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Space data and information transfer systems — Space link extension (SLE) — Forward space packet service specification

Systèmes de transfert des informations et données spatiales — Extension de liaisons spatiales (SLE) — Spécification d'envoi de données spatiales par paquets

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted (see www.iso.org/directives).

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This document was prepared by the Consultative Committee for Space Data Systems (CCSDS) (as CCSDS 912.3-B-3, August 2016) and was adopted (without modifications) by Technical Committee ISO/TC 20, *Space vehicles,* Subcommittee SC 13, *Space data and information transfer systems*.

This third edition cancels and replaces the second edition (ISO 22672:2011), which has been technically revised.

The main changes compared to the previous edition are as follows:

— adds clarifications and corrections.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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1 INTRODUCTION

1.1 PURPOSE OF THIS RECOMMENDED STANDARD

This Recommended Standard defines the Forward Space Packet (FSP) service in conformance with the transfer services specified in reference [1], *Cross Support Reference Model—Part 1: SLE Services*. The FSP service is a Space Link Extension (SLE) transfer service that enables a mission to send Space Packets to a spacecraft in sequence-controlled or expedited mode.

1.2 SCOPE

This Recommended Standard defines, in an abstract manner, the FSP service in terms of:

a) the operations necessary to provide the transfer service;

b) the parameter data associated with each operation;

c) the behaviors that result from the invocation of each operation; and

d) the relationship between, and the valid sequence of, the operations and resulting behaviors.

It does not specify:

a) individual implementations or products;

b) the implementation of entities or interfaces within real systems;

c) the methods or technologies required to radiate Space Packets to a spacecraft and to acquire telemetry frames from the signals received from that spacecraft for extraction of the Operational Control Field;

d) the methods or technologies required for communications; or

e) the management activities necessary to schedule, configure, and control the FSP service.

NOTE – While the FSP service as described in reference [1] is conceived to handle a variety of packet data structures, this version of the FSP Recommended Standard is restricted to the handling of Space Packets as defined in reference [6].

This version of the FSP Recommended Standard is specific to the transfer of Space Packets to be transmitted via the Telecommand protocol stack as defined in references [3], [4], and [5]. The Cross Support Reference Model (reference [1]) specifies that the FSP service may also be used in conjunction with the Advanced Orbiting System protocol stack, but that mode of operation is outside the scope of this version of the Recommended Standard.

The FSP service is provided in the online delivery mode, as defined in reference [1]. The offline delivery mode is the subject of further study.

1.3 APPLICABILITY

1.3.1 APPLICABILITY OF THIS RECOMMENDED STANDARD

This Recommended Standard provides a basis for the development of real systems that implement the FSP service. Implementation of the FSP service in a real system additionally requires the availability of a communications service to convey invocations and returns of FSP service operations between FSP service users and providers. This Recommended Standard requires that such a communications service ensures that invocations and returns of operations are transferred:

a) in sequence;

b) completely and with integrity;

c) without duplication;

d) with flow control that notifies backpressure to the application layer in the event of congestion; and

e) with notification to the application layer in the event that communications between the FSP service user and the FSP service provider are disrupted, possibly resulting in a loss of data.

It is the specific intent of this Recommended Standard to define the FSP service in a manner that is independent of any particular communications services, protocols, or technologies.

1.3.2 LIMITS OF APPLICABILITY

This Recommended Standard specifies the FSP service that may be provided by an SLE System for inter-Agency cross support. It is neither a specification of, nor a design for, real systems that may be implemented for the control and monitoring of existing or future missions.

1.4 RATIONALE

The goal of this Recommended Standard is to create a standard for interoperability between the tracking stations and/or ground data handling systems of various agencies and the users of forward services.

