The Consultative Committee for Space Data Systems

SPACE LINK EXTENSION SERVICES—

EXECUTIVE SUMMARY

INFORMATIONAL REPORT

CCSDS 910.0-G-2

GREEN BOOK

March 2006

FOREWORD

This Informational Report provides an overview of Space Link Extension (SLE) Services. It is designed to assist readers with their review of existing and future SLE documentation.

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DOCUMENT CONTROL

Document	Title	Date	Status/ Remarks
CCSDS 910.0-Y-1	Space Link Extension Services—Executive Summary	April 2002	Original issue, superseded
CCSDS 910.0-G-2	Space Link Extension Services—Executive Summary, Informational Report, Issue 2	March 2006	Current issue

CONTENTS

1 BACKGROUND TO SLE SERVICES

1.1 WHAT ARE SLE SERVICES?

The Space Link Extension (SLE) Services extend the return Telemetry (TM), forward Telecommand (TC) and forward Advanced Orbiting Systems (AOS) Space Link services defined by the Consultative Committee for Space Data Systems (CCSDS) that are used by many spacecraft operators between ground stations and spacecraft (see figure 1-1.). The SLE services extend the Space Link services:

– over distance;

– in time; and/or

– by adding information (i.e., annotation).

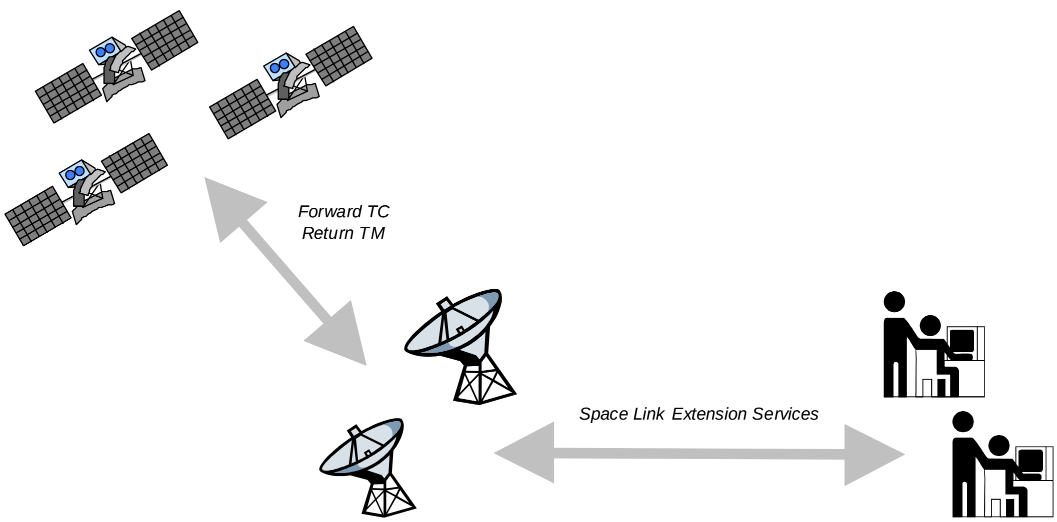

Figure 1-1: Ground Stations Provide SLE Services to Users

The SLE Services include two major elements:

– data transfer services that move space link data units between ground stations, control centers and end-user facilities;

– management services that control the scheduling and provisioning of the transfer services.

The SLE Services operate in two phases:

– the definition phase, when most of the management activities take place;

– the utilization phase, when the data transfer takes place (this can be either in real-time or off-line with respect to the contact time with the spacecraft).

The information carried by the SLE services can be anything from spacecraft commands in the forward direction to science data in the return direction. In addition, the service will convey information such as TM data reception times and ground station configuration information.

1.2 WHY DO WE NEED SLE SERVICES?

The need for SLE Services arises from the desire of spacecraft operations organizations to standardize the interfaces for the transport and management of space data on the ground so that the technical, management and operational costs of providing Cross Support between the organizations can be greatly reduced.

The SLE Services that have been defined by CCSDS at the time of writing cover on-line ‘conventional’ TM and TC services. These are the services that are used by the majority of missions.

Other SLE services may be defined in the future, as the need for them arises.

1.3 WHAT ARE THE BENEFITS OF SLE SERVICES?

SLE Services enable the ground segment assets of space agencies, ground station operators, and space data users to interoperate without the need for ad hoc and complicated gateways specifically designed for each new mission.

By standardizing on the SLE Services, different organizations will be able to link discrete elements of their ground segments to suit a given mission’s needs without having to re-create the interfaces for each new mission.

Since the SLE protocols run over existing communications infrastructure, they help integrate Space Data Systems into the global communications network.

The advantages of SLE services are that:

– space organizations will be able to provide Cross Support to one another more efficiently;

– ground station owners will be able to provide standard services to operators of spacecraft that use CCSDS Space Link protocols;

– users of spacecraft data will be able to command their payloads and access their data through a familiar interface, using widely available underlying telecommunications technology such as ISDN lines or, in some cases, the internet;

– the standardization of ground station, control center and end user interfaces will permit re-use of systems for successive missions and eliminate the costs and risks associated with mission-specific implementations;

– a global market for standard Telemetry, Tracking and Command (TT&C) Commercial Off The Shelf (COTS) products will be stimulated, reducing the cost of these systems;

– SLE services are scalable so that only the actual services required by a service user or a service provider need to be implemented.

