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FOR SPACE STANDARDIZATION

Space engineering

Communications — Part 1: Principles and requirements

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Foreword

This Standard is one of the series of ECSS Standards intended to be applied together for the management, engineering and product assurance in space projects and applications. ECSS is a cooperative effort of the European Space Agency, national space agencies and European industry associations for the purpose of developing and maintaining common standards.

Requirements in this Standard are defined in terms of what shall be accomplished, rather than in terms of how to organize and perform the necessary work. This allows existing organizational structures and methods to be applied where they are effective, and for the structures and methods to evolve as necessary without rewriting the standards.

The formulation of this Standard takes into account the existing ISO 9000 family of documents.

This Standard is published in two parts:

- Part 1 – to define the principles and requirements applicable to the communication system for spacecraft.
- Part 2 – to define the contents of the document requirements definition (DRDs) that are referred to in Part 1.

This Standard has been prepared by the ECSS Communications Working Group, reviewed by the ECSS Engineering Panel and approved by the ECSS Steering Board.

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Contents

Figures

Tables

1

Scope

This Standard is intended to guide the development of the end-to-end data communications system for spacecraft.

Specifically, this standard defines:

- The terminology to be used for space communication systems engineering.
- The activities to be performed as part of the space communication system engineering process, in accordance with the ECSS-E-10 "System engineering" standard.
- Specific requirements on space communication systems in respect of functionality and performance.

The communications links covered by this Standard are the space-to-ground and space-to-space links used during spacecraft operations, and the communications links to the spacecraft used during the assembly, integration and test, and operational phases.

Spacecraft end-to-end communication systems comprise components in three distinct domains, namely the ground network, the space link, and the space network. This Standard covers the components of the space link and space network in detail. However, this Standard only covers those aspects of the ground network that are necessary for the provision of the end-to-end communication services. Other aspects of the ground network are covered in ECSS-E-70 "Ground systems and operations".

When viewed in a specific project, the requirements defined in this Standard should be tailored to match the genuine requirements of a particular profile and circumstances of a project.

NOTE Tailoring is a process by which individual requirements of specifications, standards and related documents are evaluated and made applicable to a specific project, by selection and in some exceptional cases, modification of existing or addition of new requirements.
[ECSS-M-00-02A, clause 3]

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2

Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this ECSS Standard. For dated references, subsequent amendments to, or revisions of any of these publications do not apply. However, parties to agreements based on this ECSS Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references the latest edition of the publication referred to applies.

ECSS-P-001	Glossary of terms
ECSS-E-50-01 [1)]	Space engineering — Telemetry channel coding
ECSS-E-50-04 [1)]	Space engineering — Telecommand
ECSS-E-50-05	Space engineering — Radio frequency and modulation
ISO 7498:1984 (E)	ISO Information processing systems — Open systems interconnection — Basic reference model

1) To be published.

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3

Terms, definitions and abbreviated terms

3.1 Terms and definitions

The following terms and definitions are specific to this Standard in the sense that they are complementary or additional to those contained in ECSS-P-001.

3.1.1
channel
combination of protocol and medium that provides a physical layer service from end-to-end

NOTE This is the transfer of the unstructured bitstream from point-to-point.

3.1.2
communication service
service that provides the capability of moving data between users.

NOTE At least two users are involved when a communication service is used, one sending data and the other(s) receiving data.

3.1.3
cross support
use by one party of part of another party's data system resources to complement its own system

3.1.4
entity
active element within a system

3.1.5
function
intended effect of a system, subsystem, product, or part

3.1.6
interface
description of the connection between real or abstract objects

3.1.7
isochronous service
service providing for the transfer of data with a defined maximum deviation from a nominal delay from end to end

3.1.8
protocol
set of rules and formats (semantic and syntactic) that determine the communication behaviour of layer entities in the performance of communication functions

3.1.9
service
capability of a layer, and the layers beneath it (a service-provider), that is provided to service-users at the boundary between the service-provider and the service-users

NOTE The service defines the external behaviour of the service-provider, independent of the mechanisms used to provide that behaviour. Layers, layer entities, and application-service-elements are examples of components of a service-provider.

3.1.10
service data unit
amount of information whose identity is preserved when transferred between peer entities in a given layer and which is not interpreted by the supporting entities in that layer

3.1.11
service-provider
abstract representation of the totality of those entities which provide a service to service-users

NOTE A service provider includes entities in the layer at which the service is provided, and in the layers beneath it.

