The Consultative Committee for Space Data Systems

Draft Recommended Practice for Space Data System Standards

SPACE COMMUNICATION CROSS SUPPORT ARCHITECTURE

Draft Recommended Practice

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FOREWORD

(WHEN THIS GUIDANCE DOCUMENT IS FINALIZED, IT WILL CONTAIN THE FOLLOWING FOREWORD:)

This document is a technical **recommended practice** for use in developing space communication cross support services and has been prepared by the **Consultative Committee for Space Data Systems** (CCSDS). The space communication cross support architecture concept described herein is intended for systems of CCSDS Agencies that provide cross support services for space missions of other CCSDS Agencies.

This **recommended practice** establishes a common framework and provides a common basis for space communication cross support services to be provided by CCSDS agencies to support space missions of other CCSDS Agencies. The architecture described in this document was developed based on the Cross Support Reference Model [1] and the Reference Architecture for Space Data Systems [2] developed by the **Consultative Committee for Space Data Systems** (CCSDS).

DOCUMENT CONTROL

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1 INTRODUCTION

1.1 PURPOSE

The purpose of this recommended practice is to specify the space communication cross support architecture. This architecture is to be used as a common framework when CCSDS Agencies provide and use space communication cross support services and develop systems that provide space communication cross support services.

1.2 SCOPE

This document defines space communication cross support architecture in terms of:

a) concepts that describe and characterize space communication cross support services and systems that provide space communication cross support services; and

It does not specify:

a) how to implement systems that provide space communication cross support services; or

b) specific technologies needed to use space communication cross support services.

1.3 RATIONALE

Since CCSDS is the only international body that links space communication service providers with space missions, it should define a standard architecture for space communication cross support services so that cross support between Agencies can be performed more efficiently.

1.4 DOCUMENT STRUCTURE

This document is divided into six numbered sections and eight annexes:

a) Section 1 presents the purpose, scope, and rationale of this document and lists the definitions, conventions, and references used throughout the document;

b) Section 2 provides an overview of the space communication cross support architecture;

c) Section 3 specifies the Service View;

d) Section 4 specifies the Physical View;

e) Section 5 specifies the Communications View;

f) Section 6 specifies the Enterprise View;

g) Annex A shows guidelines on how to present space communication scenarios based on this architecture;

h) Annex B presents an example of a space communication scenario described based on this architecture; and

i) Annex C lists the acronyms used in this document.

1.5 DEFINITIONS AND CONVENTIONS

1.5.1 DEFINITIONS

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

cross support service: a function provided by a space Agency to support operations of a space mission of another space Agency.

cross support service element (CSSE): a physical element involved in providing one or more cross support services (including functions for managing services).

cross support service system (CSSS): a set of cross support service elements that are managed by a single authority with a single set of management policies.

forward data: data sent from a ground element to a space element.

ground side interface: the interface of a cross support service element closer to the ground user element.

ground user element: a physical element located on the ground that uses a cross support service provided by a cross support service system.

return data: data sent from a space element to a ground element.

service provider: the role played by a physical, functional, or organizational entity that provides a cross support service for a service user. (A single entity may play the roles of service provider and service user at the same time.)

service user: the role played by a physical, functional, or organizational entity that uses a cross support service provided by a service provider. (A single entity may play the roles of service provider and service user at the same time.)

space link: a communications link between an element in space and an element on the ground or between two elements in space.

space side interface: the interface of a cross support service element closer to the space user element.

space user element: a physical element located in space that uses a cross support service provided by a cross support service system.

supported Agency: a space Agency that uses cross support services.

supporting Agency: a space Agency that provides cross support services.

1.5.2 GRAPHICAL CONVENTIONS

For the purposes of this document, the following graphical conventions are used, which are shown in Figure 1-1.

Physical elements are depicted with solid three-dimensional boxes.

Organizations are depicted with dotted three-dimensional boxes.

Functional elements (except for communications protocols) are depicted with ovals.

Communications protocols are depicted with two-dimensional boxes.

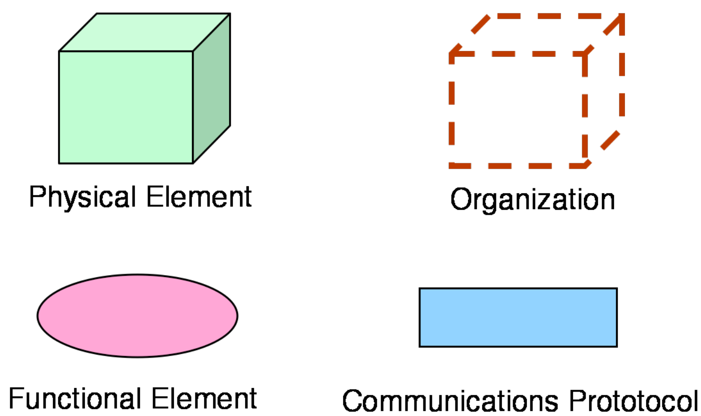


Figure 1–1: Graphical Conventions

1.6 REFERENCES

The following documents are referenced in the text of this document. At the time of publication, the editions indicated were valid. All documents are subject to revision, and users of this guidance document are encouraged to investigate the possibility of applying the most recent editions of the documents indicated below.

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

[2] *Reference Architecture for Space Data Systems*. Recommended Practice, CCSDS 311.0-M-1. Magenta Book. Issue 1. Washington, D.C.: CCSDS, September 2008.

[3] *Information Technology—Open Distributed Processing—Reference Model: Architecture.* International Standard, ISO/IEC 10746-3. 1st ed.. Geneva: ISO, 1996.

[3] *Space Communication Cross Support Service Catalogs (Template)*. Draft Recommended Standard, CCSDS xxx.x-W-1. White Book. Issue 1. Washington, D.C.: CCSDS, xxx 200x.

[4] *Space Communication Cross Support Service Agreements (Template)*. Draft Recommended Standard, CCSDS xxx.x-W-1. White Book. Issue 1. Washington, D.C.: CCSDS, xxx 200x.

[5] *Cross Support Service Catalog Volume 1*. IOAG xxx. Interagency Operations Advisory Group, xxx 200x.

[6] *Radio Frequency and Modulation Systems—Part 1: Earth Stations and Spacecraft.* Recommendations for Space Data System Standards, CCSDS 401.0-B-17. Blue Book. Issue 17. Washington, D.C.: CCSDS, July 2006.

[7] *TC Synchronization and Channel Coding.* Recommendation for Space Data System Standards, CCSDS 231.0-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, September 2003.

[8] *TM Space Data Link Protocol.* Recommendation for Space Data System Standards, CCSDS 132.0-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, September 2003.

[9] *AOS Space Data Link Protocol.* Recommendation for Space Data System Standards, CCSDS 732.0-B-2. Blue Book. Issue 2. Washington, D.C.: CCSDS, July 2006.

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

[11] *CCSDS File Delivery Protocol (CFDP).* Recommendation for Space Data System Standards, CCSDS 727.0-B-4. Blue Book. Issue 4. Washington, D.C.: CCSDS, January 2007.

2 OVERVIEW

2.1 GENERAL

Cross support is an activity of using resources of one space Agency to support operations of a space mission of another space Agency. Cross support has been used by many space missions to reduce the cost of developing systems for operating space missions.

To facilitate space communication cross support, the Consultative Committee for Space Data Systems (CCSDS) developed standard protocols to transfer telecommand and telemetry over space links, which can ensure interoperability between space elements and ground elements belonging to different Agencies. CCSDS also developed standard services called the Space Link Extension (SLE) services to transfer telecommand and telemetry on the ground (for example, between a ground station and a spacecraft control center). By using these CCSDS protocols and services, interoperability between elements of different Agencies can be guaranteed to some extent, but coordination and negotiation for cross support is still done in mission-specific, labor-intensive ways.

The Space Communication Cross Support Architecture specified in this document establishes a common framework that provides a basis for developing, providing and using space communication cross support services through the definition of a set of common concepts and terms. This architecture will facilitate development of space communication cross support systems, description of characteristics of space communication cross support services, documentation of requirements and agreements for space communication cross support.