1.4 OVERVIEW OF RETURN SLE SERVICES

The return SLE Services associated with conventional TM include:

– **Return All Frames (RAF)**, which provides the TM frames from a single space link symbol stream to spacecraft operators and other users who might need all the frames;

– **Return Channel Frames (RCF)**, which provides Master Channel (MC) or specific Virtual Channels (VCs), as specified by each RCF service user;

– **Return Frame Secondary Header (RFSH)**, which provides MC or VC Frame Secondary Headers (FSHs), as specified by each RFSH service user;

– **Return Operational Control Field (ROCF)**, which provides MC or VC Operational Control Fields (OCFs) channel, as specified by each ROCF service user;

– **Return Space Packet (RSP)**, which enables single users to receive packets with selected Application Process Identifiers (APIDs) from one spacecraft VC.

Figure 1-2 shows the data transfer interfaces for these services. (Depending on the services required, implementations will expose only a subset of these interfaces as SLE services.)

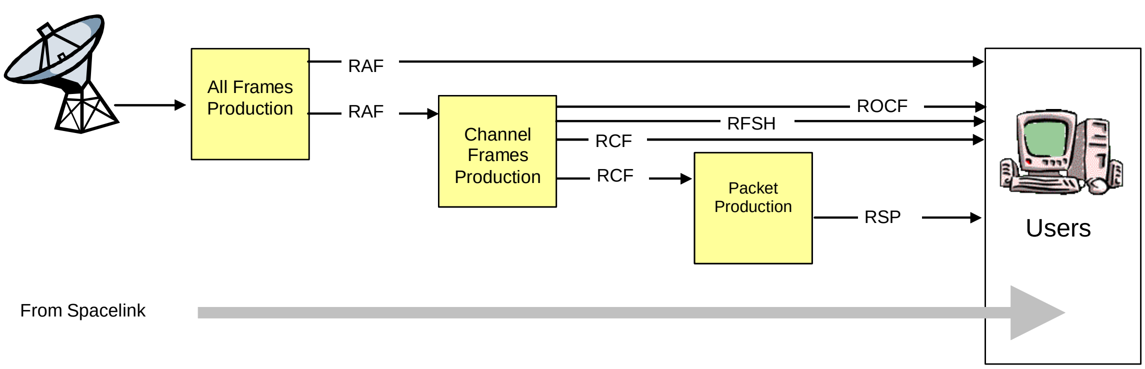

Figure 1-2: Conventional Return SLE Services Are Produced in Three Stages

1.5 OVERVIEW OF FORWARD SLE SERVICES

The forward SLE Services associated with conventional TC include:

– **Forward Space Packet (FSP)**, which enables single users to provide packets for uplink to a spacecraft without needing to co-ordinate with other users of the spacecraft;

– **Forward Telecommand Virtual Channel Access (FTCVCA)**, which enables users to provide complete VCs for uplink;

– **Forward Telecommand Frame (FTCF)**, which enables users to supply TC frames to be transformed to Communications Link Transmission Units (CLTUs) ready for uplink;

– **Forward Communications Link Transmission Unit (CLTU)**, which enables users to provide CLTUs for uplink to spacecraft.

Figure 1-3 shows the data transfer interfaces for these services. (Depending on the services required, implementations will expose only a subset of these interfaces as SLE services.)

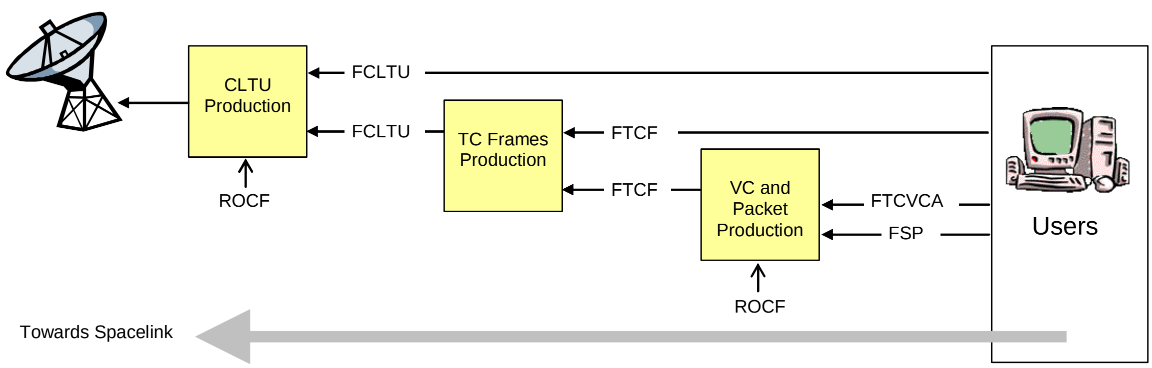

Figure 1-3: Three Stage Approach to Conventional Forward SLE Services

Figure 1-3 shows the ROCF service as an input to the CLTU Service Provider and the VC and Packet Service Provider. The ROCF service provides the Communications Link Control Word (CLCW), which is required by the CLTU Service Provider to determine the availability of the physical space link channel and by the VC and Packet Service Provider to determine if TC frames need to be retransmitted when the Communications Operation Procedure 1 (COP-1) is in effect.