1.5 DOCUMENT STRUCTURE

1.5.1 ORGANIZATION

This Recommended Standard is organized as follows:

a) section 0 provides the purpose, scope, applicability, and rationale of this Recommended Standard and lists definitions, nomenclature, conventions, and references used throughout the Recommended Standard;

b) section 2 provides an overview of the FSP service including a functional description, the service management context, and protocol considerations;

c) section 3 specifies the operations of the FSP service;

d) section 4 specifies the dynamic behavior of the FSP service in terms of the state transitions of the FSP service provider;

e) annex A provides a formal specification of FSP service data types, using the Abstract Syntax Notation One (ASN.1);

f) annex B provides a specification of the multiplexing between concurrent FSP service instances sharing the same TC Virtual Channel (VC) as well as the multiplexing between TC VCs sharing the same physical space link data channel;

g) annex C presents the FSP production status and its transitions;

h) annex D defines the production requirements the FSP service imposes on the forward Functional Groups;

i) annex E provides a conformance matrix that defines what capabilities must be provided for an implementation to be considered compliant with this Recommended Standard;

j) annex F lists all terms used in this document and identifies where they are defined;

k) annex G lists all acronyms used within this document;

l) annex H contains examples of usage of the FSP-THROW-EVENT operation;

m) annex I contains a list of informative references.

1.5.2 SLE SERVICES DOCUMENTATION TREE

This Recommended Standard is based on the architectural model for cross support defined in reference [1]. It expands upon the concept of an SLE Transfer Service as interactions between an SLE Mission User Entity (MUE) and an SLE Transfer Service provider for the purpose of providing the FSP Transfer Service.

This Recommended Standard is part of a suite of documents specifying the SLE services. The SLE services constitute one of the three types of Cross Support Services:

a) Part 1: SLE Services;

b) Part 2: Ground Communications Services;

c) Part 3: Ground Domain Services.

The basic organization of the SLE services documentation is shown in figure 1-1. The documents are described in the following paragraphs.

