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The China-Brazil Earth Resources Satellite - CBERS-4A: A proposal for Ground Segment based on the Space Link Extension Protocol Services

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Abstract

The CBERS program is a unique partnership between Brazil and China in the space technical and scientific sector for the primary remote sensing data generation technology, this partnership agreement involves the National Institute for Space Research (INPE) and China Academy of Space Technology (CAST). The program is a family of remote sensing satellites CBERS (CBERS-1 and 2, CBERS-3 and 4) that brought significant scientific advances to Brazil. The INPE, using only the CBERS-4, has distributed for free over the internet, approximately 90,000 images. Their images are used in important fields such as controlling deforestation and burning in the Amazon, the monitoring of water resources, agriculture, urban growth, land use and education. It is also critical for large strategic national projects such as Measurement of Deforestation by Remote Sensing (PRODES) and Brazilian Real-Time Deforestation Detection (DETER). The next satellite, CBERS-4A, is due to be concluded in 2019, its will be placed in a sun-synchronous Low Earth Orbit. Their optical payloads will be operated in the visible spectrum with resolutions in the range of 2 to 60 meters. As in previous missions, the Ground Segment is responsible for tracking and controlling of the satellites CBERS during the routine phase, including the orbit adjustment maneuvers to maintain the proper phase, that are made by Brazil, and by China, in alternating periods. In Brazil, the Ground Segment is comprised by the Satellite Control Center (SCC) - located in São José dos Campos, the TT&C Ground Stations of Cuiabá and Alcântara, the Mission Control Center, the Data Processing Center and the End User. The Ground Segment has more and more served as cross support and interoperability to space agencies, which requires an appropriate architecture to support them. The architecture proposal is based on Dynamic Management of the Space Link Extension (SLE) Protocol Services. These services are recommendations of the Consultative Committee for Space Data Systems (CCSDS) for cross support and have been adopted by several space agencies, for example: CNES, ESA, JAXA, NASA and INPE. This paper presents an overview of the CBERS Program, its science objectives and the CBERS-4A satellite's ground segment. It will then describe a proposal for implementation an Architecture for Dynamic Management of the Space Link Extension Protocol Services to be applied as part of the Ground Segment at INPE. The design's status and the possible contributions for a reduction the cost of space missions are also presented.

Keywords: CBERS-4A, Remote Sensing Satellite, Space Link Extension (SLE) Protocol, Satellite Control System, Space Mission Cost, CCSDS.

Acronyms

ACU	Antenna Control Unit
ALC	Alcântara (Brazilian TT&C Ground Station)
AIT	Assembly phase, Integration and Test
API	Application Program Interface
CAST	China Academy of Space Technology
CBA	Cuiabá (Brazilian TT&C Ground Station)
CBERS	China-Brazil Earth Resources Satellite
CCSDS	Consultative Committee for Space Data Systems
CDSR	Remote Sensing Data Center
CLTU	Communications Link Transmission Unit
CM	Complex Management
CMCD	Mission Center
DCS	Data Collection System
DDR	Digital Data Recorder
DETER	Real Time Deforestation Detection
DSS	Divisão de Desenvolvimento de Sistemas de Solo (Ground Systems Development Division)
DTS	Data Transmitter System
ERTS	Earth Resources Technology Satellite
ESA	European Space Agency
FDR	Project Final Review
GS	Ground Station
IBS	Integrated Baseband System
INPE	Instituto Nacional de Pesquisas Espaciais (National Institute for Space Research)

ISP1	Internet SLE Protocol One
LIT	Laboratório de Integração e Testes (Integration and Tests Laboratory)
LM-4B	Long-March 4B
MUX	Regular Multispectral Camera
NASA	National Aeronautics and Space Administration
RAF	Return All Frames
RCF	Return Channel Frames
RF	Radio Frequency
RG	Ranging Data
RGB	Red Green Blue
RR	Range Rate
POV	Plano de Operação de Voo (Fly Operation Plane)
PRODES	Measurement of Deforestation by Remote Sensing
SATCS	SATellite Control System
SCC	Satellite Control Center
SCCS-SM	Space Communication Cross Support - Service Management
SCD1	Satélite de Coleta de Dados 1 (Data Collecting Satellite 1)
SEM	Space Environment Monitor
SICF	Service Instance Configuration File
SL	Space Link
SLE	Space Link Extension
TC	Telecommand
TM	Telemetry
TSL C	Taiyuan Satellite Launch Base
TT&C	Telemetry, Tracking and Command
UM	Utilization Management
WFI	Wide Field Imager
WPM	Multispectral and Panchromatic Wide-Scan Camera

1. Introduction

The CBERS program was born out a unique partnership between Brazil and China in the space technical and scientific sector for the primary remote sensing data generation technology, this partnership agreement involves the National Institute for Space Research (INPE) and China Academy of Space Technology (CAST).

The program is a family of remote sensing satellites CBERS (CBERS-1 and 2, CBERS-3 and 4) that brought significant scientific advances to Brazil. The INPE, using only the CBERS-4, has distributed for free over the internet, approximately 90,000 images. Their images are used in important fields such as controlling deforestation and burning in the Amazon, the monitoring of water resources, agriculture, urban growth, land use and education. It is also critical for large strategic national projects such as Measurement of Deforestation by Remote Sensing (PRODES) and Brazilian Real-Time Deforestation Detection (DETER) and monitoring of sugarcane areas, among others.

Both systems DETER and PRODES are affected by the high frequency of clouds over the Amazon region. So, to ensure that the monitoring and measurement of deforestation is feasible, it is necessary to have remote sensing data in spatial and temporal resolutions compatible with these phenomena [1].