1.6 REFERENCES

The following documents are referenced in this Administrative Report. At the time of publication, the editions indicated were valid. All documents are subject to revision, and users of this Administrative Report 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-9. Yellow Book. Issue 9. Washington, D.C.: CCSDS, November 2003.

[2] *Cross Support Concept — Part 1: Space Link Extension Services*. Report Concerning Space Data System Standards, CCSDS 910.3-G-3. Green Book. Issue 3. Washington, D.C.: CCSDS, March 2006.

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

[4] *Space Link Extension—Service Management—Service Specification*. Draft Recommendation for Space Data System Standards, CCSDS 910.11-R-1. Red Book. Issue 1. Washington, D.C.: CCSDS, March 2006.

[5] *Space Link Extension—Return Operational Control Fields Service Specification*. Recommendation for Space Data System Standards, CCSDS 911.5-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, December 2004.

[6] *Space Link Extension—Return Channel Frames Service Specification*. Recommendation for Space Data System Standards, CCSDS 911.2-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, December 2004.

[7] *Space Link Extension—Return All Frames Service Specification*. Recommendation for Space Data System Standards, CCSDS 911.1-B-2. Blue Book. Issue 2. Washington, D.C.: CCSDS, December 2004.

[8] *Space Link Extension—Forward CLTU Service Specification*. Recommendation for Space Data System Standards, CCSDS 912.1-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, April 2002.

[9] *Space Link Extension—Forward Space Packet Service Specification*. Recommendation for Space Data System Standards, CCSDS 912.3-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, December 2004.

[10] *Space Link Extension—Internet Protocol for Transfer Services*. Draft Recommendation for Space Data System Standards, CCSDS 913.1-R-1. Red Book. Issue 1. Washington, D.C.: CCSDS, October 2005.

2 SLE SERVICE OPERATIONS

2.1 SLE DATA TRANSFER

The way in which SLE data transfer is organized is best illustrated by an example. Figure 2-1 shows how the Service Provider modules described in the previous section combine into ‘SLE complexes’ that together form the ‘SLE System’. SLE Complexes are formed from a combination of one or more forward and/or return Service Provider modules. The SLE System interacts with the end-users who are part of a ‘Mission Data Operations System (MDOS)’. The figure illustrates the transfer of space packets to the end users.

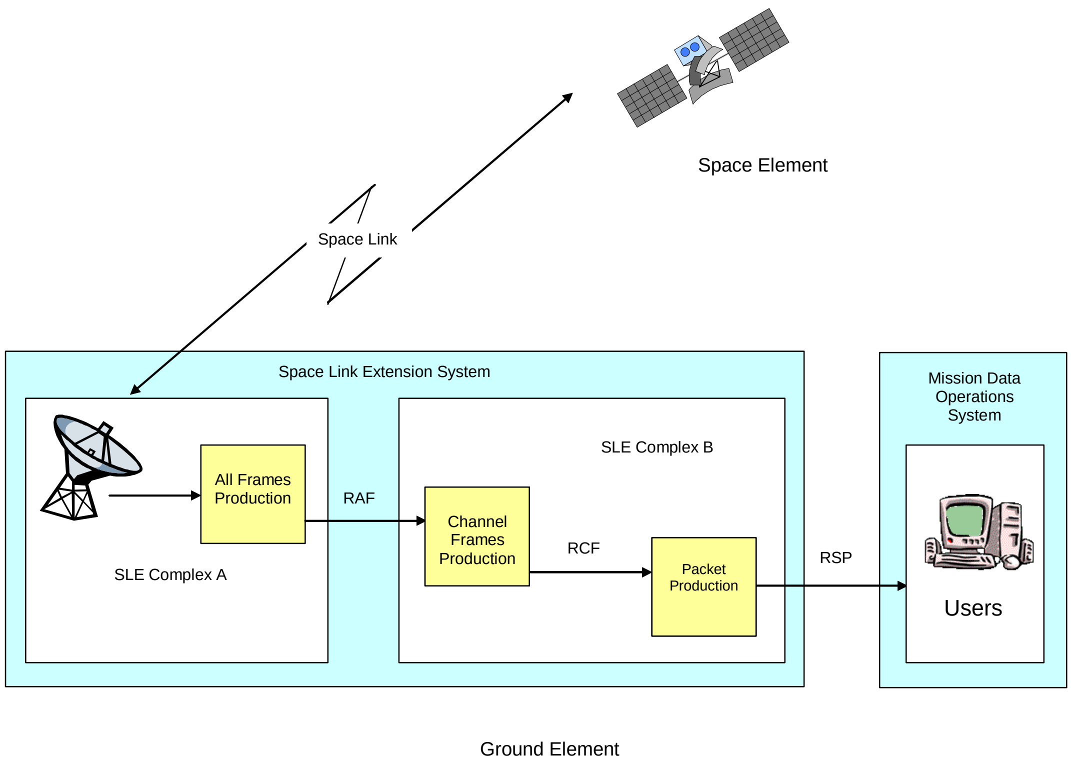

Figure 2-1: Example of SLE Data Transfer

Several features of this example are worth highlighting:

– SLE Complex A represents the installation at a ground station of an RAF service provider. In a real system, there could be a number of ground stations providing this service from various locations on the Earth. In this example, the ground station includes a ‘production’ element to extract frames from the TM stream.

– SLE Complex B represents the TM processing system of a typical operations center, which acts as a user of the RAF data service from one or more ground stations and provides a space packet data service for its users. (In some implementations, the operations center may be integrated with the MDOS).

- The MDOS represents users of the RSP service. These could be scientists in universities receiving data from their instruments or operations engineers in spacecraft control centers receiving spacecraft housekeeping data.
- In a cross support scenario, SLE Complex A and SLE Complex B will typically be operated by different organizations. However, once SLE Services are implemented throughout an organization, they are likely to provide a cheaper and more effective way to operate that organization's internal services as well.
- The underlying telecommunications technology between the complexes and between Complex B and the MDOS may be different. For instance, there may be an ISDN link between the complexes to assure a high quality of service, whereas the interface between Complex B and science data users in the MDOS may be the Internet.

Figure 2-1 shows only the return path. In reality, many complexes will handle both forward and return services. For example, it would be normal for Complex A to also provide CLTU service, as shown in figure 2-2.

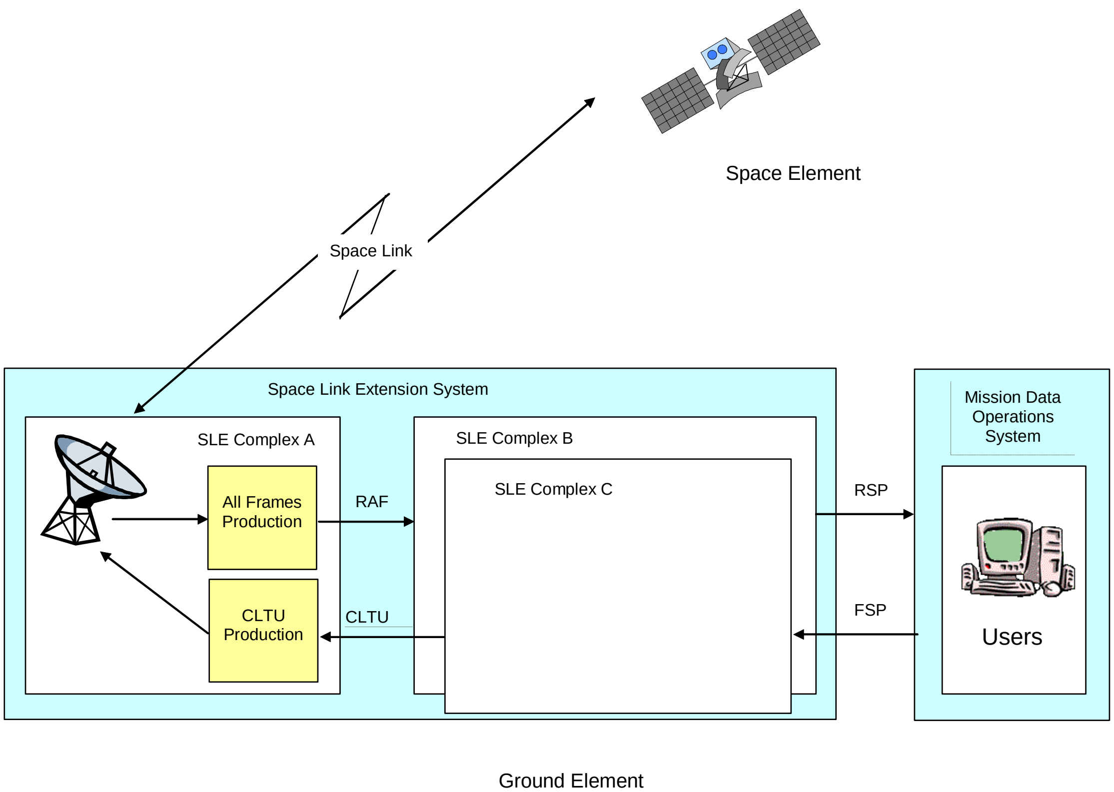

Figure 2-2: An SLE Complex May Provide Both Forward and Return Services

In figure 2-2, the ground station corresponding to SLE Complex A provides both RAF and CLTU services. Typically these services may be provided simultaneously from and to a particular spacecraft. Sometimes several complexes will require the services of Complex A over a period of time.