Figure 2-1 shows a typical physical configuration of space missions. Space communication cross support can occur across all of the red lines shown in this figure. The Space Communication Cross Support Architecture is intended to provide a common framework applicable to all of the space communication cross support services that are provided and used across all of these red lines. In this issue of this architecture, it is assumed that a space communication cross support service is always used by a pair of users (one in space and the other on the ground). Other cases (for example, cases in which both users are in space) will be treated in a future issue of this architecture.

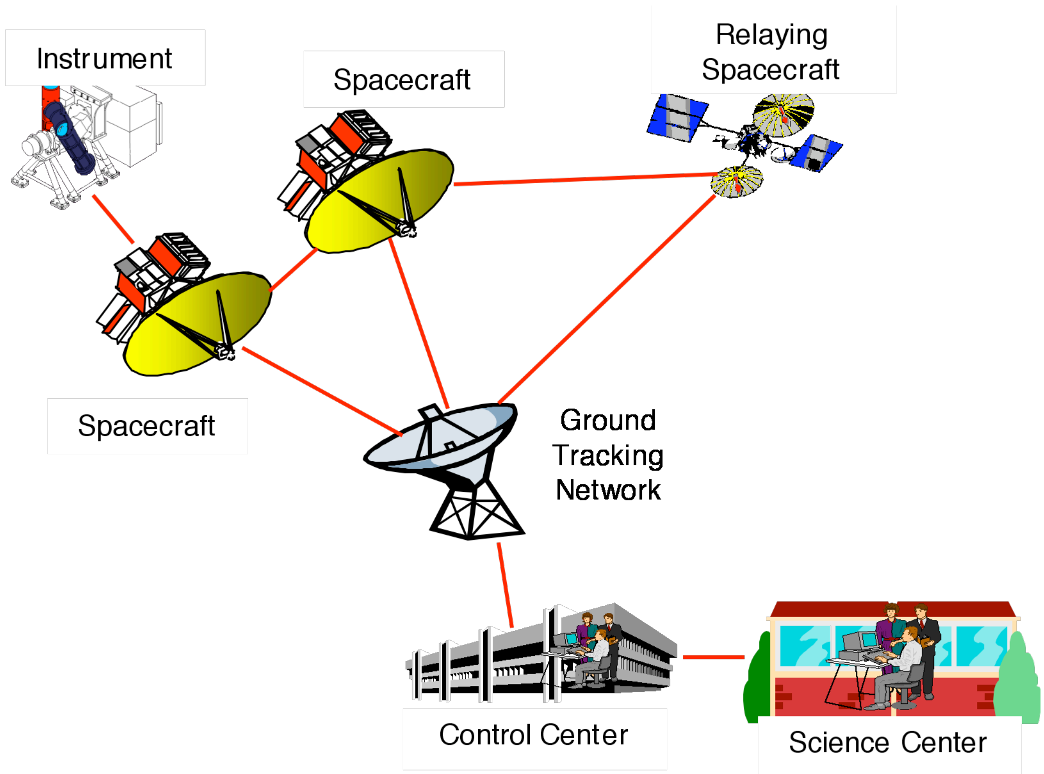


Figure 2–1: Physical Configuration of Space Missions

The Space Communication Cross Support Architecture was developed based on the Cross Support Reference Model [1] and the Reference Architecture for Space Data Systems [2] developed by CCSDS. The Cross Support Reference Model specified in reference [1] provides an architectural model for SLE services provided by ground stations, and the Space Communication Cross Support Architecture extends it in order to cover cross support services provided by other elements such as orbiting spacecraft, elements on the surface of other planets, etc. The Reference Architecture for Space Data Systems (RASDS) specified in reference [2] provides a common framework for describing space data systems and the Space Communication Cross Support Architecture is a customized version of it that focuses on space communication cross support services.

2.2 BASIC ELEMENTS

2.2.1 CROSS SUPPORT SERVICE ELEMENTS

In this architecture, a cross support service element (CSSE) is defined to be a physical element that is (possibly together with some other CSSEs) involved in providing one or more space communication cross support services. One or more CSSEs functioning together provide communications and/or navigation services for any space mission element of any space Agency provided that the user element conforms to the technical interface specifications and management policies specified for the CSSE.

A CSSE may be an element on the surface of a heavenly body (e.g., the earth, the moon, and Mars), an element orbiting around a heavenly body, or an element in cruise through space. It may be a single computer or a large complex consisting of many subsystems. The internal configuration of a CSSE is not visible from its users. What is visible to the users are (1) services (functions) provided for users, (2) methods for using and managing the services, and (3) physical location or trajectory of the CSSE. Examples of CSSEs are relaying satellites orbiting around the earth, the moon, or Mars, landed elements on the moon or Mars, data management systems onboard spacecraft, ground stations, and spacecraft control centers.

2.2.2 CROSS SUPPORT SERVICE SYSTEMS

A cross support service system (CSSS) is defined to be a set of cross support service elements (CSSEs) that are managed by a single authority with a single set of management policies. Table 2-1 shows some examples of cross support service systems and cross support service elements contained in them.

Table 2-1: Examples of Cross Support Service Systems

Cross Support Service System	Cross Support Service Elements
Deep Space Network	Deep Space Stations, Network Control Center
Ground Network	Tracking Stations, Network Control Center
Space Network	Data Relay Satellites, Ground Terminals
Lunar Network	Lunar Relay Satellites
Mars Network	Mars Relay Satellites

2.3 BASIC CONFIGURATIONS

2.3.1 SIMPLE CASES

For a space communication cross support service provided by a cross support service system (CSSS), there is usually a service user element in space and another service user element on the ground. Figure 2-2 shows a configuration in which a CSSE (for example, a ground station), which belongs to a CSSS, provides a service for a space user element (for example, a spacecraft) and a ground user element (for example, a spacecraft control center). The interface of the CSSE with the ground user element is called the ground side interface and the interface with the space user element is called the space side interface.

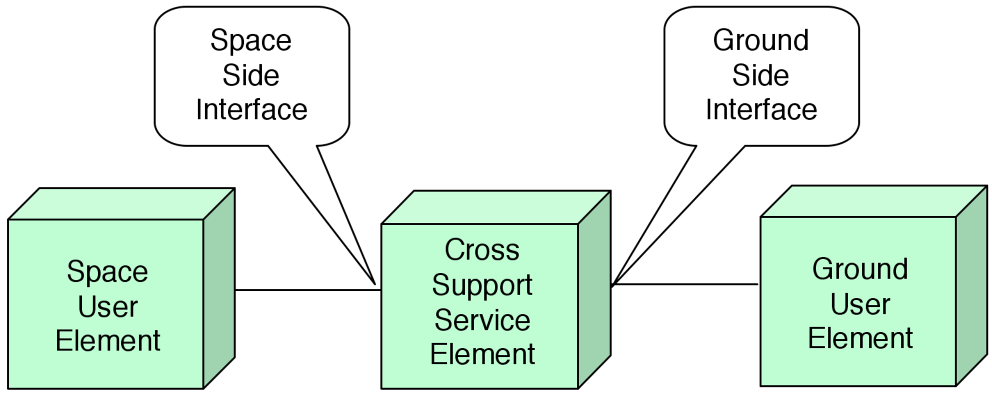


Figure 2–2: Simple Case

In addition to the space and ground user elements, there may be another user element that manages, controls, and/or monitors the service provided by a CSSE, which is called the utilization management element (see Figure 2-3). The utilization management element may be the same as the space or ground user element. The utilization management may be connected directly to the CSSE that provides the service to be managed or to another CSSE that manages the service remotely. The interface of the CSSE with the utilization management element is called the service management interface.

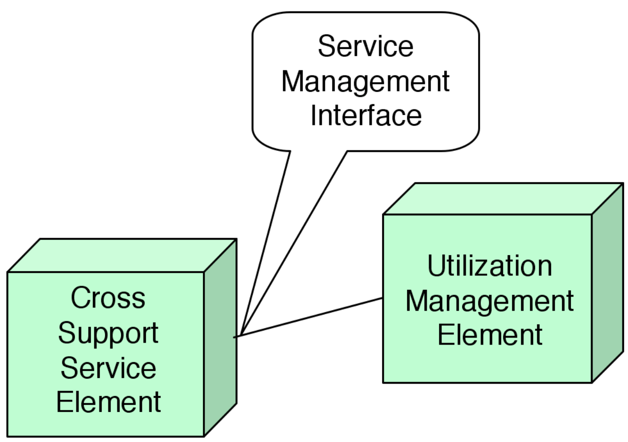


Figure 2–3: Service Management Interface

NOTE - There may be cases in which both user elements are located in space or on the ground. Such cases will be treated in a future issue of this document.