The requirement of high rate of revisits and the need of controlling and data reception of other remote sensing satellites available in Brazil, for example, the Amazonia-1 – it due to be concluded in 2019 - (5 days to revisit) impose challenges for the ground segment. As in previous missions, the Ground Segment is responsible for tracking and controlling of the satellites CBERS during the routine phase, including the orbit adjustment maneuvers to maintain the proper phase, that are made by Brazil, and by China, in alternating periods.

The Ground Segment has more and more served as cross support and interoperability to space agencies, which requires an appropriate architecture to support them. The architecture proposal is based on Dynamic Management of the Space Link Extension (SLE) Protocol Services. In this scenario, the CCSDS recommends normalizing cross support services [2-10] between the space agencies aiming at interoperability and standardization of data transfer services [11].

This paper is organized as follows: section 2 explains the Mission and Project Description, section 3 presents the INPE`S Ground Station, section 4 provides the Space Link and Space Link Extension Concepts, section 5 presents an proposed Architecture for Dynamic Management of the SLE Protocol Services to the CBERS-4A Satellite's Ground Segment, section 6 Mission Status, and section 7 the Conclusions.

2. Mission and Project Description

2.1. Mission

The CBERS-4A objective is to provide remote sensing images to observe and monitor vegetation - especially deforestation in the Amazon region - the monitoring of water resources, agriculture, urban growth, land use and education with a high revisit rate and considering the synergy with the existing programs PRODES and DETER.

CBERS-4A mission is an example of cooperation among the main areas of INPE. This project involves the Engineering and Space Technology; Satellite Tracking and Controlling, and Integration and Testing Laboratory as providers of solutions and the Earth Observation and Earth System Science areas as users.

The data from CBERS Program are available to users in the online catalog from INPE. The free offer of satellite images benefits the government's own territory management system, research universities and the development of private enterprises.

2.2. *Project*

The specifications of the Sino-Brazilian satellite - remote sensing satellite medium resolution provided optical payloads operating in the visible spectrum with resolutions in the range of 2 to 60 meter - are similar to remote sensing programs most used worldwide, such as Landsat (United States), ResourceSat (India) and Copernicus (European Union).

The configuration of the CBERS 04A is similar to that of CBERS-3 & 4 satellites, with improvements to accommodate the new Chinese Imager camera that has superior quality in geometric and spectral resolution.

2.2.1. *Spacecraft*

The satellite, figure 1, consists of two independent modules: a service Module and a Payload module, which houses image cameras and recording equipment and transmission of image data.

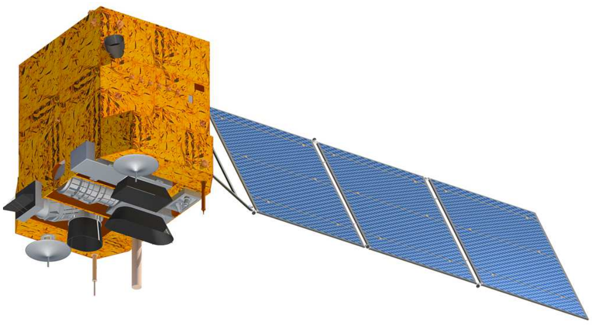

Figure 1. CBERS-4A Artistic Conception

In addition to the subsystems that make up the satellite, each country is responsible for providing a set of test equipment used to test the satellite during the assembly phase, Integration and Test (AIT).

In the table 1 below are shown the differences between the first generation satellite and the second generation.

Table 1. Differences between the satellites of the 1st and 2nd generation

	1st Generation		2nd Generation
Feature	CBERS 1,2 and 2B	CBERS 3,4	CBERS 4A
Total mass [kg]	1450	2080	1980
Generated Power [W]	1100	2300	2100
Data Rate [Mbps]	100	300	900
Service life [years]	2	3	5

2.2.2. *Orbit*

CBERS 04A will operate in a sun-synchronous orbit, which ensures uniform illumination during imaging, since the angle between the plane of the orbit and the line joining the center of the earth to the sun is kept constant throughout the mission and frozen applicant with the following nominal parameters:

- Altitude: 628.6 km;
- Inclination: 97.9 degrees;
- local time at descending node: 10:30 am;
- Repetition Cycle: 31 days;
- Revolutions/day: 14 +25/31;
- Stability in the downward local node: ± 10 minutes;
- Orbital Period: 97.25 minutes;
- Interval between adjacent tracks: 3 Days;
- Trace stability at the equator: ± 5 km.

Another important feature is the almost circularity of the orbit, which maintains a regularity in the imaging range, making objects in the scene in any orbital positions. The fixed distance between tracks on the equator aims to ensure an overlap between tracks of two images. The interval of three days between adjacent strips remains the same pattern as the previous imaging CBERS, and allows phenomena occurring in areas adjacent two imaging ranges may be viewed in a short time.

2.2.3. *Imagers*

The CBERS 04A is equipped with cameras to optical observations from around the globe, and a data collection system and environmental monitoring.

The satellite takes on board two Brazilian cameras (MUX and WFI) and Chinese (WPM). A MUX will generate images of 16 meters resolution, with revisits 31 days. The WFI has a resolution of 55 meters and revisit 5 days while WPM, has resolution of 2 meters in panchromatic and 8 meters in RGB. Payloads are all instruments directly related to the acquisition of scientific or related to satellite mission data:

- Multispectral and Panchromatic Wide-Scan Camera (WPM);
- Regular Multispectral Camera (MUX);
- Wide Field Camera (WFI);
- Image Data Transmitter (DTS);
- Digital recorder (DDR);
- Data Collection System (DCS);
- Space Environment Monitor (SEM).