2.2 SLE SERVICE MANAGEMENT

SLE Service Management facilitates the collection and exchange of all information which is required to agree, schedule, prepare and access SLE services. To achieve this, SLE Service Management provides standardized information templates and interaction mechanisms.

Information templates capture all the parameters necessary for:

– detailing the service types and service instances required to support a mission phase;

– scheduling of the service instances;

– determining the SLE Complex resources to be allocated for SLE service production;

– creating and exposing interfaces for access to, and control of, service instances;

– configuring, monitoring and controlling by the provider of the SLE Complex resources during the execution of the service.

Interaction mechanisms ensure the safe and efficient exchange of the information items between 'Utilization Management' (UM) on the user side and 'Complex Management' (CM) on the provider side.

The management interactions between space mission users and service providers cover:

– negotiating a Service Agreement;

– defining Configuration Profiles for the service;

– generating Service Packages;

– and, where applicable, Trajectory Predictions used by the provider to acquire the spacecraft.

The standard operations and data structures associated with these processes are defined in the *SLE Service Management Service Specification* (reference [4]).

The entities involved in SLE Service Management are shown in figure 2-3 and include:

– Complex Management in one or more SLE Complexes;

– Utilization Management in an MDOS.

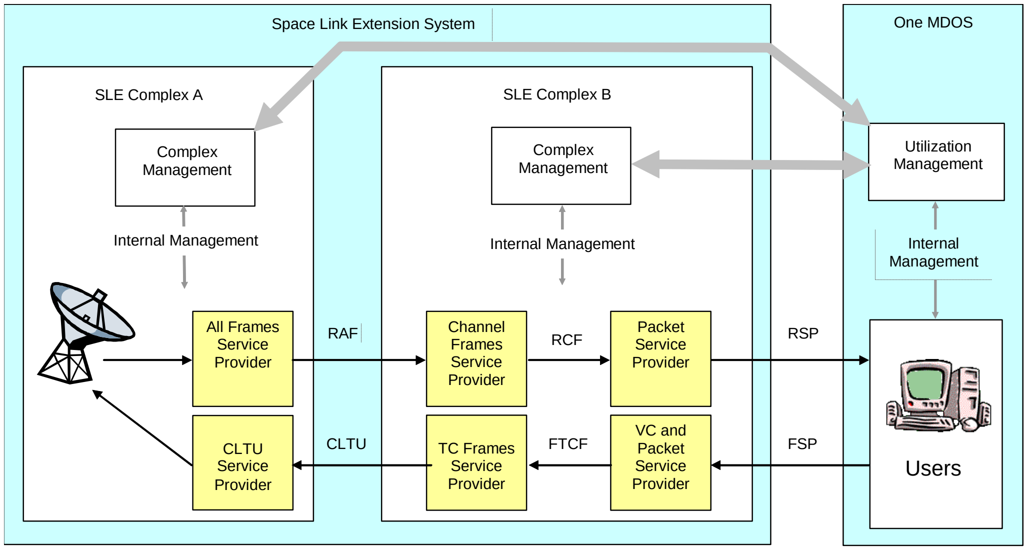

Figure 2-3: Managing SLE Services

It is the responsibility of Utilization Management to request the ground station and mission operations services needed by the mission. The way in which a particular mission coordinates the requirements of scientists, engineers and operations staff is an internal matter for that mission. Utilization Management would typically be the function of a spacecraft's mission manager, supported by the payload manager and operations manager.

Complex Management interacts with Utilization Management through service-oriented operations. Complex Management then translates these operations into the interactions with the equipment that is needed to monitor and control the complex resources. The interface between the Complex Management and Utilization Management is defined in the SLE Service Management Service Specification (reference [4]). The internal interfaces are a matter for the SLE Complex. The Complex Management is typically exercised by ground station operators and operations centers.

Figure 2-4 shows the relationship of SLE Service Management to both the resources needed to execute the SLE data transfer and the resources needed to manage the service, using the example of RAF and CLTU services. The interfaces between Complex Management and these resources are a matter for internal design. However, the design must be able to pass the parameters that are required by SLE Service Management.

Figure 2-4 also shows that the interactions between the Utilization Management and Complex Management are governed by a Service Agreement that governs the types of services and the number of service instances to be executed.

