

CCSDS SPACE LINK EXTENSION (SLE) SERVICES -- OVERVIEW AND PROGRESS REPORT

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Abstract

CCSDS Space Link Extension (SLE) Services enable the ground segment assets of space agencies to interoperate, allowing for ground stations and space data users to interact without the need for ad hoc, complicated gateways designed specifically for each new mission. Their goal is to reduce the development, management, and operational costs of providing cross support between space organizations.

This paper first presents an overview of the underlying SLE architecture, as defined in the SLE Reference Model. The SLE data transfer services, which move data between mission facilities and ground stations are defined, along with the management services that enable missions to make requests for ground station services. Next, up-to-date status of the testing, prototyping, and implementation of SLE services over the past few years is presented, as well as plans for adoption of SLE services by a number of space networks and space mission organizations. Finally, efforts to adapt SLE services to support legacy missions are briefly described.

CCSDS

The Consultative Committee for Space Data Systems (CCSDS) was formed in 1982 by major space agencies of the world to provide a forum for discussion of common problems of space data systems. It is currently composed of ten member agencies, twenty-three observer agencies, and over 100 industrial associates. Since its establishment, it has been actively developing recommendations for data and information systems standards to:

- Reduce the cost to the various agencies of performing space missions

- Enable cross support for space missions

- Improve understanding of space related data

- Ensure preservation of archived space related data.

After CCSDS recommendations are approved by member agencies, they become international data standards through the International Standards Organization (ISO). Over 100 worldwide space missions have used CCSDS communications protocols to communicate with their spacecraft.

Origin of SLE Services

The Space Link Extension services are the result of an effort undertaken by CCSDS in the early 1990's to standardize cross support services that transfer spacecraft command and telemetry data among ground stations, mission operations centers, data processing facilities, and other parties that communicate with the spacecraft. That effort produced the *Cross Support Reference Model* [Ref. 1], which provides an architectural framework for definition of the SLE cross support services.

The Cross Support Reference Model

The focus of SLE services, and thus of the Cross Support Reference Model, is the interface between ground stations and the mission data systems that they support (Figure 1).

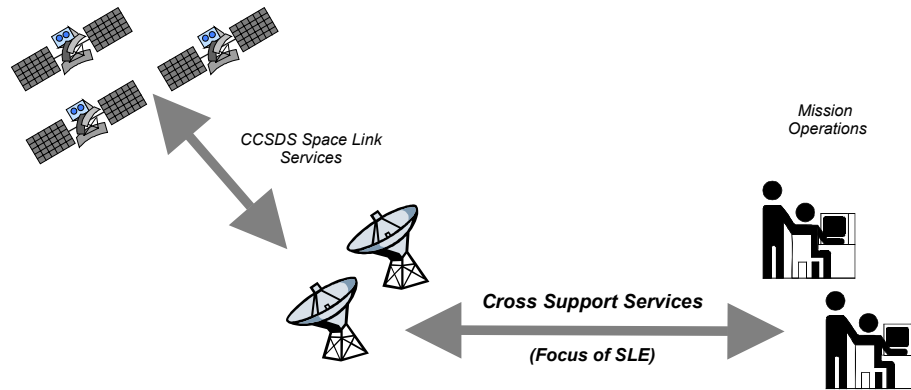


Figure 1: Cross Support Services Extend the Space-Ground Link

A Space Data System (Figure 2) has two primary elements: a space element and a ground element. The space element and ground element are linked by space link communications services, which carry return data and forward data. Return data is sent from the space element to the ground element (e.g., telemetry). Forward data is sent from the ground element to the space element (e.g., telecommand).

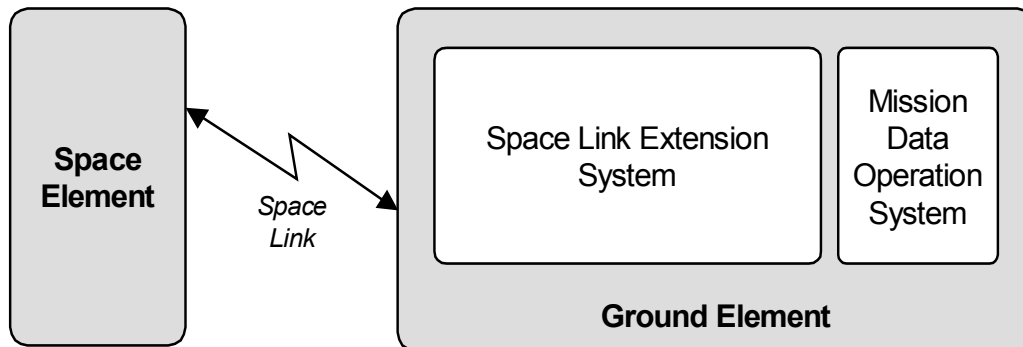


Figure 2: Space Data System

The ground element of a Space Data System includes an SLE System and a Mission Data Operation System (MDOS). It may also contain other components, but these are outside the scope of the Reference Model.

The SLE System extends the transfer and delivery of forward and return data between a space link ground termination point and the MDOS. The set-up and use of the SLE System by a mission is managed by the MDOS (e.g., by mission operators or systems in a control center).