The application potential of a given sensor is a function of their spatial resolution characteristics, temporal resolution, and spectral and radiometric characteristics.

In order to maximize the results for better cost and benefit should be considered a compromise between the needs of the application and the characteristics of the sensors.

2.3. The System Elements

The terrestrial infrastructure will be used to support the mission. The system is composed of the following segments (in details only the Brazilian infrastructure):

a) **The Space Segment**, is comprised of the spacecraft configured with the service module and the payload of instruments for Earth observation;

b) **Ground Control Segment,** being configured to: control the satellite, monitor and analyze its on-orbit operation is relying in the use of the two INPE Telemetry, Tracking, and Command (TT&C) Stations and Satellite Control Center (SCC);

c) **Application Segment,** will be comprised by INPE Reception and Recording Station (Brazilian Station), under upgrading process, located in Cuiabá, Mato Grosso state, and by the Mission Center (CMCD) to plan and define and coordinate the operation of the satellite imaging acquisitions by the payload, also comprising the corresponding Remote Sensing Data Center (CDSR, acronym in Portuguese) which collects, processes and stores the images received, making them available to the users;

d) ***The Launch Segment,*** responsible for placing the satellite in orbit. The launch of the satellite is scheduled for the second half of 2019 from the Taiyuan Satellite Launch Base (TSL C), located in Shanxi province, 700 km southwest of Beijing, through the launch vehicle Long-March 4B (LM-4B).

The CBERS-4A System Elements and their inter-relationship are shown in Figure 2.

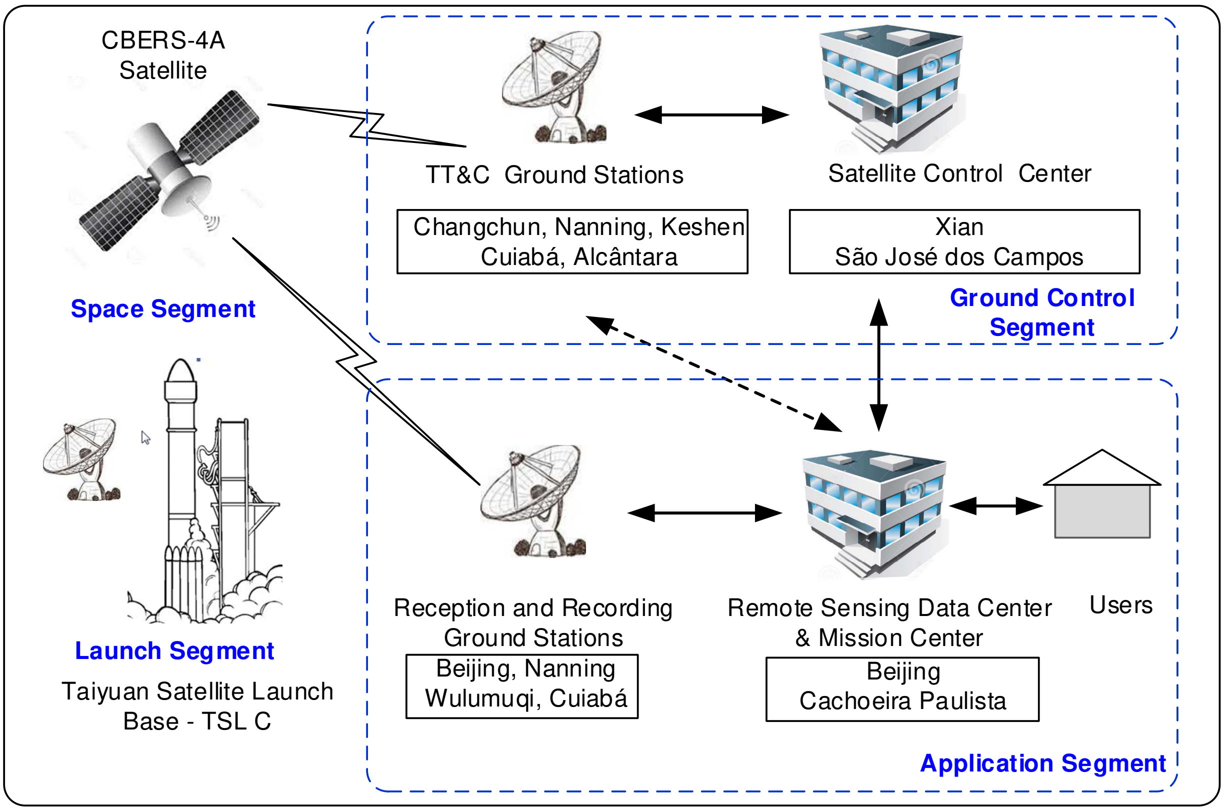

Figure 2. CBERS-4A - System Elements Overview.

3. INPE`S Ground Stations

3.1. Image Reception

Brazil was one of the first countries in the world to make civil use of Earth Observation satellites. The INPE, in 1973, started the tracking and obtaining the data from the first remote sensing satellite, called Earth Resources Technology Satellite-1 (ERTS-1), Landsat Series [1].

The Reception and Data Recording Station - ERG INPE, in Cuiabá, MT receives and continuously records the images transmitted by the CBERS satellites, Landsat-5 and 7, SPOT-4, ERS-2, and Radarsat-1.