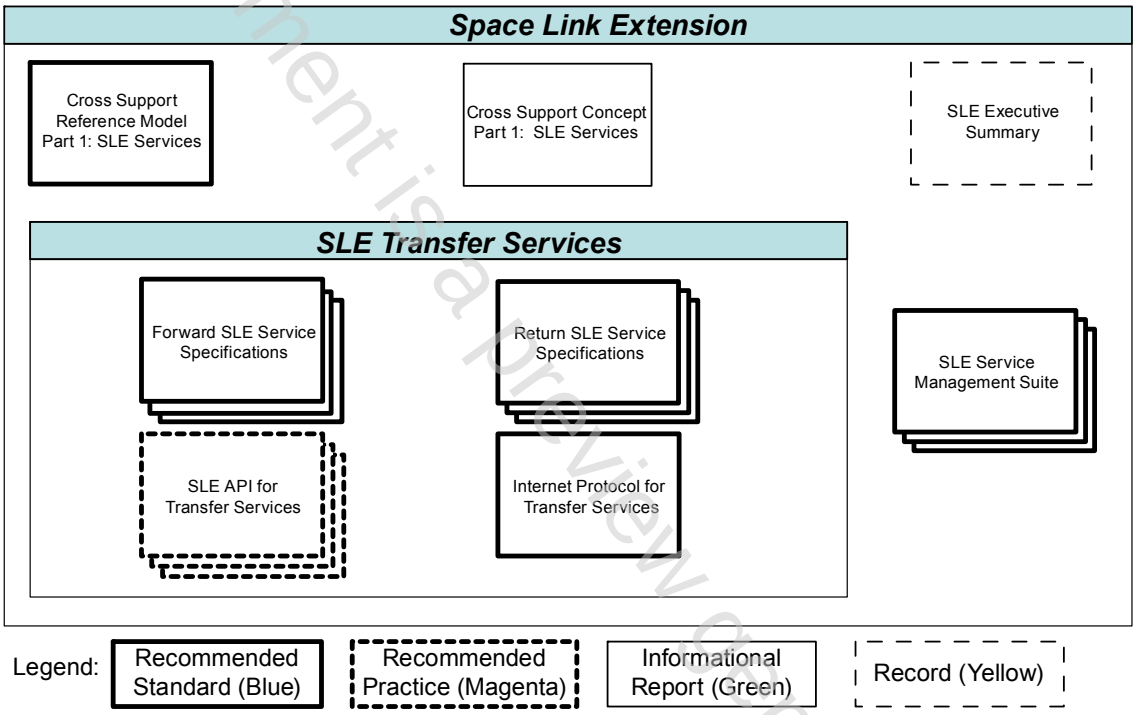

Figure 1-1: SLE Services Documentation

a) *Cross Support Concept—Part 1: Space Link Extension Services* (reference [I3]): a Report introducing the concepts of cross support and SLE services;

b) *Cross Support Reference Model—Part 1: Space Link Extension Services* (reference [1]): a Recommended Standard that defines the reference model that provides a common framework and terminology for the specification of SLE services;

c) *Return SLE Transfer Service Specifications:* a set of Recommended Standards that will provide specification of all return link SLE transfer services.

d) *Forward SLE Transfer Service Specifications:* a set of Recommended Standards that will provide specification of all forward link SLE transfer services (this Recommended Standard is one of the specifications in that set);

e) *SLE API for Transfer Services Specifications:* a set of Recommended Practices that provide specifications of an Application Program Interface; a set of Recommended Standards that provide specifications of an Application Program Interface and a mapping to TCP/IP as underlying communications service for SLE services;

f) *Internet Protocol for Transfer Services:* defines a protocol for transfer of SLE Protocol Data Units using TCP/IP as underlying communications service for SLE services;

g) *SLE Service Management Specification Suite*: a set of Recommended Standards that establish the basis for SLE service management.

1.6 DEFINITIONS, NOMENCLATURE, AND CONVENTIONS

1.6.1 DEFINITIONS

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

This Recommended Standard makes use of a number of terms defined in reference [8]. The use of those terms in this Recommended Standard shall be understood in a generic sense, i.e., in the sense that those terms are generally applicable to technologies that provide for the exchange of information between real systems. Those terms are:

a) abstract syntax;

b) application entity;

c) application layer;

d) flow control;

e) Open Systems Interconnection (OSI);

f) real system;

g) service access point (SAP).

1.6.1.2 Definitions from Abstract Syntax Notation One

This Recommended Standard makes use of the following terms defined in reference [7]:

a) Abstract Syntax Notation One (ASN.1);

b) object identifier;

c) (data) type;

d) (data) value.

NOTE – In annex A of this Recommended Standard, ASN.1 is used for specifying the abstract syntax of the invocations and returns of the operations of the FSP service. The use of ASN.1 as a descriptive language is intended to support the specification of the abstract FSP service; it is not intended to constrain implementations. In particular, there is no requirement for implementations to employ ASN.1 encoding rules. ASN.1 is simply a convenient tool for formally describing the abstract syntax of the invocations and returns of the FSP service.

1.6.1.3 Definitions from TC Synchronization and Channel Coding

This Recommended Standard makes use of the following term defined in reference [3]:

Communications Link Transmission Unit (CLTU).

1.6.1.4 Definitions from TC Space Data Link Protocol

This Recommended Standard makes use of the following terms defined in reference [4]:

a) AD, BD, BC;

b) Communications Link Control Word (CLCW);

c) Communications Operation Procedure (COP);

d) Control Word Type;

e) Frame Operation Procedure (FOP);

f) Frame Sequence Number;

g) Multiplexer Access Point (MAP);

h) Operational Control Field (OCF);

i) Segment;

j) Telecommand Transfer Frame (TC Transfer Frame or TC frame);

k) Virtual Channel (VC).

1.6.1.5 Definitions from Communications Operation Procedure-1

This Recommended Standard makes use of the following terms defined in reference [5]:

a) FOP_Sliding_Window_Width;

b) Receiver_Frame_Sequence_Number V(R);

c) Timeout_Type;

d) Transmitter_Frame_Sequence_Number V(S);

e) T1_Initial.