2.3.2 CASCADED CASES

There are cases in which a space user element and a ground user element are supported by two or more CSSEs. Figure 2-3 shows such an example, in which a space user element (a spacecraft) and a ground user element (a spacecraft control center) are supported by CSSE1 (a data relay satellite) and CSSE2 (a ground terminal for the data relay satellite). For each of the CSSEs, the interface closer to the space user element is called the space side interface and the interface closer to the ground user element is called the ground side interface. There may also be a utilization management element, which is not shown in this figure.

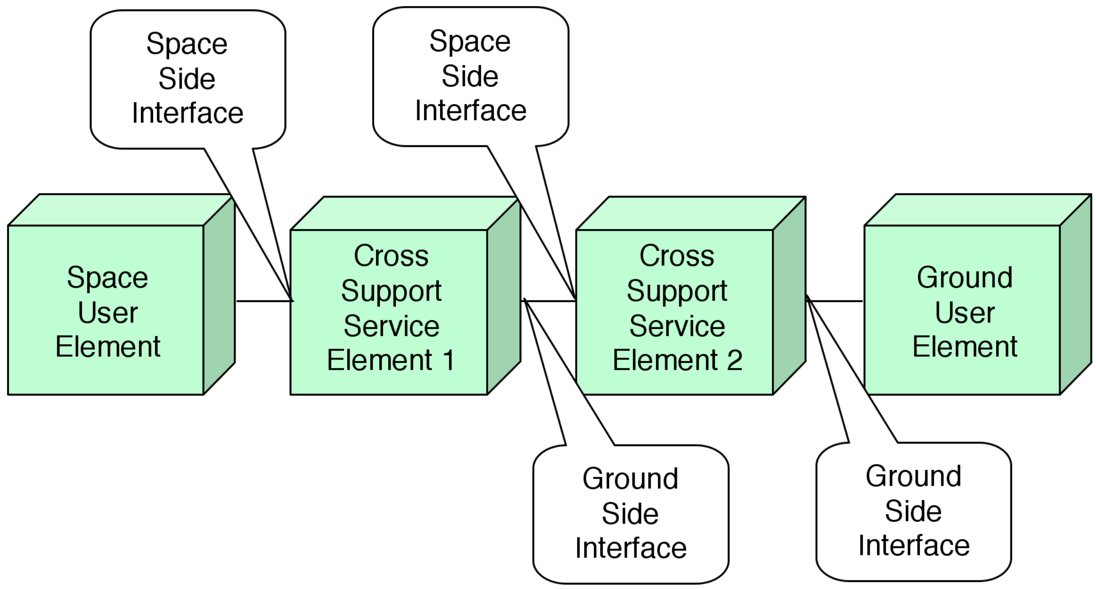


Figure 2–4: Cascaded Case

From the administrative point of view, there are two different cases for the cascaded case of Figure 2-4. In the first case, both CSSE1 and CSSE2 belong to the same CSSS, and in the second case, CSSE1 and CSSE2 belong to different CSSSs. In the first case, the interface between CSSE1 and CSSE2 may be invisible to the space/ground user elements. In the second case, how to establish the interface between CSSE1 and CSSE2 depends on each project.

2.4 FOUR VIEWS

2.4.1 GENERAL

Since there are many aspects associated with space communication cross support services and service systems/elements, this architecture uses multiple Views to describe space communication cross support services and systems, each focusing on different aspects associated with the space communication cross support services and systems.

The Views defined in this architecture are:

a) The Service View;

b) The Physical View;

c) The Communications View; and

d) The Enterprise View.

These Views were defined based on the five Viewpoints of the Reference Architecture for Space Data Systems (RASDS) [2], which were defined based on the five Viewpoints of the Reference Model of Open Distributed Processing [3].

2.4.2 SERVICE VIEW

The Service View is used to describe services provided by cross support service systems/elements and their functional characteristics.

Specifically, it describes:

a) Functional characteristics of services;

b) Performance characteristics of services;

c) Methods and/or standards for using services; and

d) Methods and/or standards for managing services.

2.4.3 PHYSICAL VIEW

The Physical View is used to describe the physical configuration of cross support service systems/elements and their physical characteristics.

Specifically, it describes:

a) Physical location;

b) Topology and connectivity; and

c) Physical media for access.

2.4.4 COMMUNICATIONS VIEW

The Communications View is used to describe communications protocols used for accessing services provided by cross support service systems/elements.

Specifically, it describes:

a) Communications protocols; and

b) Parameter values of communications protocols.

2.4.5 ENTERPRISE VIEW

The Enterprise View is used to describe processes and rules governing the initiation, negotiation, and agreement between the supported and supporting Agencies for the provision of cross support services. Differing from the other Views which are technical in nature, it addresses the administrative and contractual aspects of the service architecture.

Specifically, it describes:

a) Policies for providing services;

b) Documents necessary for using services ;

c) Pricing information;

d) Service agreement: and

e) Activities for testing cross support interfaces.

3 SERVICE VIEW

3.1 GENERAL

The Service View is used to describe space communications cross support services provided by cross support service systems and their functional characteristics, separately from physical locations where the services are provided (which are treated in the Physical View), communications protocols used to access the services (which are treated in the Communications View), and organizational or administrational issues involved in using the services (which are treated in the Enterprise View).

NOTE - This architecture was developed based on the Cross Support Reference Model (CSRM) [1] but extends it in such a way that it can be applicable to services provided at different places than ground stations such as onboard communication/data systems, spacecraft control centers, etc.. In the CSRM, processing of space link protocols by the service provider (which is assumed to be a ground station) is treated as production of a service (see 4.2.2 of reference [1]). In this architecture, however, it is treated as processing of communications protocols used on the space side interface of the CSSE so that services can be defined independently of the location of the service provider. For example, a service of delivering Space Packets [10] can be provided at a spacecraft control center (not at a ground station) and in such a case only processing of the Space Packet Protocol [10] is required for producing the service at the spacecraft control center. The attributes for service production are specified as those of communications protocols used on the space link in this architecture. For detailed discussion, see 3.6.

3.2 CROSS SUPPORT SERVICES

3.2.1 SIMPLE CASE

A space communication cross support service is a communication function provided by a space Agency to support operations of a space mission of another space Agency. In a simple case, a cross support service is provided at a cross support service element (CSSE) of a cross support service system (CSSS) and used by a service user (which is a space mission) located in a space user element and a ground user element (see Figure 3-1).

In Figure 3-1, the space user element, the cross support service element and the ground user element (which are depicted as three-dimensional boxes) are physical entities, whereas the space service utilization, the cross support service provision, and the ground service utilization (which are depicted as ovals) are functional entities that reside in these physical entities. The pipes between the space service utilization and the cross support service provision and between the cross support service provision and the ground service utilization represent logical interactions between these functional entities, which are realized using communications protocols shown in the Communications View. The CSSE belongs to a space Agency (the supporting Agency) and the space and ground user elements belong to another space Agency (the supported Agency). The organizational relationship between these Agencies is described in the Enterprise View.

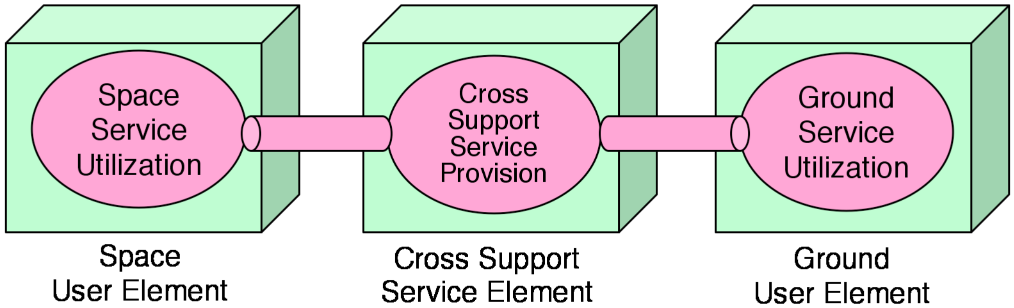


Figure 3–1: Cross Support Service (Simple Case)

3.2.2 CASCADED CASE

There are cases in which there exist two or more CSSEs between the space and ground user elements (see 2.3.2). In the case of Figure 3-2, the space user element and CSSE2 play the role of service user for CSSE1, which plays the role of service provider, and CSSE1 and the ground user element play the role of service user for CSSE2, which plays the role of service provider. The space and ground user elements belong to a space Agency (the supported Agency). CSSE1 and CSSE2 may belong to a single space Agency (the supporting Agency) or two different space Agencies (the supporting Agencies 1 and 2). If CSSE1 and CSSE2 belong to the same Agency, the interface between cross support service provisions 1 and 2 may be invisible to the space and ground service utilizations. The organizational relationship between these Agencies is described in the Enterprise View.