The station consists of two subsystems reception and two recording subsystems. The reception subsystems are basically constituted by the antenna 10 m in diameter operating in bands S and X, the antenna 11.28 m in diameter operating in the X band and the respective Radio Frequency equipment. The recording subsystems consist of the two subsystems, whose recording capacity of each is of up to 160 Mbit/s, and the recording subsystem MATRA/CBERS intended for reception of CBERS images.

Regularly received data are transferred to the Image Processing Center Imaging Division in Cachoeira Paulista, in São Paulo State, for further processing and dissemination to end users.

Figure 3 shows details of the Reception and Recording Station in the ground system.

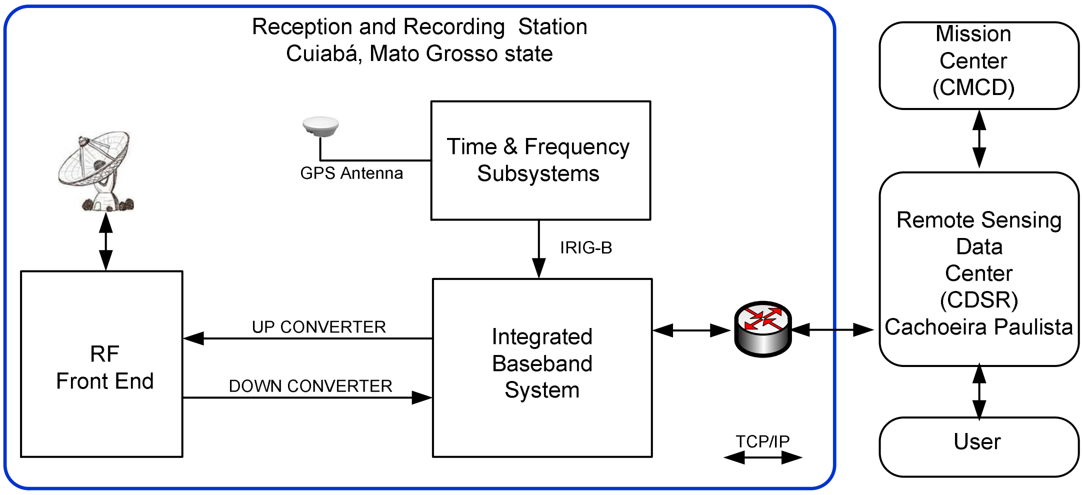

Figure 3. X-Band Reception and Recording Station

3.2. *TT&C Ground Station*

The operation and control of the satellites CBERS program during the routine phase including the orbit adjustment maneuvers to maintain the proper phase are made now by Brazil, now by China, in alternating periods, according to a unified program of the Center Xian Control.

The CBERS ground segment supports the activities necessary to control the satellites and to achieve the objectives of its remote sensing missions. Includes means for tracking, command and control the satellites and receiving, storing, processing and distribution of images.

The functions related to programming of the operations of the satellite cameras in response to user requests are made by the Mission Center in Cachoeira Paulista. However, the central element of all operations relating to the CBERS satellite and its mission control is the Satellite Control Center (SCC).

The Telemetry, Tracking and Command (TT&C) Ground Stations provide the link between the control personnel and the satellite, and are the stations used for the acquisition of raw data from the CBERS data collection system in S-band.

The Satellite Control Center receives a variety of satellite information that allows drivers keep themselves fully informed about the status of the satellite equipment, allowing to perform the necessary actions to ensure its proper operation.

The TT&C Ground Stations [10, 11] (GS) of INPE were built in 1988 to support the Data Collecting Satellite-1 (SCD1), which was launched 1993. They operate in S-band and are located Brazilian cities of Cuiabá and Alcântara. TT&C GSs are in charge of establishing communication between the ground control system and the satellites monitored during the visibility periods [10,12].

Figure 4 shows the INPE's Ground Station: SCC and the main systems of the GS: RF Front End, Receiver, Antenna Control Unit (ACU) and Time & Frequency. The functions of TM, TC, Ranging Data (RG), Range Rate (RR) and the SLE Provider are based on the Integrated Baseband System (IBS). The IBS allows the implementation of Space Link Extension (SLE) services for cross support and the interoperability between space agencies.

The SCC is responsible for plan and executes all activities related to the satellites control and is the administrative headquarters. The SCC is located in the city of São José dos Campos, Brazil. The main functions of a SCC are: orbit and attitude control, maneuvers calculation, operational payload configuration, real-time monitoring of the satellite health.

Over the structure of the SCC is embedded a software system, **SATellite Control System** (SATCS); developed by the Ground Systems Development Division (DSS) of coordination of Space Engineering and Technology at INPE. The SATCS is designed to be easily configurable and customized to meet different kind of satellites [13, 14].

The receiving stations images and processing centers in Brazil and China are the backbone of receiving images stations can be installed in other countries to extend the potential coverage of CBERS.