1.6.1.6 Definitions from Space Packet Protocol

This Recommended Standard makes use of the following terms defined in reference [6]:

a) Application Process Identifier (APID);

b) Space Packet.

1.6.1.7 Definitions from SLE Reference Model

This Recommended Standard makes use of the following terms defined in reference [1]:

a) abstract binding;

b) abstract object;

c) abstract port;

d) abstract service;

e) Forward CLTU SLE data channel (Forward CLTU data channel);

f) Forward Space Packet channel (FSP channel);

g) Forward Space Packet service (FSP service);

h) Forward Telecommand Frame SLE data channel (Forward TC Frame data channel);

i) invoker;

j) Mission Data Operation System (MDOS);

k) Mission User Entity (MUE);

l) offline delivery mode;

m) online delivery mode;

n) operation;

o) Operational Control Field SLE data channel (OCF data channel);

p) performer;

q) physical channel;

r) service agreement;

s) service provider (provider);

t) service user (user);

u) SLE Complex;

v) SLE Complex Management;

w) SLE data channel;

x) SLE Functional Group (SLE-FG);

y) SLE protocol data unit (SLE-PDU);

z) SLE service data unit (SLE-SDU);

aa) SLE service package;

bb) SLE transfer service instance;

cc) SLE transfer service production;

dd) SLE transfer service provision;

ee) SLE Utilization Management;

ff) space link;

gg) space link data channel;

hh) space link data unit (SL-DU);

ii) space link session.

1.6.1.8 Additional Definitions

For the purposes of this Recommended Standard, the following definitions also apply.

1.6.1.8.1 Acknowledged (Space Packet)

A Space Packet is said to be acknowledged when evaluation of the CLCWs returned by the space element shows that all TC frames containing parts of the Space Packet reported have been acknowledged by the space element.

NOTE — This status applies only to the sequence-controlled transmission mode (AD). Although a Space Packet is 'acknowledged', packet re-assembly and/or execution may still fail. This can only be determined by examining telemetry.

1.6.1.8.2 Association

An association is a cooperative relationship between an SLE service-providing application entity and an SLE service-using application entity. An association is formed by the exchange of SLE protocol data units through the use of an underlying communications service.

1.6.1.8.3 CLTU Transfer Data SLE-SDU

A CLTU Transfer Data SLE-SDU contains a CLTU plus information (see D1.2.2.2) required by the Forward TC Space Link Processing SLE Functional Group (see 2.4.1.4) to process that CLTU. In the context of the FSP SLE transfer service, the CLTU Transfer Data SLE-SDU is generated by the Forward CLTU Generation SLE Functional Group (see 2.4.1.3).

NOTE – When the F-CLTU transfer service is used, the CLTU Transfer Data SLE-SDU is carried (along with other information) in the CLTU-TRANSFER-DATA invocation.

1.6.1.8.4 Communications Service

A communications service is a capability that enables an SLE service-providing application entity and an SLE service-using application entity to exchange information.

NOTE – If an SLE service user and an SLE service provider are implemented using different communications services, then interoperability between them is possible only by means of a suitable gateway. Adherence to this Recommended Standard ensures, at least in principle, that it is possible to construct such a gateway.

1.6.1.8.5 Confirmed Operation

A confirmed operation is an operation that requires the performer to return a report of its outcome to the invoker.

1.6.1.8.6 Initiator

The initiator is the object that issues the request to bind to another object (the responder).

NOTE – In other words, the initiator is always the invoker of the request to bind to another object. Therefore, in the context of the request to bind, the terms ‘initiator’ and ‘invoker’ refer to the same object and are synonyms.

1.6.1.8.7 Invocation

The invocation of an operation is the making of a request by an object (the invoker) to another object (the performer) to carry out the operation.

1.6.1.8.8 Parameter

A parameter of an operation is data that may accompany the operation's invocation or return.

NOTE – The term parameter is also used to refer to mission-dependent configuration information used in the production or provision of the service.