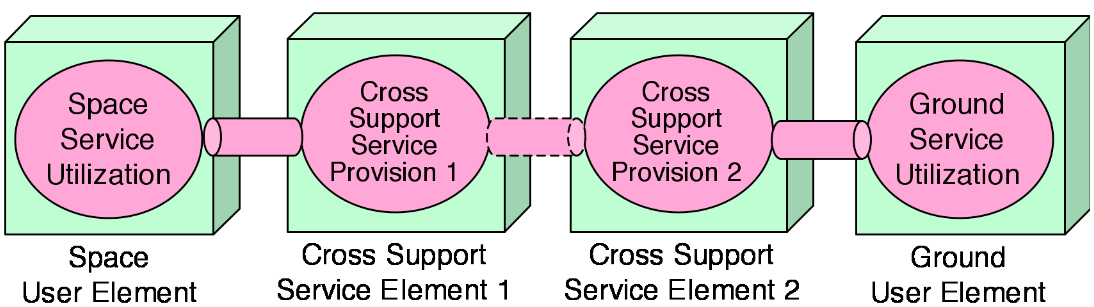


Figure 3–2: Cross Support Service (Cascaded Case)

3.2.3 SERVICE ATTRIBUTES

Each service provided by a CSSE is characterized by a set of standard service attributes defined in Space Communication Cross Support Service Catalogs (Template) [4]. For each of the cross support services listed in Cross Support Service Catalog Volume 1 [5], a standard attribute set is provided in [3], which should be used to describe the functional and performance characteristics of services provided by specific CSSSs/CSSEs and services used for specific space missions.

3.3 SERVICE MANAGEMENT

As discussed in 2.3.1, there may be a user entity that manages, controls, and/or monitors the service provided by a CSSE. In Figure 3-3, the service utilization management represents the function of managing, controlling and/or monitoring the service through the service provision management on behalf of the space and ground service users. The service utilization management may be located at the space or ground user element, or at a separate utilization management element. The service provision management, by interacting with the service utilization manager, directly manages, controls, and/or monitors the cross support service provision through an interface internal to the CSSS. The service provision management may be located at the same CSSE as the cross support service provision function or at another CSSE within the same CSSS.

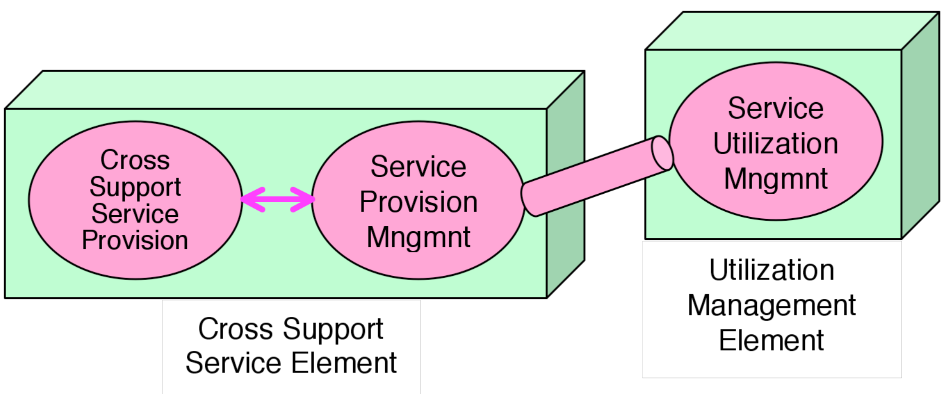


Figure 3–3: Service Management

The characteristics of each service provision management are presented with a set of standard service attributes defined in [3]. The interface between the service provision management and the cross support service provision is internal to the CSSE or CSSS and not visible to the service utilization management.

3.4 SERVICES

Some examples of space communication cross support services are shown in table 3-1.

Table 3-1: Examples of Space Communication Cross Support Services

Cross Support Service Type	Cross Support Service	Function
Forward Delivery Services	Forward Bitstream Delivery Service	Deliver bitstream received from the ground user element to the space user element
	Forward CLTU Delivery Service	Deliver Communications Link Transmission Units [7] received from the ground user element to the space user element
	Forward Packet Delivery Service	Deliver Space Packets [10] received from the ground user element to the space user element
	Forward File Delivery Service	Deliver files received from the ground user element to the space user element with CCSDS File Delivery Protocol [11]
Return Delivery Services	Return Bitstream Delivery Service	Deliver bitstream received from the space user element to the ground user element
	Return Frame Delivery Service	Deliver frames of the TM or AOS Space Data Link Protocol [8 or 9] received from the space user element to the ground user element
	Return Packet Delivery Service	Deliver Space Packets [10] received from the space user element to the ground user element
	Return File Delivery Service	Deliver files received from the ground user element to the space user element with CCSDS File Delivery Protocol [11]
Tracking Services	Radio Metric Data Service	Perform radio metric measurements for the space user element and deliver validated radio metric data to the ground user element
	Delta-DOR Service	Perform delta-DOR measurements for the space user element using multiple tracking stations and deliver validated delta-DOR data to the ground user element
	Orbit Determination Service	Perform radio metric and/or delta-DOR measurements for the space user element

		and deliver its positions and velocities to the ground user element
Time Service	Spacecraft Time Correlation Service	Receive information on the onboard clock from the space user element and deliver to the ground user element correlation coefficients to convert the onboard clock time to UTC
Voice and Video Services	Voice Service	Relay two-way voice signals between the space and ground user elements
	Video Service	Relay one-way or two-way video signals between the space and ground user elements

Space communication cross support services that should commonly be used for space projects are recommended by the Interagency Operations Advisory Group (IOAG) in its Cross Support Service Catalog Volume 1 [5]. Cross support service systems and elements may provide other services that are not listed in [5], but it is recommended that any cross support service systems and elements implement services listed in [5] in order to maximize the chances for cross support. For each of the cross support services listed in [5], a standard attribute set is provided in [3].

3.5 DELIVERY MODES

For the delivery services shown in [5], two delivery modes are provided: online and offline. The online delivery mode is employed to deliver data to the receiving user element at the same time as the data is being received by the CSSE from the sending user element. The offline delivery mode is employed to deliver data to the receiving user element at a time later than the time the data is received by the CSSE from the sending user element. The offline delivery mode is also called the store-and-forward delivery mode.

Further, there are two QoS (quality of service) modes in the return online delivery mode: complete online and timely online. In the complete online mode, the complete data received by the CSSE from the sending user element is delivered to the receiving user element but there may be a delay in delivery if the communications circuit between the CSSE and the receiving user element does not have a sufficient bandwidth. In the timely online mode, the data received by the CSSE from the sending user element is delivered to the receiving user element within a certain delay and some data may be lost if the communications circuit between the CSSE and the receiving user element does not have a sufficient bandwidth. For forward online delivery, the complete data received from the sending user element by the CSSE is always delivered to the receiving user element.

3.6 DEPENDENCE OF COMMUNICATIONS PROTOCOLS ON SERVICES

The definition of services is made independently of the communications protocols used to support the services. For example, a service to deliver Space Packets [10] may use different communications protocols depending on where the cross support service element (CSSE) and the user elements are located. This is the reason why the communications protocols are specified in the Communications View, not in the Service View. In some cases, the selection of communications protocols is determined by the location of the CSSE. For example, CSSEs at ground stations always use space link protocols on the space side interface.

The communications protocols used to support a particular service provided by a particular CSSE should be specified using the Service-Protocols Chart shown in section 5.4.

NOTE - In this architecture, the Space Link Extension (SLE) services are considered to define the functional interface between the service provision and the (ground) service utilization, not as communications protocols dealt with in the Communications View.