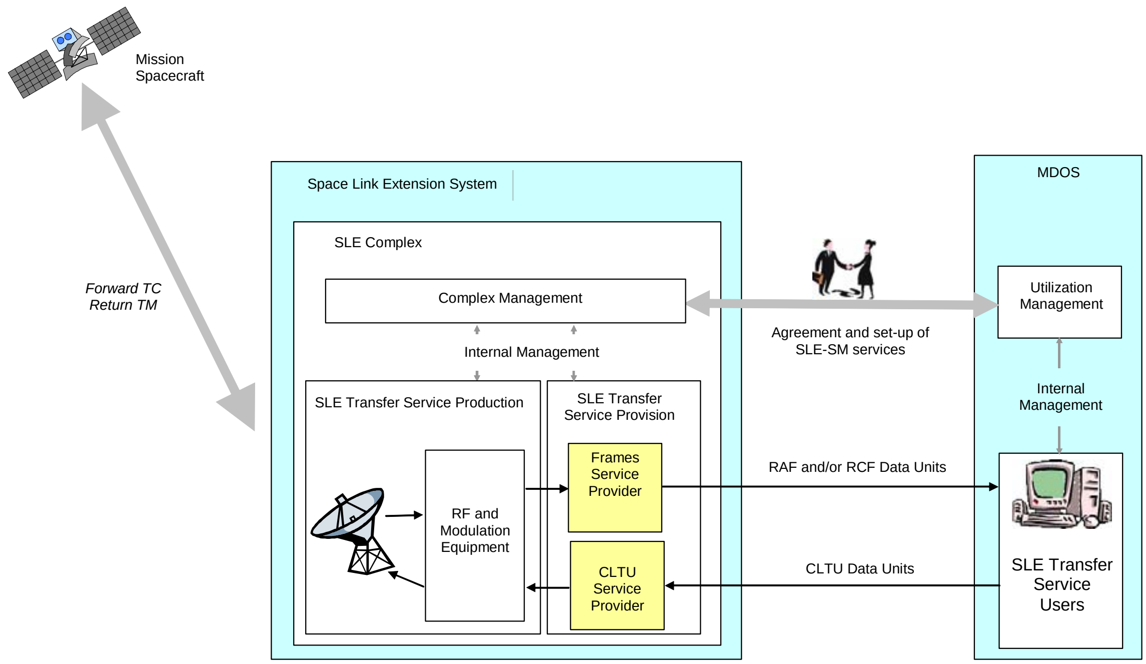

Figure 2-4: Data Transfer and Management Resources

2.3 THE SLE SERVICE LIFECYCLE

The activities involved in planning and utilizing an SLE service are shown in figure 2-5. The four main activities are as follows:

1. Make an Agreement

   A mission will contact ground station providers and/or operation centers requesting an appropriate set of SLE Services. The provider(s) will respond according to the suitability and availability of their resources at the times requested by the user. If the user and provider proceed, the result will be a Service Agreement and a set of provisional Configuration Profiles and Trajectory Predictions that contain the information about the space link characteristics and spacecraft position that are required to execute the services requested by the user.

2. Iterate the Details of the Service

   For a new mission, the space link TT&C parameters will be finalized and the predicted orbit parameters will become more accurate as the launch approaches. The user will be able to generate Service Packages that call up the specific Configuration Profiles and Trajectory Predictions that are needed to execute the SLE services that are required.

3. Set Up the Complex

   As the time for the execution of each Service Package approaches, each complex will need to commit the resources needed to execute the Service Package.

4. Execute the Service

   SLE data transfers take place in accordance with the negotiated Service Package(s).

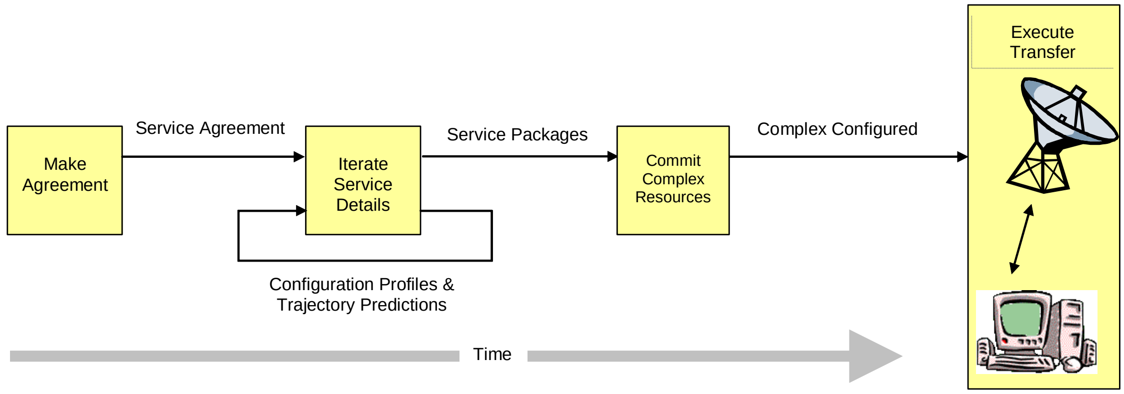

Figure 2-5: The SLE Service Agreement Lifecycle

3 IMPLEMENTING SLE SERVICES

3.1 IMPLEMENTATION OPTIONS

The SLE Services may be implemented incrementally in existing user and provider ground systems. New implementations may take advantage of commercially available implementations of the SLE Transfer Service Application Program Interface (API) specification (reference [10]).