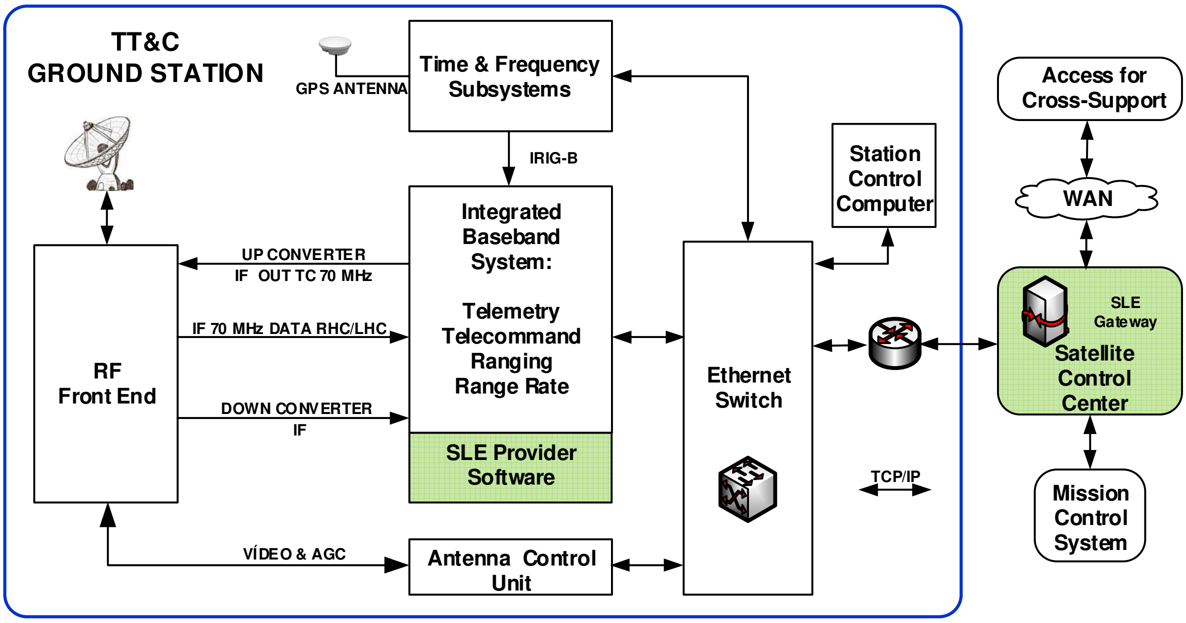

Figure 4. INPE's Ground Station

4. Space Link Extension Concepts

Space Link is the communication link between the spacecraft and ground systems, or between two spacecrafts, as described in Ref. [15-17]. The **Space Link Extension protocol services** [18, 19] extending the Space Link service in distance, in time and by adding information, of the systems onboard the spacecraft to ground systems, for Local Area Networks and Wide Area Networks enabling processing, control and storage of data in one or more intermediate points, Figure 5 illustrated the concepts.

These services are the result of the CCSDS normalization of the cross support in the transport of Telecommand and Telemetry.

There are two categories of services: (i) data transfer services, category responsible for space link data transfer between the ground stations, control center, and the end user; and (ii) management services that controls the planning of data transfer services

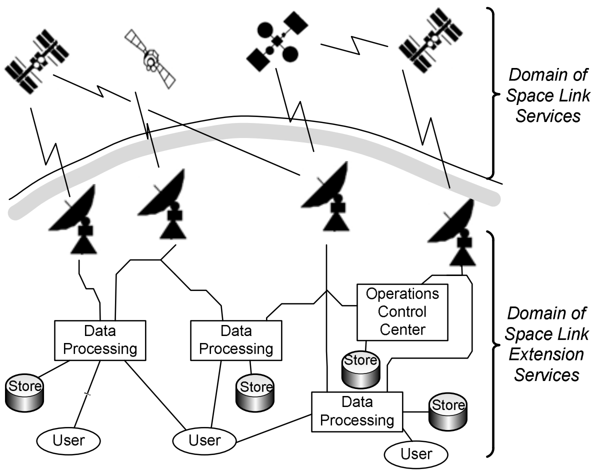

Figure 5. Domain of SL and SLE Services

The SLE data transfer services are based on client/server architecture [10]. The client is located at SCC and called SLE User. The server is located in the GS and called SLE Provider.

4.1. Space Communication Cross Support - Service Management

Space Communication Cross Support - Service Management (SCCS-SM) [3,8] is a generalization of SLE. The SCCS-SM includes the data transfer services and management services, and a framework for the user and the provider to configure the parameters of space link, transfer services and set up ground stations.

The SCCS-SM defines two entities:

- The Utilization Management [9] (UM), on the server side, coordinates requests from users to the space link.
- The Complex Management [7,10] (CM), on the provider side, performs the negotiate the types and duration of services.

Figure 6 illustrates the attributes needed to instantiate a data transfer service: identifier, user/provider, service type, start and end time, port identifier and configuration [11].

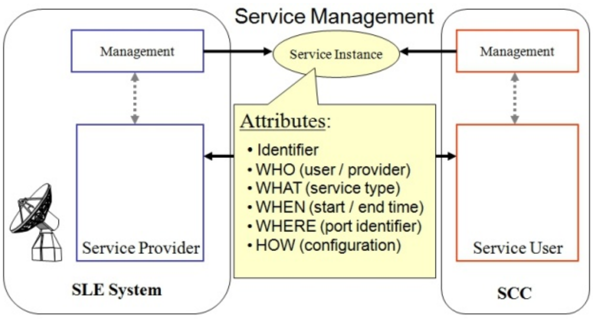

Figure 6. Overview of SCCS-SM

4.2. Internet SLE Protocol One

CCSDS recommends the Internet SLE Protocol One (ISP1) [20] for transfer of the SLE Protocol Data Units. A layered architecture model, as shown in Figure 7, represents the ISP1. The upper layers represent specific features of transfer services (CLTU, RAF and RCF) [21-23].