4 PHYSICAL VIEW

4.1 GENERAL

The Physical View is used to describe (1) the physical configuration of cross support service systems/elements and their physical characteristics and (2) the topology and connectivity of the physical elements (including user elements) to support specific space missions.

4.2 PHYSICAL ELEMENTS

There are various types of physical elements involved in space communication cross support: from such individual hardware elements as antennas, receivers, computers to such large complex elements as tracking stations, control centers, spacecraft. In this architecture, physical elements are shown as long as they are necessary for showing how cross support services are provided. For example, if a tracking station provides a cross support service for a pair of space and ground user elements and the knowledge of the internal configuration of the tracking station is not necessary for using the service, only the tracking station is shown as the cross support service element and the physical attributes of the tracking station as a whole are presented to the users. The internal components of the tracking station and their physical attributes are not shown in this architecture.

A physical element may be an element on the surface of a heavenly body (e.g., the earth, the moon, and Mars), an element orbiting around a heavenly body, or an element in cruise through space. Examples of physical elements are orbiting spacecraft (deep space and near earth), landed elements on the moon or Mars, data management systems onboard spacecraft, ground stations, control centers, and computers at control centers.

Figure 4-1 is the Physical View of a space mission, in which the space user element is a Mars lander and the ground user element is the control center that controls the lander on the ground. To support these user elements, three cross support service elements (CSSEs) are used: a Mars relay satellite and two tracking stations on the ground. These CSSEs may belong to a single cross support service system (CSSS) or different CSSSs.

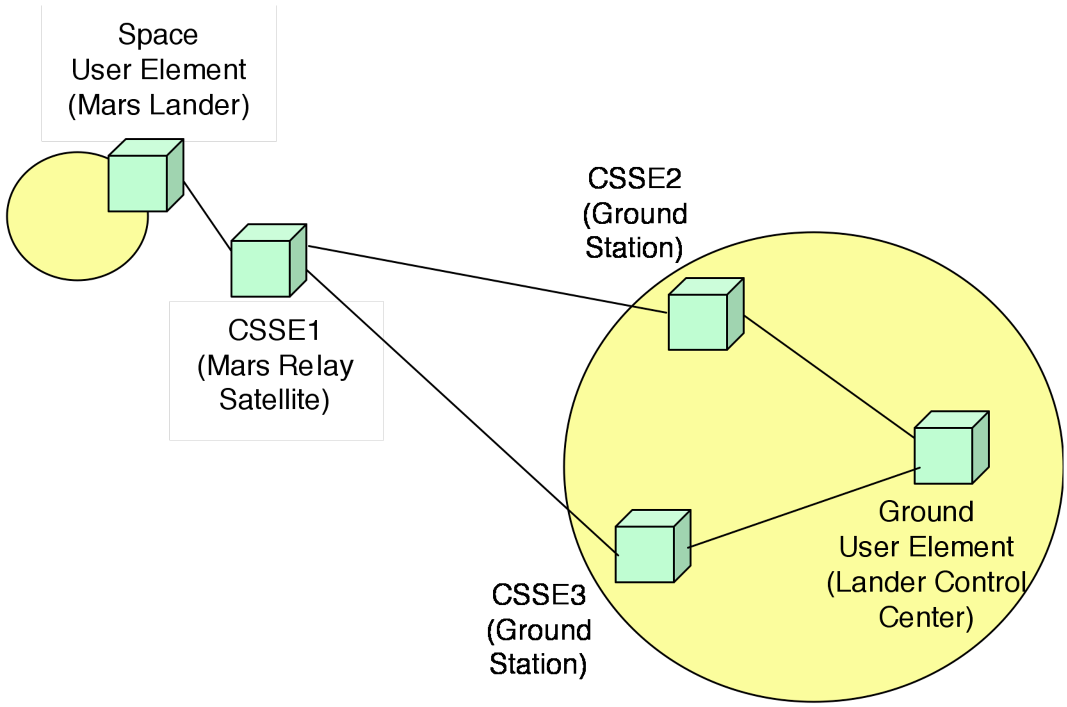


Figure 4–1: Physical View of a Space Mission (Mars Lander)

The physical characteristics of each CSSE is characterized by a set of standard physical attributes defined in [3].

4.3 PHYSICAL ELEMENTS

Table 4-1 lists some examples of physical elements that can be used as cross support service elements (CSSEs) and space/ground user elements. There may be other types of physical elements used as CSSEs.

Table 4-1: Examples of Physical Elements

Physical Element Class	Physical Element Type	Explanation
Orbiting Elements	Earth Orbiter	Spacecraft orbiting around the earth
	Lunar Orbiter	Spacecraft orbiting around the moon
	Mars Orbiter	Spacecraft orbiting around the Mars
	Planet Orbiter	Spacecraft orbiting around a planet other

		than Mars
	Sun Orbiter	Spacecraft orbiting around the sun
	Payload	Payload of a spacecraft
Landed Elements	Lunar Lander	Spacecraft fixed on the surface of the moon
	Lunar Rover	Spacecraft that moves on the surface of the moon
	Mars Lander	Spacecraft fixed on the surface of Mars
	Mars Rover	Spacecraft that moves on the surface of Mars
	Planet Lander	Spacecraft fixed on the surface of a planet other than Mars
	Planet Rover	Spacecraft that moves on the surface of a planet other than Mars
Ground Elements	Ground Station	Ground element with (an) RF interface(s) to communicate with spacecraft
	Operations Facility	Ground element for operating spacecraft
	Science Facility	Ground element for processing science data from spacecraft

5 COMMUNICATIONS VIEW

5.1 GENERAL

The Communications View is used to describe communications protocols used for accessing space communication cross support services (including service provision management) provided by cross support service systems/elements. Its focus, different from that of the Service View, is on the communications interfaces between the CSSEs and user elements.

The communications protocols used for accessing a space communication cross support service are sometimes determined by the cross support service and/or where the service is provided. For example, for a service to deliver telemetry frames from a space user element to a ground user element by a cross support service element (CSSE) at a ground station, the CCSDS TM or AOS Space Data Link Protocol [8 or 9] and the CCSDS RF & Modulation Recommendation [6] must be used on the space side interface (that is, on the link between the space user element and the CSSE). However, for a service to deliver Space Packets [10], different communications protocols may be used depending on where the CSSE and the user elements are located. For this reason, a set of communications protocols should be specified for each of the cross support services provided by each CSSE (see 5.4).

NOTE - As discussed in NOTE of section 3.1, processing of communications protocols used on space links at ground stations is defined as production of a service in the Cross Support Reference Model (see 4.2.2 of reference [1]). In this architecture, however, it is treated in the Communications View as processing of communications protocols used on the space side interface at CSSEs so that services can be specified independently of the communications protocols that supports them and the attributes of communications protocols can be specified independently of the cross support services used and the locations where they are processed.

5.2 COMMUNICATIONS PROTOCOLS

To support the interactions between the space/ground service utilizations and the cross support service provision (see Figure 3-1), a set of communications protocols are used (see Figure 5-1). In Figure 5-1, the pink ovals are functional entities that provide and use a cross support service and the pink pipes between the pink ovals represent logical interactions between these functional entities, which are realized using communications protocols shown as blue boxes. One set of communications protocols is used to support interactions between the space service utilization and the cross support service provision and another set is used between the cross support service provision and the ground service utilization. Actual flows of information occur along the black lines.