1.6.1.8.9 Performance

The performance of an operation is the carrying out of the operation by an object (the performer).

1.6.1.8.10 Port Identifier

A port identifier identifies a source or a destination in a communications system.

NOTE – See 2.6.4.5 for more information.

1.6.1.8.11 Radiated (Space Packet)

A Space Packet is said to be radiated when, based on the ground equipment monitoring, the FSP production process can assume that all the CLTUs containing parts of the Space Packet reported have been transmitted to the spacecraft.

1.6.1.8.12 Responder

The responder is the object that receives a request to bind and completes the binding (if possible) with the initiator in order for a service association to exist between the two objects.

NOTE – In other words, the responder is always the performer of the binding. Therefore, in the context of binding, the terms 'responder' and 'performer' refer to the same object and are synonyms.

1.6.1.8.13 Return

The return of an operation is a report, from the performer to the invoker, of the outcome of the performance of the operation.

1.6.1.8.14 Service Instance Provision Period

A service instance provision period is the time during which a service instance (i.e., the capability to transfer one or more SLE data channels of a given type) is scheduled to be provided.

1.6.1.8.15 TC Frame Transfer Data SLE-SDU

A TC Frame Transfer Data SLE-SDU contains a TC Frame plus information (see D1.3.2.2) required by the Forward CLTU Generation SLE Functional Group (see 2.4.1.3) to process that TC frame. In the context of the FSP SLE transfer service, the TC Frame Transfer Data SLE-SDU is generated by the Forward TC VC Data Insertion SLE Functional Group (see 2.4.1.2).

1.6.1.8.16 Unconfirmed Operation

An unconfirmed operation is an operation that does not require a report of its outcome to be returned to the invoker by the performer.

1.6.2 NOMENCLATURE

The following nomenclature applies throughout this Recommended Standard:

a) the words ‘shall’ and ‘must’ imply a binding and verifiable specification;

b) the word ‘should’ implies an optional, but desirable, specification;

c) the word ‘may’ implies an optional specification;

d) the words ‘is’, ‘are’, and ‘will’ imply statements of fact.

1.6.3 CONVENTIONS

1.6.3.1 Specification of Operations

1.6.3.1.1 General

Section 3 of this Recommended Standard specifies the operations that constitute the FSP service. The specification of each operation is divided into subsections as follows:

1.6.3.1.2 Purpose Subsection

The Purpose subsection briefly describes the purpose and functioning of the operation. Additionally, it indicates whether the operation may be invoked by the user, provider, or both; whether the operation is confirmed or unconfirmed; and whether there are any constraints on when the operation may be invoked.

1.6.3.1.3 Invocation, Return, and Parameters Subsection

The Invocation, Return, and Parameters subsection describes the parameters associated with each operation, including their semantics. A table accompanying the description of each

operation lists all parameters associated with the operation and, for both the invocation and return, whether the parameter is always present, always absent, or conditionally present.

For parameters that are conditionally present, the parameter description specifies the conditions for the presence or absence of the parameter. The condition is generally based on the value of another parameter in the same invocation or return; for example, in the return of an operation, the `diagnostic` parameter is present if and only if the value of the `result` parameter is 'negative result'. For a conditional parameter in a return, the condition may be based on the value of a parameter in the corresponding invocation.

In the table, the following convention is used to indicate whether a parameter is always present, always absent, or conditionally present:

M	always present (mandatory)
C	conditionally present
Blank	always absent

NOTE – Even though a parameter may be characterized as always present, its description may specify that its value is permitted to be 'null' or 'unused' or the like.

1.6.3.1.4 Effects Subsection

The Effects subsection describes the effects an operation has on the invoker, the performer, the association between them, or any combination thereof. The details of how those effects occur or the mechanisms used are outside the scope of this Recommended Standard.

1.6.3.2 Typographic Conventions

Typographic conventions used in this Recommended Standard are described in the following subsections.