Typical steps in the process are as follows:

1. Implement the data transfer protocols using the SLE Transfer Service API.

   Only the services actually needed by the user or provider need to be implemented. For example, only the CLTU, RAF and RCF services have been implemented to enable the Jet Propulsion Laboratory (JPL) to support the European Space Agency's (ESA) International Gamma-Ray Astrophysics Laboratory (INTEGRAL) mission. Service management issues can still be handled in an ad hoc way at this stage.

2. Implement the service management protocols in order to simplify the setting up and provisioning of the service.

   Only those service management services that support the required transfer services need to be implemented at this stage e.g. Service Package service for RAF only, plus heritage implementations of Configuration Profile and Trajectory Prediction.

3. Implement the data transfer protocols and service management services completely.

   Typically, only a limited number of providers of SLE Services would do this. Users of the SLE Services would tend to focus on a particular service, e.g., control centers might just need to use the CLTU and RAF services, and science users might just need to use the FSP and RSP services.

3.2 TECHNOLOGY CONSIDERATIONS

The SLE Service Recommendations are written in a way that is intended to be as independent of the implementation technology as possible. However, the following points should be noted:

– The SLE data transfer protocols are straightforward messaging protocols. They are currently supported by an SLE Transfer Service API that uses Transmission Control Protocol (TCP) and Internet Protocol (IP) as the underlying communications technology. Other APIs could be developed to support other communications protocols.

– The SLE Service Management specification has also been written using a messaging protocol approach typical of telecommunications network management. The formal service management specification is written in eXtensible Mark-up Language (XML).

3.3 FUTURE CROSS SUPPORT SERVICES

3.3.1 OVERVIEW

The SLE Services that have been defined by CCSDS at the time of writing cover ‘conventional’ TM and TC services. These are the services that are used by the majority of missions.

When there is a demand, the SLE Services will be extended to cover other CCSDS-defined services, including:

– off-line conventional TC services;

– forward Advanced Orbiting Systems (AOS) services.

In addition, the SLE Services will be complimented by Ground Domain Services (GDS) that will provide the additional cross support standards needed for operational implementations, including:

– security;

– tracking and orbit propagation;

– ground station monitoring and control interfaces;

– ground station planning interfaces.

The latter three items are discussed in subsections 3.3.2 through 3.3.4.

3.3.2 TRACKING AND ORBIT PROPAGATION SERVICES

In order to set up a Service Agreement for an SLE service, the mission manager needs to pass the orbit parameters to the provider using the Trajectory Prediction service. The provider then needs to check that the spacecraft will be visible from his ground station so that the service can be provided in principle.

Later, when the user submits the accurate orbit parameters, the provider needs to check that the spacecraft is visible from the ground station at the particular times and for the required durations specified by the user. To carry out this function, the provider will need to use a tracking and orbit propagation tool to validate the information provided by the user.

In addition, the user may need the support of the ground station to track the satellite. This type of service is about to be defined within the Cross Support Services Area (CSSA).

3.3.3 GROUND STATION MONITORING AND CONTROL INTERFACES

The provision of the CLTU and RAF services is intimately associated with the status of the ground station involved. It may therefore be efficient to standardize the interfaces between SLE Service Management and the various ground station monitoring and control implementations used by different organizations.

3.3.4 GROUND STATION PLANNING INTERFACES

When a user requests a particular service over a particular period, the provider needs to check the availability of the assets required (in particular, whether a ground station is available to provide the requested service). In order to do this, the provider needs to have a means of planning the use of the ground station.

Most ground station planning is currently carried out manually. In the longer term, a more automated system will be required that can:

– check the long-term availability of the ground station when a user initially requests a service;

– ‘block out’ periods allocated to particular users in the medium-term;

– schedule the detailed operations in the short-term.

A further degree of complexity arises when a provider operates several ground stations, each of which can support particular phases of a given mission. In this case, there is an additional layer of planning that needs to allocate certain ground stations to certain users. The planning systems will need to be flexible enough to accommodate changes in allocations at each planning stage. The SLE service management Service Package service is designed to accommodate this flexibility.

Space agencies, through the CSSA, will need to examine the ground station planning issue and recommend standard ways of interchanging planning information between users and providers. Although ground station operators should then comply with a standard interface to be CCSDS-compliant, they will still be free to implement planning systems in a way best suited to their normal practices.

4 SLE DOCUMENTATION

4.1 ROADMAP TO SLE DOCUMENTS

The SLE Documentation is organized as shown in figure 4-1.