3.1.12
service-user
entity in a single system that makes use of a service

NOTE The service-user makes use of the service through a collection of service primitives defined for the service.

3.1.13
simplex
communicating in one direction from data source to data sink

3.1.14
source
entity that sends service-data-units, using a service provider

3.1.15
sink
entity that receives service-data-units from a service provider

3.1.16
user
service-user

3.1.17
user application
application that makes use of data handling system services

NOTE An application can be a software entity or a non-software entity which is controlling an onboard system.

3.1.18
telecommand
communication link from ground to space by which a spacecraft is commanded

3.1.19
telemetry
housekeeping data and payload data

NOTE Housekeeping telemetry is usually transmitted at low rate, but payload data can be transmitted at a very high rate.

3.1.20
telemetry link
link from spacecraft to ground over which data generated on the spacecraft is provided to ground

3.2 Abbreviated terms

The following abbreviations are defined and used within this Standard.

Abbreviation	Meaning
AIT	assembly, integration, and test
AR	acceptance review
ARQ	automatic repeat request
BER	bit error rate
CCITT	Consultative Committee for International Telegraph and Telephone
CCSDS	Consultative Committee for Space Data Systems
CDMU	central data management unit
CDR	critical design review
CSAD	communication system analysis document
CSADD	communication system architectural design document
CSBD	communication system system baseline definition
CSDDD	communication system detailed design document
CSOM	communication system operations manual
CSPD	communication system profile document
CSRD	communication system requirements document
CSVP	communication system verification plan
DRD	document requirements definitions
EIRP	equivalent isotropically radiated power
EMC	electromagnetic compatibility
ISO	International Organization for Standardization
ITU	International Telecommunication Union
ITU-R	ITU – Radiocommunication
ITU-RR	ITU – Radio Regulations
MEC	mission experiment centre

OSI	open system interconnection
OCC	operational control centre
PDR	preliminary design review
PFD	power flux density
QR	qualification review
RF	radio frequency
SDU	service data unit
SRR	system requirements review
TT&C	telemetry, tracking and command

4

Space communications engineering

4.1 Context

Space communications engineering is concerned with the provision of end-to-end communication services to and from spacecraft. Communication links are generally between the spacecraft and ground. However, this Standard also addresses spacecraft-to-spacecraft links, e.g. in spacecraft constellations, and can be applied to links between spacecraft and landed elements such as orbiter-lander or orbiter-lander-rover configurations.

End-to-end communication is used both to control the operation of the spacecraft, and to transfer data, such as payload data. However, the requirements on the communications system for controlling the spacecraft differ from those for payload data transfer. For control operations, the communication system objective is to provide guaranteed delivery of commands in the order of transmission. Commands can be repeated, but not lost. By contrast, the requirement for payload data transfers is to transfer as much data as possible. Some loss of data may be acceptable, and delivery order is generally unimportant, provided the data can be reconstituted.

In addition to the end-to-end transfer of commands and data, some additional services are provided across space communication links, such as time correlation and ranging. Time correlation is used to accurately relate the local time maintained at each end of the communication link in order to determine the absolute time relationship between events. Ranging is used to determine the distance to the spacecraft, e.g. between a ground station antenna and the spacecraft, or between two spacecraft, and is used for orbit determination.

The goals of standardization for space communication systems are:

- to ensure efficient use of the RF spectrum allocated to the space infrastructure in a non-interfering manner;
- to ensure that the RF links to and from the spacecraft can be used for orbit determination and ranging;
- to ensure reliable and error free end-to-end communication between ground stations and the spacecraft;
- to enable the use of the same ground segment infrastructure by different spacecraft;

- to ensure that standard communication interfaces are provided to the spacecraft payloads and experiments in order to simplify the spacecraft development process;
- to enable cross support between agencies.

Cross support can be beneficial for many reasons, including:

- Technical: to attain additional network coverage or to conduct some programmatic endeavour, such as very long baseline interferometry measurements.
- Economic: to avoid the expense of duplicate implementation, especially to meet some short term requirement.
- Emergency: to increase mission support over that normally planned.
- Research: to avoid the cost and time delay of repeating investigations or re-flying an experiment and to obtain unique data acquired in the past and held by another agency.

These arguments were apparent as long ago as the early 1970s. For this reason, the Consultative Committee for Space Data Systems (CCSDS) was established to standardize space link protocols. Where appropriate, this ECSS Standard calls up CCSDS recommendations directly.