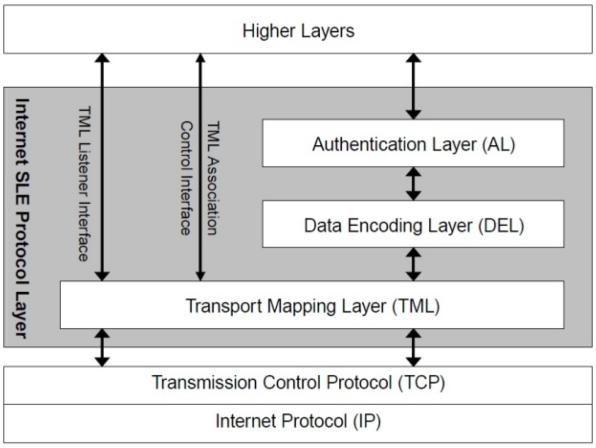

Figure 7. ISP1 Architecture model

5. Architecture for Dynamic Management of the SLE Protocol Services

The architecture proposal is based on Dynamic Management of the Space Link Extension (SLE) Protocol Services and it allows a solution to new challenges for the ground segment. These services are recommendations of the CCSDS for cross support and have been adopted by several space agencies, for example: CNES, ESA, JAXA, NASA and INPE.

5.1. Main Requirements

The high level requirements to be accomplished are:

- Req.01: it shall allow the consistency connection from the user to the SLE provider;
- Req.02: it shall allow the configuration from the SLE user to the SLE;
- Req.03: it shall allow redundancy Return SLE services;
- Req.03: it shall allow interoperability for cross support;
- Req.03: it shall allow automatic switching between ground stations (SLE providers) and the SCC (SLE user).

The architecture observes the layered structure recommended by CCSDS – ISP1 and were included Provider Application Control layers in the Provider Side and User Application Manager and Control layer the User SideThe SLE Provider layer is responsible for the transfer services RAF, RCF, and CLTU [21-23] and sends/receives data to/from the Provider Application Control.

The SLE User layer is responsible for requesting a transfer service, and the User Application Manager and Control layer is responsible for the dynamic management of SLE protocol services and management services. Figure 8 shows the structure of the layered mode.

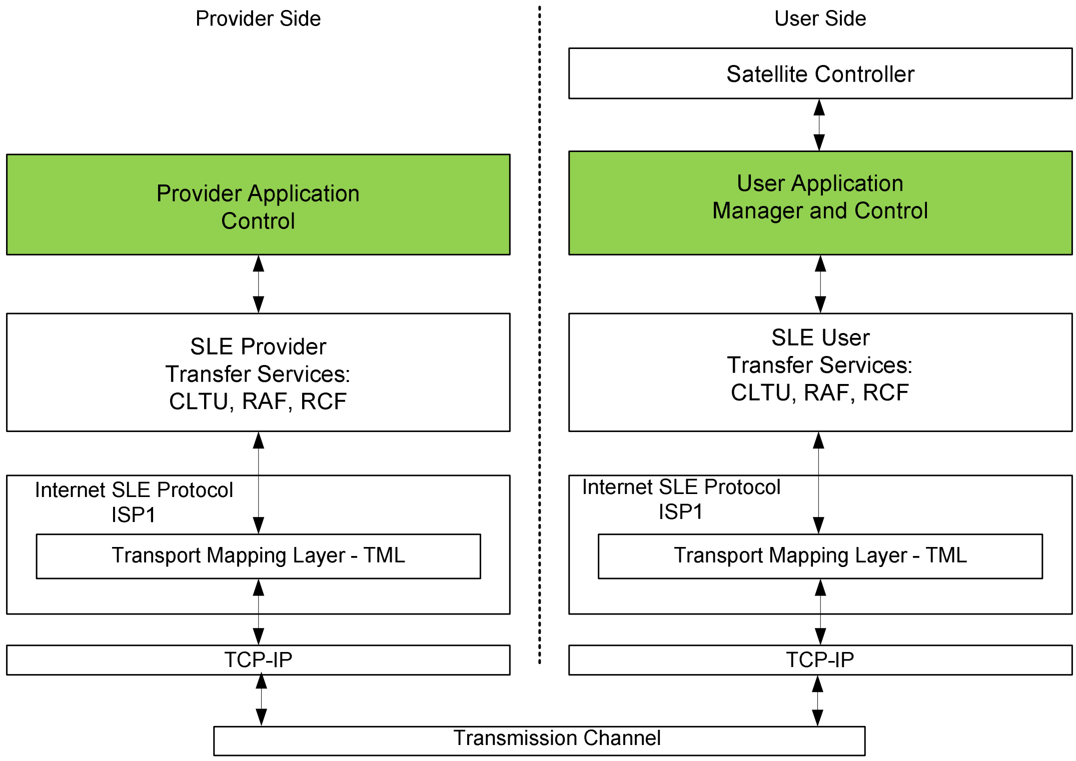

Figure 8. Architecture Model based on ISP1

5.2. The Architecture

The architecture for Dynamic Management is based on the SLE Protocol Services. The SLE Services are part of a CCSDS Recommendation for standards, for use in interoperable and cross-supportable scenarios, for the benefit of data transfer services [1].

The basic idea behind the Dynamic Management of the Space Link Extension Protocol Services Architecture concept is that of simplifying the approach that performs the accesses to the ground stations. This proposed architecture also opens new challenges for the ground segment. It is also expected such a concept of Dynamic Management based on SLE Service for tracking and command may influence in the reduction of cost of a space mission.

In the Satellite Control Center, the SLE Services architecture is composed by the Gateway SLE User, Satellite Control System itself, and by the Dynamic Management (of the SLE Protocol Services). In the two Ground Stations, the SLE function is composed by the SLE Provider. Figure 9 shows the ground system environment for the operation of the satellite which embeds the function aimed for the dynamic management of the SLE protocol services.