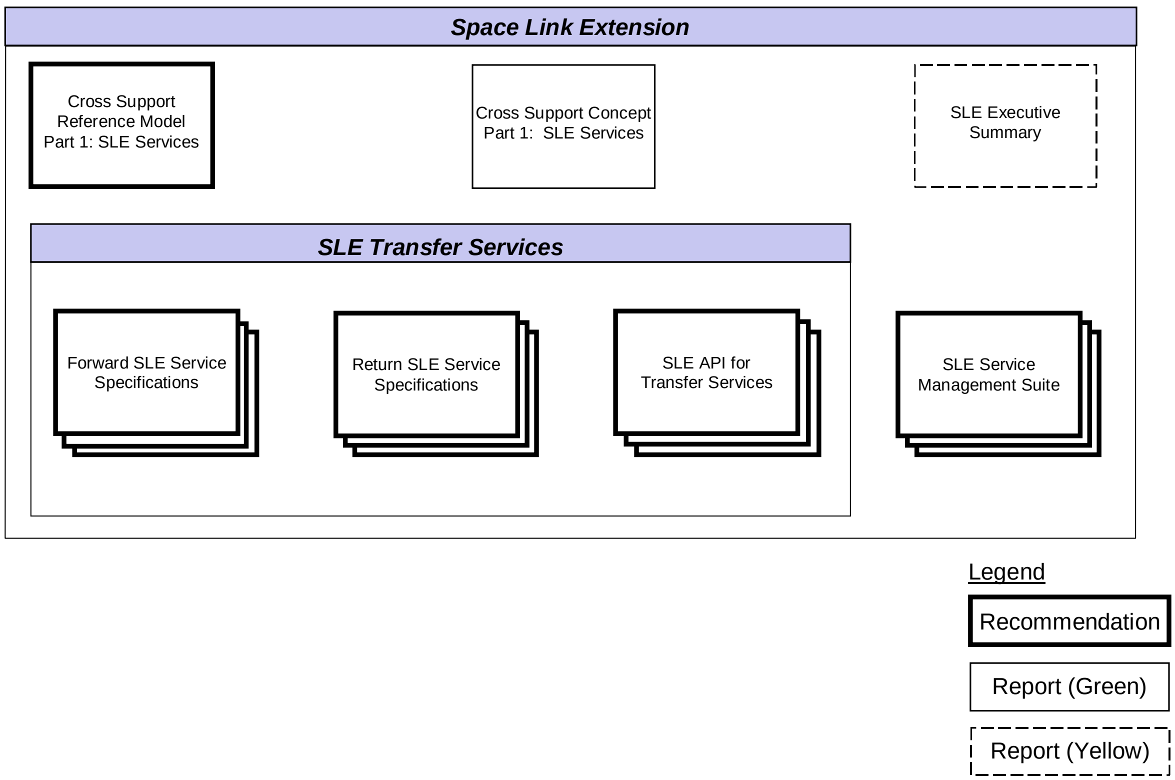

Figure 4-1: Space Link Extension Services Documentation Hierarchy

The SLE documentation includes:

– A CCSDS Report that describes the SLE cross support concept (reference [2]);

– A CCSDS Recommended Standard that defines the cross support Reference Model used in the data transfer and service management specifications (reference [3]);

– A CCSDS Recommended Standard that specifies SLE Service Management services (reference [4]);

– A set of CCSDS Recommended Standards that specify the Return transfer services (references [5] – [7]);

– A set of CCSDS Recommended Standards that specify the Forward transfer services (references [8] - [9]);

– A CCSDS Recommended Standard that specifies the SLE API (reference [10]).

4.2 GUIDE TO FURTHER READING

Readers wishing to have a more complete understanding of the SLE services may like to read one or more of the Reference Documents (RD) listed in subsection 1.6. The following guide indicates which documents are most appropriate in a given situation:

For an introduction to the concepts of cross support and SLE Services,	→ read the Concept Document [2]
To understand the model underlying the SLE Recommendations,	→ read the Reference Model [3]
To implement only the SLE data transfer service, with ad hoc service management,	→ read both of the above, plus the Transfer Service Specifications, [5] to [10]
To implement a complete SLE Service, including Service Management,	→ read all the above, plus relevant sections from the Service Management Specification [4]

Further information on the SLE Services may be found on the CCSDS web site at http://www.ccsds.org.

ANNEX A

ACRONYMS AND ABBREVIATIONS

AOS	Advanced Orbiting Systems
API	Application Program Interface
APID	Application Process Identifier
CCSDS	Consultative Committee for Space Data Systems
CFDP	CCSDS File Delivery Protocol
CLCW	Communications Link Control Word
CLTU	Communications Link Transmission Unit
COP-1	Communications Operation Procedure 1
COTS	Commercial Off The Shelf
CSSA	Cross Support Services Area
ESA	European Space Agency
FSH	Frame Secondary Header
FSP	Forward Space Packets
FTCF	Forward Telecommand Frames
FTCVCA	Forward Telecommand Virtual Channel Access
GDS	Ground Domain Services
IP	Internet Protocol
ISDN	Integrated Services Digital Network
JPL	Jet Propulsion Laboratory
MC	Master Channel
MDOS	Mission Data Operations System
OCF	Operational Control Field
RAF	Return All Frames

RCF	Return Channel Frames
RD	Reference Document
RFSH	Return Frame Secondary Header
ROCF	Return Operational Control Field
RSP	Return Space Packet
SCPS	Space Communications Protocol Standards
SLE	Space Link Extension
TC	Telecommand
TCP	Transmission Control Protocol
TM	Telemetry
TT&C	Telemetry, Tracking and Command
UML	Unified Modeling Language
VC	Virtual Channel
XML	eXtensible Mark-up Language