The space link services are extended on the ground using the Space Link Extension services. In addition to extension over the distance between ground station and data users, SLE services add annotation to the data, and may provide delayed delivery through off-line services.

The SLE services include two major elements:

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

SLE management services that control the scheduling and provision of the SLE transfer services.

The SLE services are used both for set-up and for data operations. During set-up, SLE management services are used to specify the configuration parameters needed to support a mission during an upcoming

spacecraft contact. During execution, SLE transfer services are provided to the mission over ordinary ground networks. SLE management services are used to monitor progress during the contact. Off-line SLE transfer services may also be provided, outside periods of contact with the spacecraft.

The Reference Model defines transfer services for all types of CCSDS data units that can transverse the space link, but, in practice, only a few are used for cross support. These are:

Forward Command Link Transmission Unit (F-CLTU) service, which enables users to provide CLTUs for uplink to the spacecraft [Ref. 2].

Return All Frames (RAF) service, which provides the stream of telemetry frames from a single space link symbol stream to spacecraft operators and other users who might need all the frames [Ref. 3].

Return Channel Frames (RCF) service, which provides a Master Channel (MC) or specific Virtual Channels (VCs) extracted from a particular RAF channel, as specified by the RCF service user [Ref. 4].

Return Space Packet (R-SP) service, which enables a user to receive packets with selected Application Process Identifiers from a Virtual Channel [Ref. 5].

Benefits of SLE Services

SLE services further the goal of interoperability by establishing a standard for services to be used in the area where most cross support activity occurs - between the tracking stations or ground data handling systems of various organizations and the mission-specific components of a mission ground system. The SLE services are applicable to routine, contingency and emergency operations. 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 are able to provide Cross Support to one another more efficiently;

ground station owners are able to provide standard services to operators of CCSDS-compliant spacecraft;

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

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

a truly global market for standard telemetry, tracking and command (TT&C) commercial off the shelf (COTS) products will be created, driving down the cost of these systems;

SLE services are scalable, so only the services actually required by a service user or a service provider need to be implemented.

SPACE LINK EXTENSION (SLE) SERVICES - STATUS

Several ground networks are already providing SLE transfer services to operational space missions, and more will do so over the next few years. All of these systems will use TCP/IP communications between the SLE Provider and User facilities. Summaries of current and planned SLE-related activities are provided below.

SLE Implementations

Europe-ESA

Currently, there are three ESA mission using SLE services. These are:

INTEGRAL, ESA's International Gamma-Ray Astrophysics Laboratory, will be launched in October 2002 on a Proton rocket from Baikonour, Kazakhstan. INTEGRAL will pinpoint and study gamma-ray sources in unprecedented detail. The INTEGRAL Science Data Centre (ISDC), located near Geneva, is supported and funded by a dozen institutes in Europe and the United States.

Rosetta will be launched in January 2003 by an Ariane-5 from Kourou, French Guiana. Rosetta will study the nucleus of comet Wirtanen and its environment in great detail for a period of nearly two years, with far-observation leading ultimately to close observation from about one kilometer.

Mars Express will be launched from Russia by a Soyuz Fregat in June 2003. Arrival at Mars is planned for the following December. The mission's main objective is to search for sub-surface water from orbit and drop a lander on the Martian surface. The lander, called Beagle 2, will perform exobiology and geochemistry research. Mars Express will also provide relay communication services between the Earth and landers deployed on the surface by other space agencies.

For each of these missions the following SLE services are provided:

Return All Frames (RAF) online/timely, online/complete and off-line for Telemetry

Return Channel Frames (RCF) online/timely, online/complete and off-line for Telemetry

CLTU service for commanding uplink

These SLE services are implemented cooperatively between ESA's European Space Operations Center (ESOC) and NASA/JPL, with ESA in the role of "service user" and JPL as the "service provider". SLE Service Management for these missions is implemented as a private (ad hoc) management scheme to support SLE operational set-up, based on predefined tables that describe frequencies, bit rates, and other parameters. Any changes needed during a pass are handled over a voice loop. Interoperability tests between ESA and NASA/JPL have been performed successfully in preparation for the launch of INTEGRAL.

ESA plans full deployment to its Ground Station Network in 2003

Germany-DLR

The German Space Agency (DLR) is planning to use SLE services in its German Spacecraft Operations Center (GSOC) in Oberpfaffenhofen, Germany, and in its Ground Station at Weilheim, Germany to support future missions. The first two missions to use SLE services are:

TerraSAR, scheduled for launch in 2004. TerraSAR is a 2-satellite earth observation system with both X-band and L-band radars having a ground resolution of 1 meter. It is a joint venture by DLR (Germany), the British National Space Centre, Matra Marconi Space U.K., and DaimlerChrysler Aerospace (Germany).

SARLupe is a Space-based reconnaissance system. The Space segment consists of monofunctional radar satellites providing high resolution images under all weather conditions.

Prototyping of SLE services is underway at GSOC, with mission checkout scheduled for 2003 and support of mission operations in 2004.