Space communication engineering involves many different disciplines. The physical layers of wireless communications links are the preserve of RF or optical specialists, and wired links are the speciality of analogue electronics engineers. The electronic components that implement the communication services are designed and implemented by analogue and digital electronics engineers, and the design of the protocols used in the provision of services is entrusted to protocol experts. In many cases, the higher level services and protocols are implemented in software by specialized software engineers. Other level 2 ECSS Standards are applicable to these disciplines, and are called up within this Standard.

4.2 Overall space communication

Figure 1 shows an example of a configuration for a space communication system.

NOTE This configuration includes a space-to-space link between two flight elements.

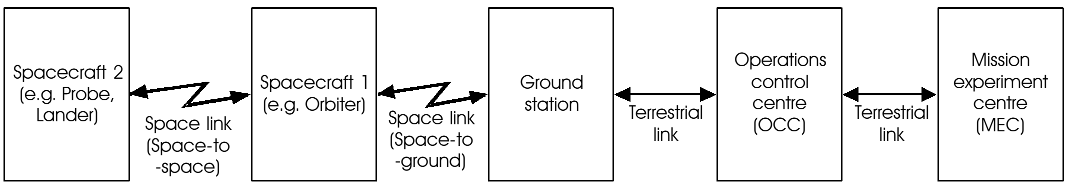

Figure 1: Example configuration of a space communication system

The overall data communication requirement is to transfer data to and from any element of the space system in accordance with the mission requirements.

The elements of a space communication system are described in the following paragraphs. In a real space communication system, the number and type of elements actually present can vary. For example, in complex missions, there can be several spacecraft, and multiple ground stations. In other missions, a single spacecraft can be controlled from a single operation control centre, without a mission experiment centre.

The space communication system elements are:

- a spacecraft linked to the ground via a space link (space-to-ground). This can also be linked to other spacecraft, landers, and probes via space-to-space (proximity) links;
- other spacecraft, landers, and probes linked only with the main spacecraft via proximity links;
- a ground station that forms the terrestrial end of the space-to-ground space link, and is connected to the operational control centre via a terrestrial link;
- an operational control centre (OCC), connected to the ground station via a terrestrial link. The OCC is used to control the spacecraft;
- a dedicated mission experiment centre (MEC) connected to the operations control centre. Mission payloads and experiments are operated from the MEC.

Each element includes a data handling system, which provides three main communication functions:

- managing data communication interfaces internal to the element (internal links);
- managing data communication interfaces with external links (i.e. space links and terrestrial links to other elements);
- performing data processing for the transfer between internal and external links.

The data handling for transferring data from a sending element to a receiving element of the space communication system via an external link consists of:

a. For the down-link data stream:

At sender side

[1] Acquisition of data from subsystems.

[2] Processing and formatting of the data stream for transmission to the ground via the external link as telemetry.

[3] Forwarding of the data stream via the external link.

At receiver side

[4] Acquisition of the data stream from the sender via the external link.

[5] De-formatting and processing for delivery to receiver internal elements (e.g. space system user for a link between ground station and OCC) and for transfer to the next element via an external link (e.g. transfer from ground station to OCC).

[6] Delivery of data to receiver internal elements (e.g. space system user).

b. For the up-link data stream:

At sender side

[1] Acquisition of data from space system user.

[2] Processing and formatting of the data stream for transmission to the spacecraft via the external link as telecommand.

[3] Forwarding of the data stream via the external link.

At receiver side

[4] Acquisition of the data stream from the sender via the external link.

[5] De-formatting and processing for delivery to receiver internal elements (e.g. spacecraft subsystems for a link between ground station and spacecraft) and for transfer to the next element via an external link.

[6] Delivery of data to receiver internal elements (e.g. commands to spacecraft subsystems).

The type of data to be transmitted can be telemetry, files, video, and digital voice for the down-link, and telecommands, files, video, and digital voice for the up-link.

For each type of data transmission, protocols defined by CCSDS or other standardization bodies may be used. Figure 2 shows some of the CCSDS and internet protocols that can be used over the space-to-ground space link.

NOTE This figure illustrates five of the seven ISO reference model layers defined in ISO 7498 (the session and presentation are not shown).