The Gateway SLE User corresponds to the interface between the Dynamic Management and SLE providers, their functions are: (i) enable communication between Dynamic Management and SLE providers and (ii) the execution of the services of management (UM).

This architecture allows: (i) The dynamism for redundancy between ground stations, (ii) the transparency in switching stations, (iii) the reduction of possible failures in the connection between the provider and the user, and (iv) The management services related to negotiation, configuration and scheduling.

In Ref. [23] the dynamic management proposed in the architecture is discussed in detail.

5.3. Implementation of the Architecture

The architecture was developed with a set of prototypes of the architecture's elements and simplified simulators to verify and validation. This implementation includes the CLTU, RAF and RCF transfer services and management services.

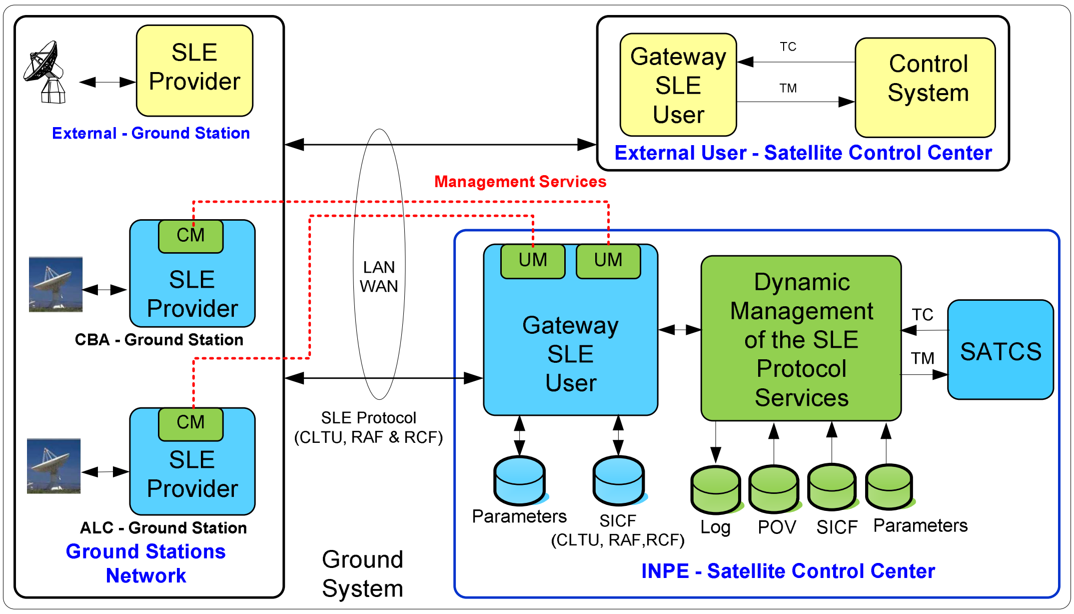

Figure 9. Environment for satellite operation with the dynamic management of the SLE protocol services

5.4. Description of architecture

The Architecture, shown in Figure 10, is distributed between the SCC (user) and the network of ground stations involved (providers).

In the Satellite Control Center the architecture is composed of a Gateway SLE User, Satellite Control System and the Dynamic Management.

In the Ground Station the architecture consists of a SLE Provider for each station belonging to the network.

The Dynamic Management of SLE Protocol Services, proposed by Julio Filho [23], consists of the Functional Groups (FG). In table 2 are shown the Functional Groups and responsibility.

The Dynamic Management requires different types of configuration files to perform its functions. The types of files defined in this architecture are: (i) the **Parameters files** contains the operational parameters of the Gateway SLE User, (ii) the **SICF** (Service Instance Configuration File) contains the type of service performed (RAF, RCF and CLTU) and (iii) the **POV** file provides the flight operation plan.

Table 2. Functional Groups and responsibility

FG	Responsibility
Control Manager	• Forwarding the requests of the TM and TC from the satellite control system. • Setting up the SLE User and Gateway providers SLE; forwarding CLTU, RAF and RCF service requests. • Forwarding to the FG Utilization Manager service requests for negotiation, management, configuration and scheduling SLE protocol services. • Executing the automatic switching between the stations: (i) the dynamism for redundancy between ground stations and (ii) transparency in the selection of stations.
POV Process	Processing the flight operation plan.
Config Process	Processing the configuration files and providing them to the Control Manager.
Heartbeat	Monitoring the signals of connection between the SLE providers and the SLE user and forwarding this information to the Control Manager.
Message Controller	Controlling of the messages between the Utilization Management.