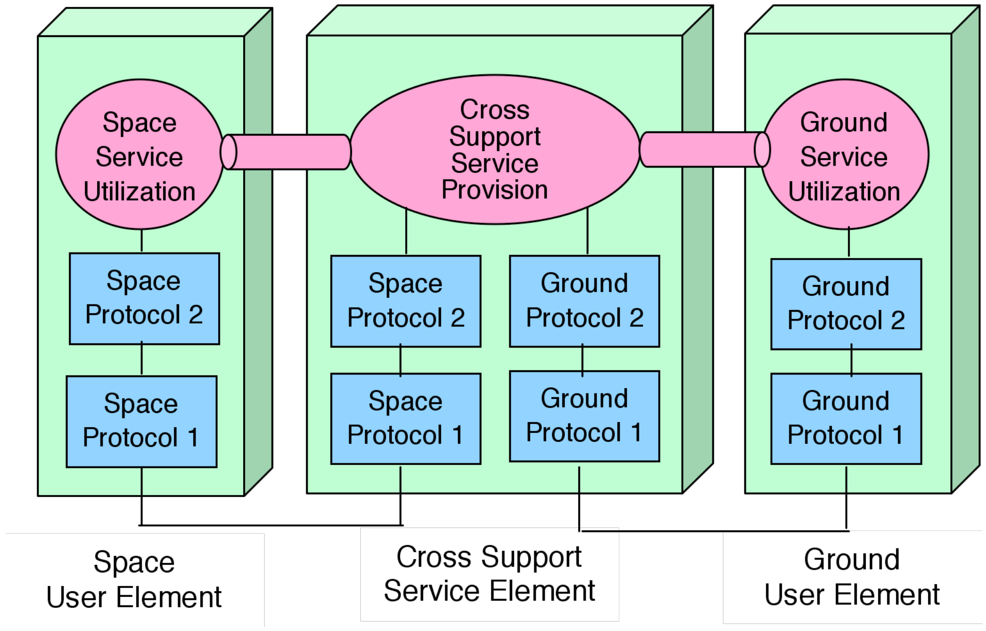


Figure 5–1: Communications Protocols to Support a Service

The set of communications protocols used for each cross support service is determined by the nature of the service, the locations of the physical elements (the CSSE and the space and ground user elements), and the characteristics of the physical links between the physical elements.

Each communications protocol used to support a space communication cross support service is characterized by a set of standard communications attributes defined in [3].

NOTE - In this architecture, the Space Link Extension (SLE) services are considered to define the functional interface between the service provision and the (ground) service utilization, not as communications protocols dealt with in the Communications View.

5.3 COMMUNICATION PROTOCOLS

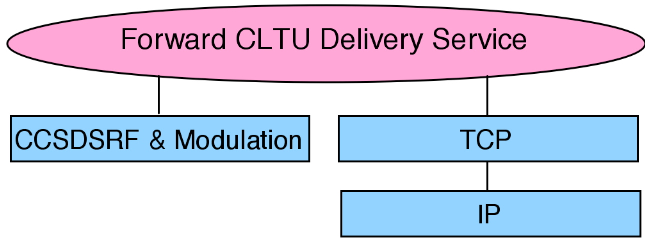
Table 5-1 lists some examples of communications protocols to support space communication cross support services. Cross support service systems and elements may use other communications protocols that are not listed in Table 5-1.

Table 5-1: Examples of Communications Protocols

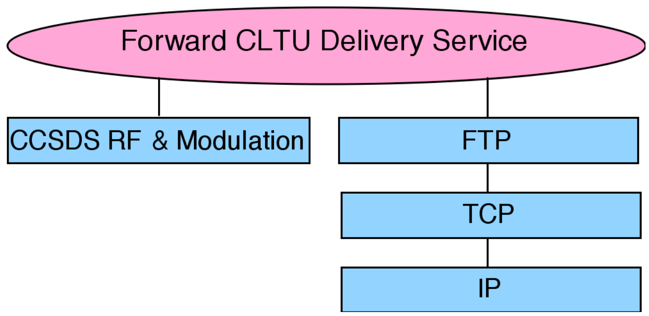
Physical Link Type	Communications Protocol	Reference
Onboard Links	MIL-STD-1553B	MIL-STD-1553B
	SpaceWire	ECSS-E50-12A
Proximity Links	Proximity-1 Space Link Protocol	CCSDS 211.0-B.4, CCSDS 211.1-B.3, CCSDS 211.2-B.1
Space-to-Ground Links	RF and Modulation	CCSDS 401.0-B.17
	TC Synchronization and Channel Coding	CCSDS 231.0-B.1
	TM Synchronization and Channel Coding	CCSDS 131.0-B.1
	TC Space Data Link Protocol	CCSDS 232.0-B.1
	TM Space Data Link Protocol	CCSDS 132.0-B.1
	AOS Space Data Link Protocol	CCSDS 732.0-B.2
End-to-End Protocols	Space Packet Protocol	CCSDS 133.0-B.1
	CCSDS File Delivery Protocol	CCSDS 727.0-B.4
Ground Communications Protocols	Internet Protocol (IP)	RFC 791
	Transmission Control Protocol (TCP)	RFC 793
	File Transfer Protocol (FTP)	RFC 959

5.4 SERVICE-PROTOCOLS CHART

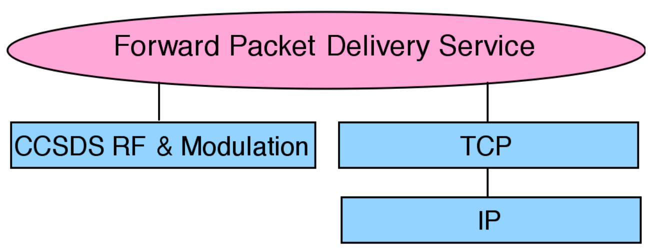
As discussed in 3.6, for each combination of a service and a cross support service element (CSSE), the communications protocols used to support the service shall be specified. The sets of communications protocols used on the space and ground side interfaces shall be specified with either a table or a diagram. Some examples are shown in Figure 5-2.



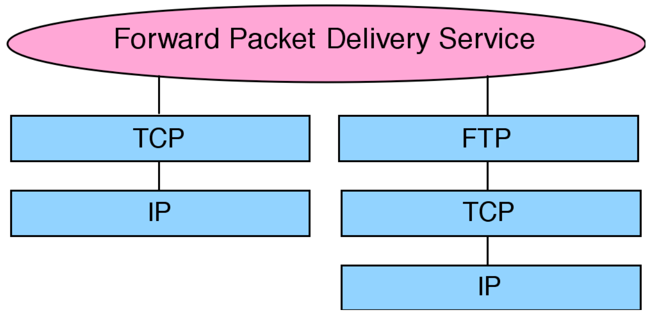
(a) When Forward CLTU Service is provided at a ground station and SLE is used as the service interface with ground service utilization



(b) When Forward CLTU Service is provided at a ground station and a file interface is used as the service interface with ground service utilization



(c) When Forward Packet Service is provided at a ground station and SLE is used as the service interface with ground service utilization



(d) When Forward Packet Service is provided at a spacecraft control center and a file interface is used as the service interface with ground service utilization. It is assumed that SLE interface is used between the spacecraft control center and the ground station but this interface may not be visible to ground service utilization.

Figure 5–2: Examples of Service-Protocol Charts

6 ENTERPRISE VIEW

6.1 GENERAL

The Enterprise View is used to describe processes and rules governing the initiation, negotiation, and agreement between the supported and supporting Agencies for the provision of space communication cross support services. Differing from the other architecture Views which are technical in nature, it addresses the administrative and contractual aspects of the architecture.

6.2 CROSS SUPPORT SERVICE AGREEMENTS

In order to perform cross support, the Agency that provides cross support services (hereafter called the supporting Agency) and the Agency that uses them (hereafter called the supported Agency) must agree on the conditions for cross support (see Figure 6-1).

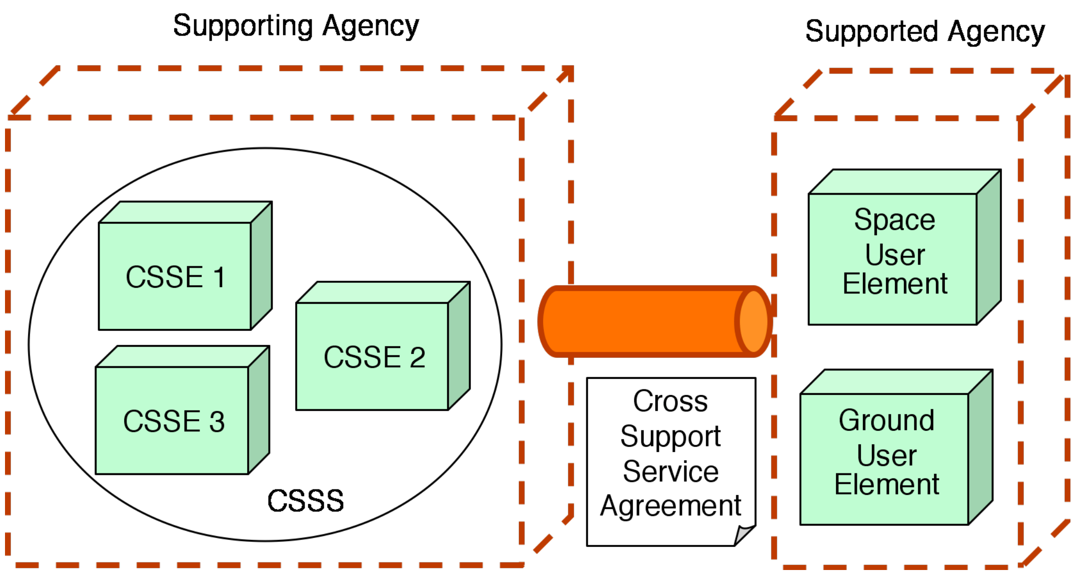


Figure 6–1: Cross Support Service Agreement

In order to make these agreements, each supporting Agency should specify policies and conditions for providing services and activities needed to establish cross support interfaces, based on which cross support agreements are made. The items that a supporting Agency should specify and the items to be agreed on by both Agencies are characterized by a set of standard enterprise attributes provided in [3].

