among the various structural elements of the CCSDS AOS and Telecommand forward links.

NOTE – Figure A-2 shows a single multiplexer between the forward space link and the physical channel(s). In a real space link acquisition function, there may be several intermediate "channels" between the space link and the physical channels (e.g., various subcarriers). However, their number and type will depend on the exact nature of the particular space link acquisition function, and they are not defined as part of the "standard" forward SLE data channel tree.



KEY

Decommutator (in return direction). Each output line (line to the right of the rectangle) indicates one channel of a given type. The number of lines correspond to the number of different channel types. The number above the output line indicates the number of instances of that type that are possible. Example values are:

0-n	zero or more instances
1-n	one or more instances
1	exactly one instance

Demultiplexer (in return direction). The output line (line to the right of the triangle) indicates one channel of the same type. The number above the output line indicates the number of instances of that type that are possible (same values as above).

{ OR. A channel to the left of the OR symbol may consist of any of the subtree types to the right of the symbol

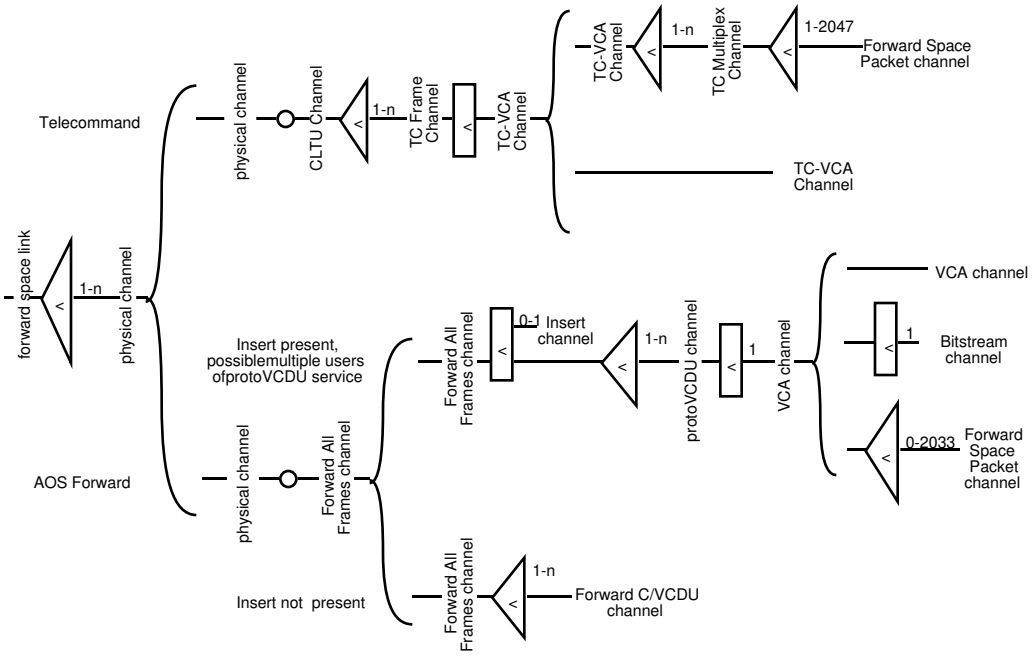
o Synchronous physical channel processing

Tap-off

Figure A-1: Return SLE Channel Tree

Table A-5: Forward SLE Data Channels

SLE Data Channel	SL-DU	Unique ID	SLE Service
Forward Space Link	not standardized as part of SLE	not standardized as part of SLE	
Forward physical channel (V1 - asynchronous channel, V2 - synchronous channel)	baseband stream of symbols	Physical channel ID	not exposed via SLE service
Forward Insert channel (V2 physical channels only)	Insert Zone	Physical channel ID	Forward Insert
CLTU channel (V1 physical channels only)	CLTU	CLTU ID	Forward CLTU
Forward All Frames (FAF)channel (V2 physical channels only)	C/VCDU	FAF channel ID	FAF
Forward C/VCDU channel (V2 virtual channels only)	C/VCDU	GVCID	Forward C/VCDU
TC Transfer Frame channel (V1 VCs only)	TC Transfer Frame	GVCID	Forward TC Frame
Forward protoVCDU (V2 physical channels only)	ProtoVCDU	GVCID	Forward ProtoVCDU
TC-VCA channel (V1 VCs only)	TC Frame Data Unit	GVCID	Forward TC-VCA
TC Multiplex channel (V1 VCs only)	TC Segment	GVCID and Multiplexer Access Point Indentifier	not exposed via SLE service
Forward VCA channel (V2 VCs only)	VCA-SDU (V2 VCs)	GVCID	Forward VCA
Forward Bitstream channel (V2 virtual channels only)	Bitstream PDU	GVCID	Forward Bitstream
Forward Space Packet channel	CCSDS Packet	GVCID and APID: for V1 GVCIDs, APID = (0-2046); for V2 GVCIDs, APID = (0-2031, 2046))	Forward Space Packet



KEY

a / b — Commutator (in forward direction). Each input line (line to the right of the rectangle) indicates one channel of a given type. The number of lines correspond to the number of different channel types. The number above the output line indicates the number of instances of that type that are possible. Example values are:

0-n	zero or more instances
1-n	one or more instances
1	exactly one instance

a — Multiplexer (in forward direction). The input line (line to the right of the triangle) indicates one channel of the same type. The number above the output line indicates the number of instances of that type that are possible (same values as above).

{ — OR. A channel to the left of the OR symbol may consist of any of the subtree types to the right of the symbol

o — Physical channel processing. In the case of Telecommand,this is the generation of the Physical Layer stream (Acquisition Sequence, Idle Sequence, and injected CLTUs). In the case of AOS, this is the attachment of sync markers to, and the synchronous injection of, C/VCDUs.

Figure A-2: Forward SLE Channel Tree

ANNEX B

CROSS SUPPORT REFERENCE MODEL INDEX TO DEFINITIONS

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

This annex provides an index to the terminology defined in this Cross Support Reference Model Recommendation.

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ANNEX C

CROSS SUPPORT REFERENCE MODEL ACRONYMS AND ABBREVIATIONS

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

This annex provides an identification of the acronyms and abbreviations used in this Cross Support Reference Model Recommendation.

APID	Application Process Identifier
ASDC	Abstract Service Definition Conventions
AOS	Advanced Orbiting System
CCSDS	Consultative Committee for Space Data Systems
CLTU	Command Link Transmission Unit
CLNP	Connectionless Network Protocol
COP	Command Operation Procedure
C/VCDU	Coded VCDU
DU	Data Unit
FAF	Forward All Frames
FG	Functional Group
FSH	Frame Secondary Header
Fwd	Forward
GE	Ground Element
GVCID	Global VCID
ID	Identifier (this abbreviation is concatenated with other acronyms/abbreviations)
ISO	International Standards Organization
MC	Master Channel
MCID	Master Channel Identification
MDOS	Mission Data Operation System
MUE	Mission User Entity
OCF	Operation Control Field
PDU	Protocol Data Unit
PLOP	Physical Link Operations Procedure
RAF	Return All Frames
RF	Radio Frequency
SCID	Spacecraft Identifier

SDU	Service Data Units
SE	Space Element
SL	Space Link
SLE	Space Link Extension
TC	Telecommand
TCM	Terminology, Conventions, and Methodology
TM	Telemetry
UM	Utilization Management
VC	Virtual Channel
VCA	Virtual Channel Access
VCDU	Virtual Channel Data Unit
VCID	Virtual Channel Identification