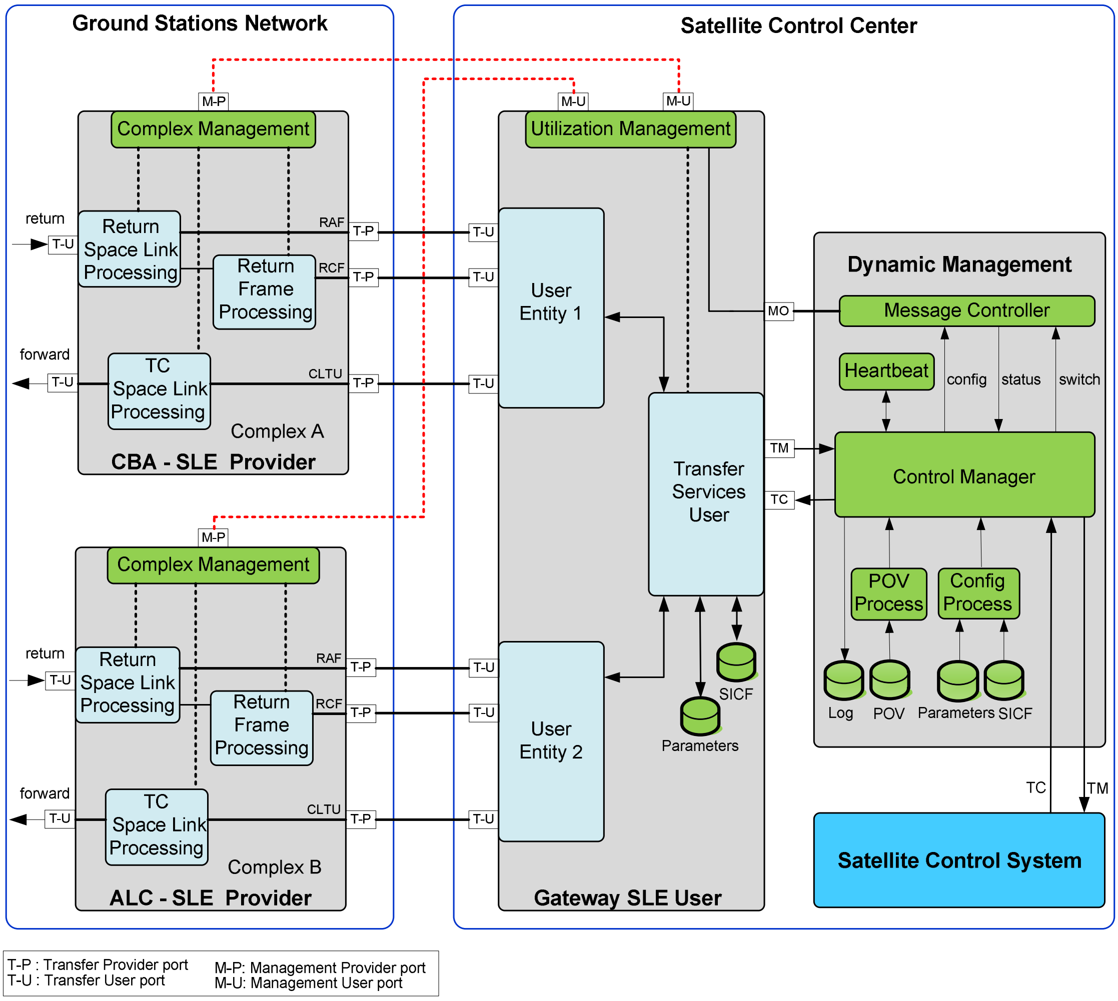

Figure 10. Architecture for Dynamic Management of the SLE Protocol Services

5.5. *Architecture Evaluation*

For the architecture evaluation was created operational scenarios to cover different aspects of sending TC, TM reception and automatic switching between two stations during an orbit.

The architecture evaluation is based on the Data Collecting Satellite-1 (SCD1), which was launched 1993 and in operation.

In this scenario, Figure 11 shows relevant aspects under normal tracking:

- The additional time on the duration of the passage of time calculation total tracking, tracking of the CBA ground station (primary station), sum up over time about the ALC ground station (secondary station).
- The continuous tracking with automatic switching between these two stations, via the dynamic management of SLE protocol services.

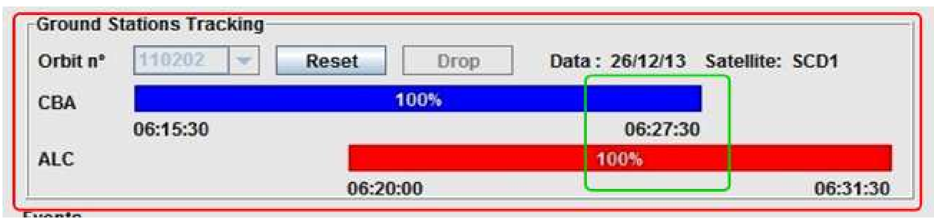

Figure 11. SLE User CCS – Ground Station Tracking

6. Mission Status

The assembly activities, integration and testing (AIT) of the satellite occurred in the Integration and Tests Laboratory (LIT) of INPE, in São José dos Campos (SP).

Experts from the National Institute for Space Research (INPE) and the Chinese Academy of Space Technology (CAST, its acronym in English), held in September in Beijing (acronym in English) the Project Final review (FDR) of the CBERS-4A.

The next step is CBERS-4A packaging to be transported to the Taiyuan Satellite Launch Base (TSL C), located in Shanxi province, 700 km southwest of Beijing, through the launch vehicle Long-March 4B (LM-4B), provided for the early November. The launch is scheduled for December this year.

7. Conclusions

The CBERS-4A is the sixth developed in partnership with China, whose program is the result of the first cooperation agreement signed in high technology between the two countries in the context of international relations South-South.

The CCSDS SLE pertinent Services are already incorporated as part of INPE ground system, which is composed by the Satellite Control Center and by INPE TT&C Ground Stations. INPE ground system SLE Services are planned to be applied in the CBERS-4A mission.

The proposed architecture allows a solution to challenges for the ground segment, related to the reception, processing and distribution of data through the ground segment using the SLE Protocol Services. It is also expected such architecture may influence the reduction of cost of a space mission through dynamic management of the cross support services between the space agencies.

Acknowledgements

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