In order to conduct the service agreement process efficiently, standard procedures described in [4] must be observed by the CCSDS Agencies.

Table 6-1 shows some of the types of information contained in cross support service agreements. A template of service agreement is provided in Space Communication Service Agreement (Template) [4].

Table 6-1: Service Agreement Information Types

Service Agreement Information Type	Explanation
Policies	Policies of supporting Agencies for providing services
Documents	Listing of documents necessary for using services
Service Agreement	High-level summary of services provided by supporting Agencies and used by supported Agencies (for example, what services are provided at what CSSEs and used at what user elements)
Pricing Information	How much cross support services cost
Testing Activities	Activities performed by supporting and supported Agencies to establish cross support interfaces

ANNEX A

GUIDELINES FOR PRESENTING SPACE COMMUNICATION SCENARIOS

This Annex shows guidelines for presenting space communication scenarios using the Space Communication Cross Support Architecture.

A.1 GENERAL

Each space communications scenario should identify the following:

j) Project name

k) Agency that owns the project

l) Objectives of the project

m) Dates of major events (launch, arrival, etc.)

Each space communications scenario should identify the things shown in the following subsections for each of the Views defined in this architecture. Two or more Views can be shown together if the scenario is presented better in that way.

A.2 PHYSICAL VIEW

For the Physical View, each space communications scenario should identify the following:

n) Name and location of each physical element used in the project, which may be an orbiting spacecraft, a lander, a rover, a ground station, or a control center.

o) How the physical elements are connected with each other via what communications links or networks

A.3 ENTERPRISE VIEW

For the Enterprise View, each space communications scenario should identify the following:

p) Name of each Agency involved in the scenario and what physical elements it owns

q) Type of interagency agreement (cooperative, reimbursable, etc.)

r) Information exchanged between Agencies

A.4 SERVICE VIEW

For the Service View, each space communications scenario should identify the following:

s) What services each physical element provides for what physical element(s) and uses form what physical element(s)

t) How the services are connected with each other or depend on each other

A.5 COMMUNICATIONS VIEW

For the Communications View, aach space communications scenario should identify the following:

u) Communications protocols used to support each connection between service elements, or alternatively,

v) Communications protocols used for each interface of each service element

ANNEX B

AN EXAMPLE OF A SPACE COMMUNICATION SCENARIO

This Annex shows an example of a space communication scenario presented based on the Space Communication Cross Support Architecture.

B.1 BEPICOLOMBO PROJECT: CRUISE PHASE

B.1.1 Summary

BepiColombo is a joint ESA-JAXA project to explore Mercury to be launched in 2013. For this project, ESA develops a Mercury orbiter called the Mercury Planetary Orbiter (MPO) and JAXA develops another Mercury orbiter called the Mercury Magnetospheric Orbiter (MMO), which will be launched by a single launch vehicle and operated as a single spacecraft until they arrive at Mercury and are separated from each other.

During the cruise phase, MMO is operated as a payload of MPO. MPO is operated at ESA/ESOC and MMO is operated at JAXA/SSOC through ESA/ESOC. The main ground station is ESA/Cebreros and JAXA/Usuda is used as a secondary station during critical operations.

NOTE - The description of the BepiColombo project is presented only as an example to illustrate how to apply the Cross Support Service Architecture to a real project and the description in this Annex is somewhat simplified and not exact.

B.1.2 Physical View

The Physical View of the BepiColombo Project is shown in Figure B-1.

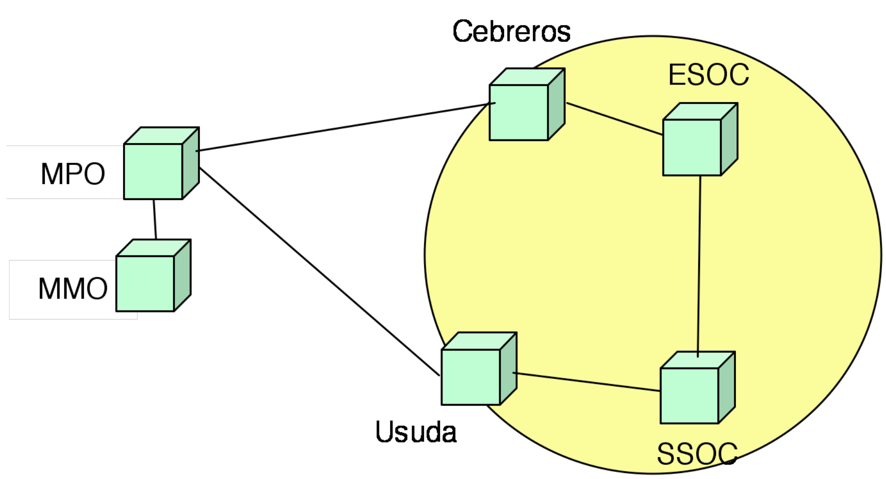


Figure B–1: Physical View for BepiColombo

B.1.3 Enterprise View

The Enterprise View superposeed on the Physical View is shown in Figure B-2.

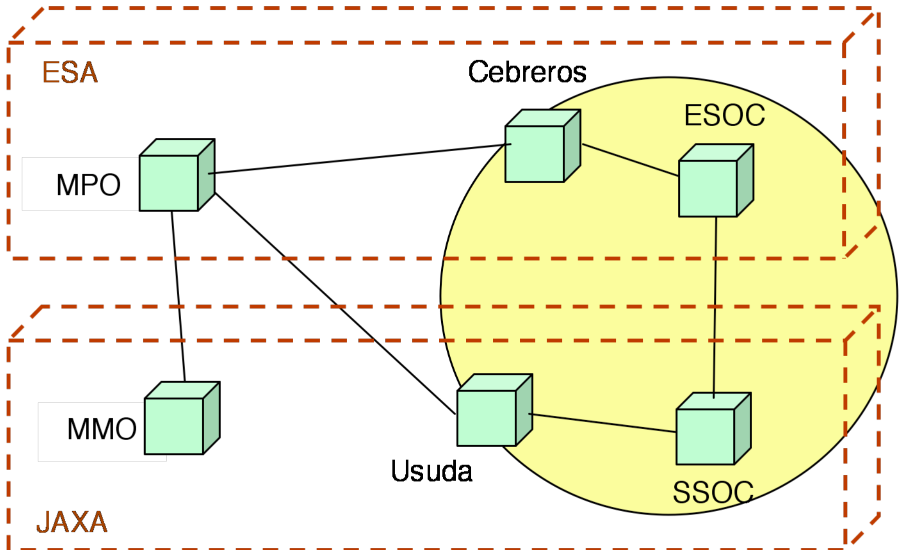


Figure B–2: Combined Enterprise and Physical View of BepiColombo

Two cross support scenarios are used for this project.

a) ESA (MPO, Cebreros and ESOC) provides support for JAXA to operate MMO.

b) The JAXA Usuda station provides support to track MMO.

Some major contents of the service agreements for scenarios a) and b) are shown in Tables B-1 and B-2, resprectively.