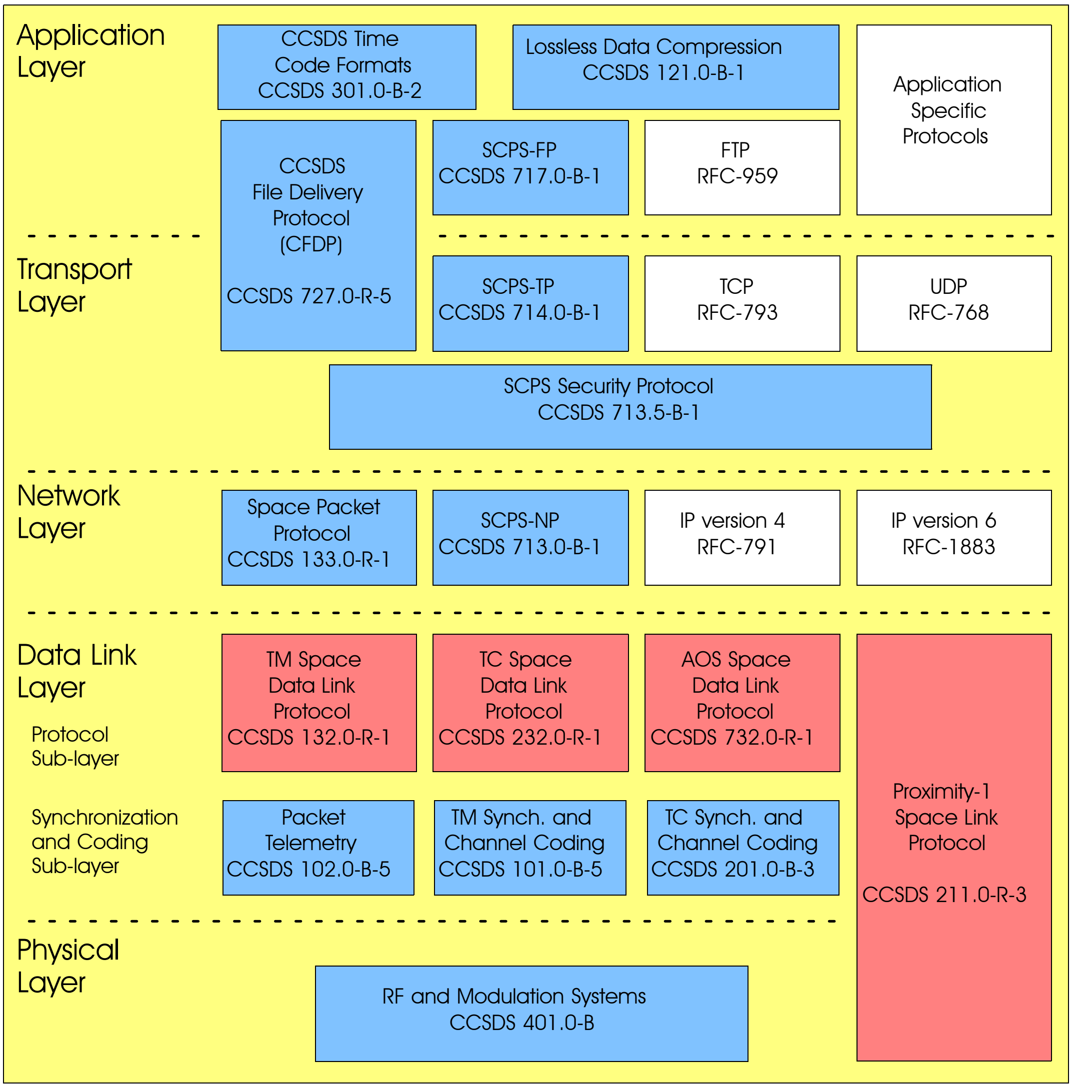

Figure 2: CCSDS and Internet space link protocols

4.3 Space communication domains

4.3.1 General

A space communication system comprises three distinct domains that each have markedly different characteristics. The three domains are

- the space network,
- the space link, and
- the ground network.

These domains are illustrated in Figure 3.

4.3.2 Space network

The space network comprises all of the nodes in the flight segment of a spacecraft mission. These nodes can all be on a single spacecraft, or can be distributed among several spacecraft, for example in a constellation. The space network therefore includes both intra-spacecraft and inter-spacecraft links.

The type of network medium and topologies of the space network are highly varied, often being based on proprietary protocols. The emphasis of this Standard in this case is on the definition of appropriate user and transfer layer services that maintain freedom of choice in the sub-network layers, while also moving towards harmonization and better definition of the subnet layers.