Japan-ISAS & NASDA

In Japan, both the Institute of Space and Astronautical Science (ISAS) and the National Space Development Agency (NASDA) are using SLE services to support their missions.

The following are the ISAS and NASDA missions that plan to use SLE in the near future:

MUSES-C has been designed to investigate an asteroid, and to bring back samples of its surface. The target asteroid is **1989ML**, about 400 meters in diameter, and is unusual in that it sometimes closely approaches Earth. MUSES_C is an ISAS mission and will be supported by NASA/JPL's Deep Space Network. Launch is planned for late 2002.

Solar-B is a Japanese Institute of Space and Astronautical Science (ISAS) mission consisting of a coordinated set of optical, extreme ultraviolet, and X-ray instruments that will investigate the interaction between the Sun's magnetic field and its corona. Instruments from investigators from the U.K. and U.S. will fly on Solar-B. The Solar-B spacecraft is scheduled for launch in the fall of 2005, into a sun-synchronous orbit about the Earth. Solar-B will be supported by SLE services from NASDA.

DRTS, the Data Relay Test Satellite is a NASDA mission that will conduct in-orbit demonstration tests to improve existing satellites' data relay functions and performance. Launch is scheduled for September, 2002, with SLE services provided by ISAS.

Both ISAS and NASDA are developing gateways that perform protocol conversion between SLE and their internal protocols.

U.K.-BNSC

QinetiQ has installed a prototype SLE system in their ground station at West Freugh in Scotland. This system was developed by VEGA Group (UK), and provides Return All Frames (RAF) and Forward CLTU (F-CLTU) transfer services, as well as a web-based SLE service management interface [Ref. 6].

The Rutherford Appleton Laboratory (RAL) are planning to install a similar system in their ground station next year, so that this facility can provide SLE services cooperatively with the QinetiQ ground station to near-earth, deep space, and communications spacecraft.

Future plans include interoperability demonstrations with ESA and NASA networks.

U.S.-NASA/JPL

JPL has developed new interfaces to its Deep Space Network (DSN) to provide SLE transfer services, in preparation for support of a number of U.S. and international missions. ESA's INTEGRAL mission was the first for which SLE services were planned, but NASA's CONTOUR mission, developed by the Johns Hopkins University Applied Physics Laboratory, was the first to launch (July, 2002) using SLE services. By that time, JPL had already transitioned to using SLE Forward CLTU service for transfer of uploads from Pasadena to DSN stations for support of previously launched spacecraft.

All future missions supported by DSN are expected to use SLE transfer services, for both forward and return data traffic.

U.S.-NASA/GSFC

NASA, through its CSOC contract, is developing a NASA-wide Ground Data Service Specification to provide CCSDS SLE Services at all NASA and commercial ground tracking stations serving NASA missions. A study team was formed to investigate the phasing out of NASA ground communications services based on Nascom blocks and to propose a replacement data service for all NASA ground facilities and commercial ground facilities that support NASA missions. The study team concluded that CCSDS Space Link Extension (SLE) meets the objectives for future science missions (based on CCSDS

space links) for Space Network (SN--i.e., TDRSS), the Ground Network (GN), and the Deep Space Network (DSN). A proposal to implement SLE Services in these networks is under evaluation.

Adaptations of SLE Services

The United States Air Force (USAF) is considering use of SLE Services in the Air Force Satellite Control Network (ASFCN) to ease transition from circuit-switched to packet-switched networking, and to provide interoperability with NASA ground sites. Global Science and Technology Inc. (GST) has developed prototype adaptations of SLE Services to demonstrate that SLE transfer services can support serial bit stream delivery in support of ASFCN legacy missions.

Outlook—Where is SLE Going?

The Interagency Operations Advisory Group (IOAG), at its fourth meeting in December 2001, reached agreement to proceed with CCSDS Space Link Extension (SLE) as the prime data service for future science missions. Also at this meeting, The French space agency, CNES, and the Italian space agency, ASI, reported plans for use of SLE Services in their new ground stations.

NASA is developing a NASA-wide Ground Data Service Specification to implement CCSS SLE Services at all NASA ground tracking stations

ESA's new 34 meter ground station in New Norcia, Australia, will provide Space Link Extension (SLE) services, including Telemetry (RAF, RVC) and Telecommand (CLTU, FSP), before December 2005.

SLE Service Management

NASA has begun development of a specification written in the eXtensible Markup Language (XML), based on the CCSDS SLE service management framework. This specification will enable the automation of service request exchanges using XML-based tools and technology. In parallel with writing of the specification, a prototype is being developed to demonstrate the XML Service Request capability [Ref. 7,8].

SLE Testbed

Efforts are underway to establish an SLE testbed to gain experience and confidence with the use of SLE Services, evaluate the feasibility of adapting SLE Services to support legacy missions, validate interoperability of SLE implementations, including commercial product and services, and demonstrate the potential of SLE Services to reduce risk and cost for future missions. Initial efforts will be directed toward demonstration of SLE transfer services, both forward and return. Later, SLE management services will be incorporated. Potential participants include: NASA/JPL, NASA/GSFC, USAF/AFSCN, international agencies, and commercial vendors.

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