Table B-1: Service Agreement for BepiColombo Cross Support Scenario A

Attribute	Values
Supporting Agency Name	ESA
Supported Agency Name	JAXA
Supported Project Name	BepiColombo (MMO)
Supported Project Description	Mercury orbiter (during cruise)
Start of Support Period	August 2013
End of Support Period	August 2019
Supporting CSSS Name	ESA BepiColombo Mission Data System
Supporting CSSE Names	MMO, Cebreros, ESOC
Supporting CSSE Types	Sun Orbiter, Ground Station, Operations Facility
Provided Service Names	Forward Packet Delivery Service, Return Packet

	Delivery Service
Space User Element Name	MMO
Space User Element Type	Payload
Ground User Element Name	SSOC
Ground User Element Type	Control Facility
Number of Contacts	1/week
Contact duration	2 hours/day

Table B-2: Service Agreement for BepiColombo Cross Support Scenario B

Attribute	Values
Supporting Agency Name	JAXA
Supported Agency Name	ESA
Supported Project Name	BepiColombo (MPO)
Supported Project Description	Mercury orbiter (during cruise)
Start of Support Period	August 2013
End of Support Period	August 2019
Supporting CSSS Name	JAXA Deep Space Operations System
Supporting CSSE Names	Usuda, SSOC
Supporting CSSE Type	Ground Station, Operations Facility
Provided Service Names	Forward CLTU Delivery Service, Return Frame Delivery Service
Space User Element name	MPO
Space User Element Type	Sun Orbiter
Ground User Element Name	ESOC
Ground User Element Type	Control Facility
Number of Contacts	1/day
Contact duration	8 hours/day

B.1.4 Service View

The Service View for scenarios a) and b) are shown in Figures B-3 and B-4, respectively. In both of these figures, the interfaces between cross support service elements are invisible to the user elements because they are internal to the supporting Agency.

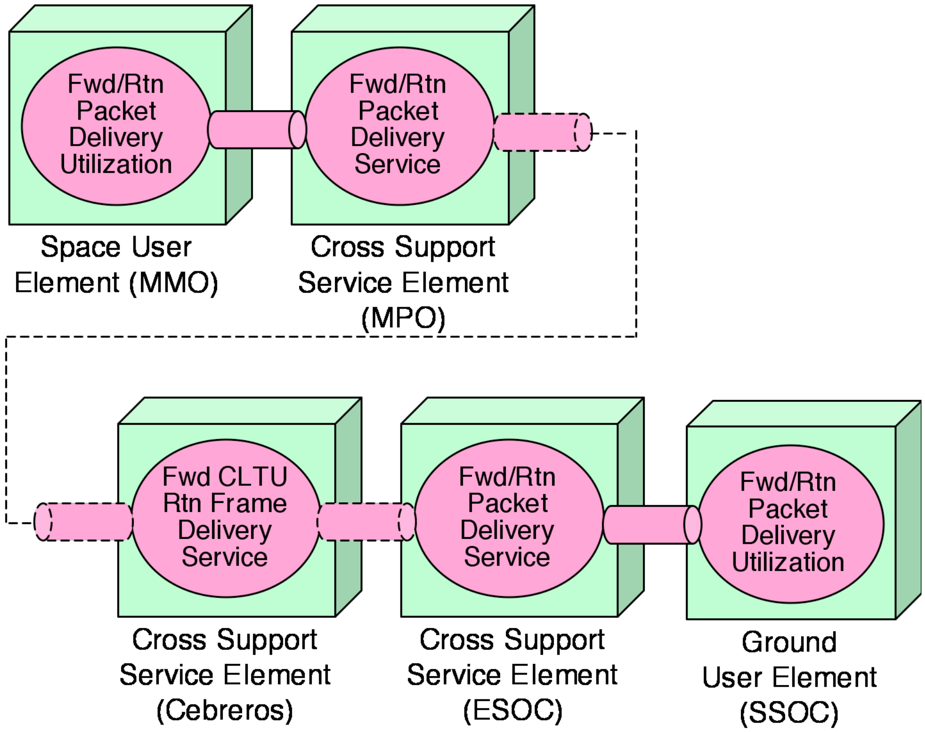


Figure B–3: Service View for BepiColombo Cross Support Scenario A

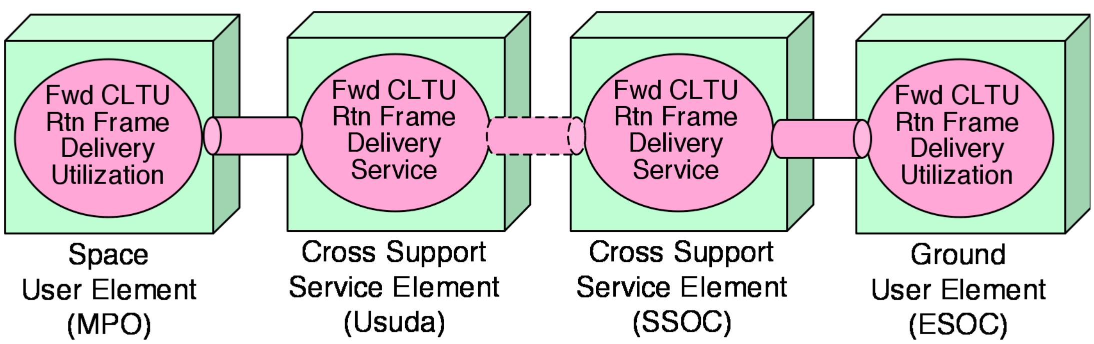


Figure B–4: Service View for BepiColombo Cross Support Scenario B

B.1.5 Communications View

The Communications View for each CSSE used for BepiColopmbo is shown in Figures B-5 through B-8. Only the CSSEs that have a direct interface with a user element are shown.

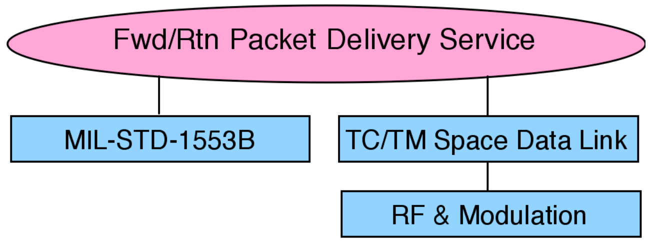


Figure B–5: Communications View for MPO for Cross Support Scenario A

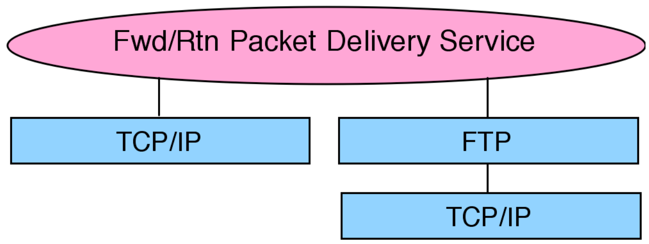


Figure B–6: Communications View for ESOC for Cross Support Scenario A

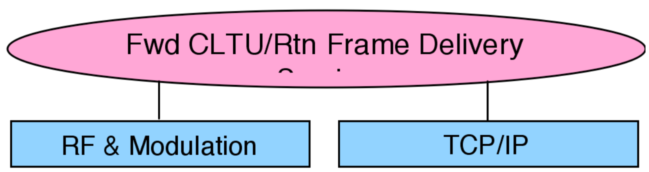


Figure B–7: Communications View for Usuda for Cross Support Scenario B

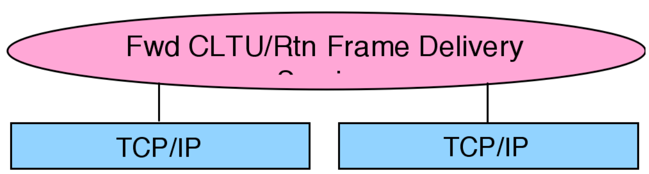


Figure B–8: Communications View for SSOC for Cross Support Scenario B

ANNEX C

ACRONYMS

This annex lists key acronyms used throughout this document.

AOS	Advanced Orbiting System
CCSDS	Consultative Committee for Space Data Systems
CLTU	Communications Link Transmission Unit
CFDP	CCSDS File Delivery Protocol
CSSE	Cross Support Service Element
CSSS	Cross Support Service System
DOR	Differential One-way Ranging
IOAG	Interagency Operations Advisory Group
QoS	Quality of Service
RASDS	Reference Architecture for Space Data Systems
RF	Radio Frequency
SLE	Space Link Extension
TC	Telecommand
TM	Telemetry
UTC	Coordinated Universal Time