Except in very rare circumstances, the space network cannot be maintained or upgraded during a mission. Usually, the technology used to implement the space network is conservative, and reflects the state-of-the-art years before launch. This severely constrains the performance available when compared with the ground network.

An increasing number of missions involve a space segment consisting of more than one element, e.g. constellations of spacecraft, or planetary missions consisting of an orbiter and lander, or orbiter-lander-rover. This Standard regards all of these elements as comprising the space network. These missions change the nature of the space network by including inherently unreliable wireless links and introducing the potential for a variable network topology.

4.3.3 Space link

The space link is essentially a point-to-point wireless link between a ground station and a spacecraft. This link is inherently unreliable, and the emphasis of this Standard here is on the achievement of reliable data transfer services. Users concerned only with the exchange of data, either onboard or on ground, do not generally use the space link services directly, accessing these services instead through their local ground or onboard subnets. However, users concerned with the operation and control of the spacecraft can access space link services for a number of reasons, including routine operations such as ranging, orbital position determination, and emergency operations such as low level commanding.

Equipment at the terrestrial end of the space link is essentially unconstrained in terms of power, mass, and volume requirements. By contrast, equipment at the onboard end of the space link is severely constrained in these respects. This limits the bandwidth that can be achieved, especially in the return (space-to-ground) direction.

The medium through which the space link signal propagates can interfere with or distort the signal, and the very high relative velocity of some spacecraft introduces severe Doppler effects. The movement of the spacecraft relative to its ground station makes the signal propagation path characteristics highly variable. The combination of these factors imposes on the space link to be capable of operating reliably over a very wide range of conditions, and to tolerate very high bit error rates (BER).

For bi-directional communications, the space link comprises at least two physical channels, one for forward (ground-to-space) and one for return (space-to-ground) communications. However, one constraint exists to achieve at least limited communications for emergency control of the spacecraft, with only a uni-directional link, i.e. with only the forward or return link operational. This again imposes severe requirements on the space link protocols and services.

4.3.4 Ground network

The ground network comprises ground-based equipment and terrestrial links that implement the ground data handling system. The ground network is largely described by ECSS-E-70.

The ground network comprises the ground data processing equipment, usually connected by a combination of local and wide area networks. Communication between nodes is achieved using a variety of reliable terrestrial links with well-defined protocols. The emphasis of this Standard in the ground network is on the transfer and user layer services and protocols used to transfer spacecraft data between nodes in the ground network and nodes in the space network.

NOTE This Standard is not concerned with ground based services and protocols used to transfer data between communication end points on the ground, or with services related to archiving and retrieval of spacecraft data.

An important aspect of the ground network is that it can be maintained and upgraded to take advantage of technological developments occurring during the lifetime of a mission. Furthermore, the performance of the ground network can be enhanced by improving the terminal equipment and by increasing the number or performance of the links in the subnet.

4.4 Communications engineering process

4.4.1 Introduction

Space communications engineering is carried out following the systems engineering process model defined in ECSS-E-10. This model includes the establishment of an appropriate engineering management and configuration control infrastructure, and the identification of interfaces with other engineering disciplines. The communication system engineering is then carried out as a sequence of activities managed within this infrastructure.

4.4.2 Communication engineering activities

4.4.2.1 General

Spacecraft communications engineering comprises the following activities:

- rommunications engineering management,
- requirement engineering,
- analysis,
- design and configuration,
- implementation,
- verification, and
- operations.

4.4.2.2 Communications engineering management

Space communications engineering management systems and procedures are put in place to administer the activities that are performed in the implementation and operation of the space communication system. Management includes the planning, scheduling, and supervision of the activities to be performed, as well as configuration control and quality assurance of all of the products of space communications engineering.

Communications engineering management is a continuous activity that extends throughout the project.

4.4.2.3 Requirement engineering

The requirement engineering phase of space communication systems engineering involves the capture of requirements specific to the space communications system.

Communication requirements are derived from the spacecraft mission requirements and by tailoring the requirements in this Standard.

The goals and activities to be performed during the requirement engineering phase are described in ECSS-E-10.

4.4.2.4 Analysis

The analysis phase of the space communications engineering process is concerned with the analysis of the requirements and the identification of appropriate ways of implementing the communication system. The analysis takes into account the performances to meet the mission objectives, mission characteristics such as satellite orbit parameters, capabilities of available technologies, and the availability of existing ground infrastructure.

The output from the analysis phase is a recommended means of implementing the space communication system, with options if necessary, which is elaborated during the design and configuration phase.