1.6.3.2.1 Operation Names

Names of FSP service operations appear in uppercase and begin with the characters 'FSP-' (e.g., FSP-TRANSFER-DATA).

1.6.3.2.2 Parameter Names

In the main text, names of parameters of FSP service operations appear in lowercase and are typeset in a fixed-width font (e.g., `responder-port-identifier`). In annex A, the corresponding name is formed by omitting any hyphens contained in the name and using mixed-case (e.g., `responderPortIdentifier`).

1.6.3.2.3 Value Names

The values of many parameters discussed in this Recommended Standard are represented by names. In the main text, these names are shown in single quotation marks (e.g., 'no such service instance'). The corresponding name in annex A is formed by omitting any hyphens or white space contained in the name and using mixed-case (e.g., `noSuchServiceInstance`). The actual value associated with the name is constrained by the type of the parameter taking on this value. Parameter types are specified in annex A of this Recommended Standard.

NOTE – The name of a value does not imply anything about its type. For example, the value 'no such service instance' has the appearance of a character string but might be assigned to a parameter whose type is integer.

1.6.3.2.4 State Names

This Recommended Standard specifies the states of FSP service providers. States may be referred to by number (e.g., state 3) or by name. State names are always shown in single quotation marks (e.g., 'active').

1.6.3.2.5 SLE-PDU Names

The names of SLE-PDUs appear in mixed-case (e.g., fspBindInvocation).

1.6.3.2.6 Data Type Definitions

Data type definitions for the FSP service are presented in annex A in the form of a set of ASN.1 modules. Regardless of the conventions used elsewhere in this Recommended Standard, the text of the ASN.1 modules is typeset entirely in a fixed-width font.

1.6.3.3 Other Conventions

This Recommended Standard uses the conventions specified in reference [1].

1.7 REFERENCES

The following documents contain provisions which, through reference in this text, constitute provisions of this Recommended Standard. At the time of publication, the editions indicated were valid. All documents are subject to revision, and users of this Recommended Standard 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 Recommended Standards.

NOTES

1 A list of informative references is provided in annex I.

2 This document takes advantage of the harmonized terminology introduced by restructured documentation of the space link protocols (references [3], [4], [5], and [6]). From an interoperability point of view, they do not introduce any incompatibilities with respect to the original set of space link protocol documents (references [I4], [I5], [I6], and [I7]).

[1] *Cross Support Reference Model—Part 1: Space Link Extension Services*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 910.4-B-2. Washington, D.C.: CCSDS, October 2005.

[2] *Time Code Formats*. Issue 4. Recommendation for Space Data System Standards (Blue Book), CCSDS 301.0-B-4. Washington, D.C.: CCSDS, November 2010.

[3] *TC Synchronization and Channel Coding*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 231.0-B-2. Washington, D.C.: CCSDS, September 2010.

[4] *TC Space Data Link Protocol*. Issue 3. Recommendation for Space Data System Standards (Blue Book), CCSDS 232.0-B-3. Washington, D.C.: CCSDS, September 2015.

[5] *Communications Operation Procedure-1*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 232.1-B-2. Washington, D.C.: CCSDS, September 2010.

[6] *Space Packet Protocol*. Issue 1. Recommendation for Space Data System Standards (Blue Book), CCSDS 133.0-B-1. Washington, D.C.: CCSDS, September 2003.

[7] *Information Technology—Abstract Syntax Notation One (ASN.1): Specification of Basic Notation*. 4th ed. International Standard, ISO/IEC 8824-1:2008. Geneva: ISO, 2008.

[8] *Information Technology—Open Systems Interconnection—Basic Reference Model: The Basic Model*. 2nd ed. International Standard, ISO/IEC 7498-1:1994. Geneva: ISO, 1994.

[9] *Space Link Extension—Forward CLTU Service Specification*. Issue 3. Recommendation for Space Data System Standards (Blue Book), CCSDS 912.1-B-3. Washington, D.C.: CCSDS, July 2010.