The analysis identifies the frequencies to be used for RF communications so that an application can be made to the International Telecommunication Union – Radiocommunication (ITU-R) for assignment of those frequencies.

The activities of the analysis phase are described in more detail in ECSS-E-10.

4.4.2.5 Design and configuration

Design involves the derivation of the architectural and detailed design of the space communication system according to the preceding requirements and analysis phases.

Configuration is the identification and naming of the component parts that make up the space communication system in order that a proper engineering management process can be applied to the development of those parts.

The design and configuration processes are described fully in ECSS-E-10.

4.4.2.6 Implementation

The implementation is the realization of the space communication system in real hardware and software. This is essentially a manufacturing activity.

4.4.2.7 Verification

Verification is the process of proving that the space communication system meets the requirements established for it. Verification is performed incrementally, starting with the individual parts of the communication system, and finishing with the complete, fully integrated system.

The verification process is described fully in ECSS-E-10.

4.4.2.8 Operations

Once the space communication system is implemented and verified, it enters its operational phase. This continues throughout the operational lifetime of the spacecraft. However, the start of the operational phase of the space communication system is normally during the spacecraft integration and test phase, since the communication system is often used during the spacecraft testing.

4.4.3 Process milestones

4.4.3.1 General

A number of process milestones in the form of project reviews are associated with the space communication engineering process. Each review comprises an analysis of the outputs of preceding activities. Generally, successful completion of a review means that the next activity of the space communication engineering process can begin.

The milestone reviews for space communication engineering are:

- system requirements review, SRR;
- preliminary design review, PDR;
- critical design review, CDR;
- qualification review, QR;
- acceptance review, AR.

During the planning phase for a real project, the need for additional reviews can be identified, and then documented and incorporated into the project plan.

NOTE For project phasing and planning, see ECSS‐M‐30.

4.4.3.2 System requirements review

The system requirements review is carried out after the requirements engineering activity is complete. Some analysis of the requirements by potential suppliers can also be desirable prior to the SRR. The goal of the SRR is to review and approve the requirements captured during the requirements engineering activity.

The output from the SRR is the baseline requirements specification for the communication system.

4.4.3.3 Preliminary design review

The preliminary design review is conducted after the analysis activity and the architectural design element of the design and configuration activity are complete. The goal of the PDR is to review and approve the architectural design for the development of the communication system, and to approve key decisions, such as make or buy, that impact the subsequent design and implementation activities. Optional implementation strategies are also evaluated during the PDR in terms of suitability, risk, and cost.

The outputs from the PDR include an approved architectural design, and an endorsed issue of the design justification file that details design decisions made up to the PDR.

4.4.3.4 Critical design review

The critical design review is conducted after all system design and configuration activities are complete. The goal of the CDR is to review and approve the communication system design and implementation plan, and to commit to the implementation phase. During this review, all of the design choices leading to the submitted design are scrutinized, and the decision path resulting in the selection or rejection of the various options is examined. Although the CDR culminates in a decision to commit to the implementation phase, this does not preclude the possibility that some implementation activities can start before the CDR where this is appropriate.

The output from the CDR is an approved design for the development of the communication system.

4.4.3.5 Qualification review

The goal of the qualification review is to determine by inspection or analysis whether the space communication system and its constituent components meets the functional, performance, and contractual requirements imposed upon it. Usually, in space communication system engineering, a rolling qualification review is conducted as part of the engineering process management, whereby the progress of design and implementation is periodically scrutinized to ensure that it meets the requirements, is on schedule, and within budget. Consequently, there can be several qualification reviews held at key stages during the project, rather than a single review.

4.4.3.6 Acceptance review

The acceptance review is conducted as part of the verification activity once the implementation is complete. The goal of the acceptance review is to review the completed implementation against the requirements baseline established by the SRR and to confirm that all requirements are met.

The output from the AR is a formal acceptance of the space communication system.

4.5 Relationship with other standards

This Standard is primarily a process oriented standard, i.e. it is concerned with the way in which the space communication system is achieved rather than the functional and performance details of the space communication system product. As such, this Standard is related to other ECSS level 2 standards, which are also process oriented, and to ECSS level 3 and external standards that are product oriented.

Specifically, this Standard refers to ECSS-E-40 “Space engineering — Software” and ECSS-E-20 “Space engineering — Electrical and electronic” to define the engineering processes to be applied to the software and electronic components of a space communication system. By contrast, ECSS-E-70 “Space engineering — Ground systems and operations” is complementary to this Standard and describes the engineering process to be used for the development of the ground system elements of a space mission.

For the product oriented definitions of the communication system elements, e.g. for the specification of functional and performance characteristics of the services to be provided, this Standard refers to appropriate ECSS level 3 standards or other external standards such as ISO or CCSDS standards.

4.6 Communications architecture

In line with modern communication engineering practice, and to be consistent with ISO, CCITT, and CCSDS standards, this Standard is based on a layered architectural reference model, as shown in Figure 3. This model comprises three layers:

- the user layer,
- the transfer layer, and
- the subnet layer.

NOTE The user layer in Figure 3 corresponds to the application and presentation layers of the OSI 7-layer reference model defined in ISO 7498, and to the application layer shown in Figure 2. The transfer layer of Figure 3 corresponds to the session, transport, and network layers of the OSI reference model, and to the transport and network layers shown in Figure 2. The sub‐network layer in Figure 3 corresponds to the data link and physical layers of the OSI reference model and of Figure 2.

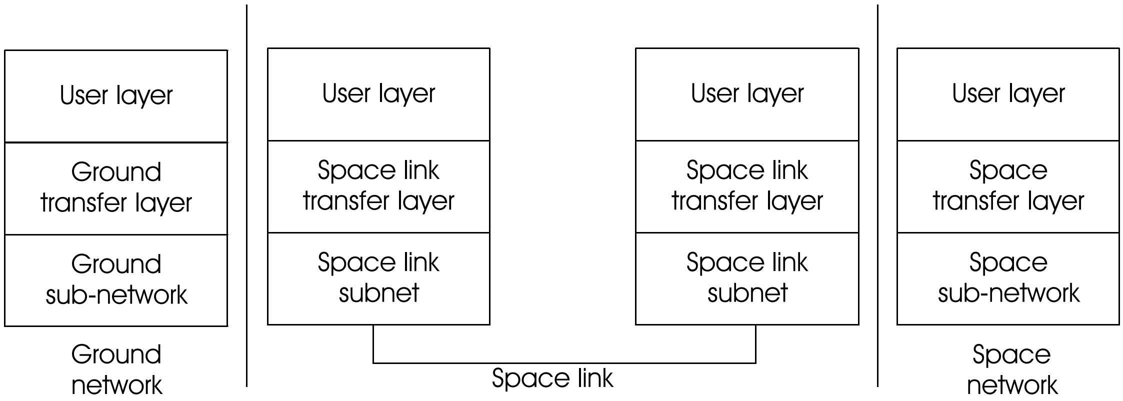

Figure 3: Space communications reference architecture

Each layer of the architecture provides services and protocols defined either in ECSS level 3 documents, or by other explicitly referenced standards such as CCSDS recommendations. Depending on their profile, users access services provided by any of the onboard or ground layers. Communications internal to the onboard and ground segments are performed via the local transfer protocols and subnets, which are not covered by this Standard. End‐to‐end communications between space and ground segments are via the spacelink transfer protocols and spacelink subnet, which do form part of this Standard.

The space link subnet enables access to the space link medium and provides basic services for the transmission of delimited or undelimited data across the link. The space link layers can be resident in a single data system or can be partitioned between data systems in space and on the ground. In general the space link layers reside within the onboard TT&C subsystem. On the ground they can reside completely in the earth station, or can be partitioned between earth station and control centre or user facility.

The ground and onboard transfer layers provide common services between the space and ground segment. They operate in a peer‐to‐peer interaction with their equivalent layers in the space and ground segments. The onboard and ground transfer layers make use of the services provided by the space link transfer and subnet layers to transfer data from data system to data system.

The ground and onboard transfer layers and subnets implement the services and protocols used for the independent operation of the onboard and ground systems. Users can directly use the services provided by the space link transfer protocols, or can access them via the services provided by their own local transfer protocols. Gateway functions can exist between the local transfer protocols and those of the space link. In some cases the space link transfer protocols can use bearer services provided by the local transfer protocols.

4.7 Spacecraft control considerations

The space communications system supports the operation and control of the spacecraft under a wide range of conditions. Under normal operating conditions, all functions onboard the spacecraft behave correctly, and the attitude and stability of the spacecraft is such that the communications link characteristics are optimal. In this state the spacecraft can be operated through the exchange of telemetry and telecommands via the space communications system, and payload data can be acquired.

However, degraded operating conditions can arise through loss of functionality due to onboard failures, or through degradation of the space link characteristics due to the attitude or motion of the spacecraft. In the case of degradation due to onboard failures or incorrect operation of the onboard functions, a general requirement is the capability to achieve some minimal level of control. In the very worst case, this means the capability to command the spacecraft in the blind, i.e. without any telemetry feedback, and to have some certainty of the execution of these telecommands. This implies that in this mode, the execution of telecommands is carried out using the minimum of onboard functionality, usually by directly decoding and executing them in hardware as they are received.

In less extreme cases, some critical telemetry can be received from the spacecraft. This critical telemetry is acquired and formatted for transmission using simple and reliable onboard functions, typically not relying on software.

Certain spacecraft attitudes or motions can significantly degrade the characteristics of the space link. This can result in severely restricted bandwidth, high bit error rates, frequent drop-outs, and the loss of the link in one direction. The objectives for the design of the space communications system are to tolerate this and to enable spacecraft operations under these conditions. For example, the sizes of data units transferred on the space link are selected to minimize the susceptibility to bit errors and drop-outs. For critical command and control functions, it is desirable to implement feedback in the form of acknowledgements, but not preclude the possibility of open loop commanding to tolerate the loss of the return link.

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5 Requirements

5.1 Introduction

This clause contains requirements applicable to spacecraft communication systems and to the engineering process for the development of spacecraft communication systems.

Subclause 5.2 contains requirements applicable to the spacecraft communication system engineering process.

Subclauses 5.3, 5.4, and 5.5 contain general requirements that are applicable to the communication system as a whole, such as bandwidth allocation, telecommanding and telemetry requirements.

Subclauses 5.6, 5.7, and 5.8 contain requirements specific to the individual domains of a spacecraft communication system.

5.2 Space communication system engineering process

5.2.1 Requirements engineering

5.2.1.1 General

The objective of space communication system requirements engineering is to capture and document all of the requirements that are applicable to the communication system. Requirements engineering is normally carried out by the customer or procurer of the communication system, and the results of this activity are then communicated to the supplier of the system.

5.2.1.2 Activities

The activities performed during communication system requirements engineering shall include:

a. analysis of top level mission requirements specifications,

b. identification and expression of requirements specific to the space communication system, and

c. formulation of new communication system requirements not derived from other mission documentation.

5.2.1.3 Outputs

One output from the requirements engineering activity shall be the space communication system requirements specification (CSRD).

5.2.2 Analysis

5.2.2.1 General

The objective of the space communication system analysis is to confirm the feasibility of the communication system and to identify possible solutions for its implementation. Analysis is usually carried out by the communication system supplier based on the customer provided outputs from the requirements engineering activity.

5.2.2.2 Activities

The activities performed during communication system analysis shall include:

a. feasibility analysis of the communication system requirements,

b. technical analysis of e.g. data rates, link margins, commandability, Doppler effects on carrier and data signals;

c. criticality analysis of the space communication system;

d. definition of the top-level space communication system architecture;

e. definition of the system verification plan, including compatibility and inter-operability testing;

f. identification of potential solutions for the realization of the space communication system;

g. identification and request for assignment of globally managed parameters such as radio frequencies and spacecraft identifiers;

h. identification of telemetry parameters, their criticality classification, and their need for time stamping at source;

i. identification of telecommand parameters;

j. identification of data flows between system elements;

k. identification of ranging requirements.

5.2.2.3 Outputs

The outputs from the space communication system analysis activity shall include:

a. communication link margin analysis and Doppler margin analysis reports (CSAD),

b. criticality analysis report (CSAD),

c. system verification plan (CSVP), and

d. inter-operability and compatibility test plans (CSVP).

5.2.3 Design and configuration

5.2.3.1 General

Space communication system design and configuration is the elaboration of potential solutions into a detailed design whose implementation can be managed through a formal configuration management process. Design and configuration is a supplier activity.

5.2.3.2 Activities

The activities performed during communication system design and configuration shall include:

a. partitioning of the detailed design from the analysis phase into system components that can be realized separately;

b. allocation of unique names or identifiers to all of the system components in accordance with the project's configuration management methodology;

c. generation of requirement specifications for all system components;

d. definition of manual and automatic operational procedures, including link acquisition procedure, link release procedure, synchronization procedure, and data rate and frequency negotiation procedures;

e. review link margin analysis and update.

5.2.3.3 Outputs

The outputs from the space communication system design and configuration activity shall include:

a. a detailed design of the space communication system (CSBD, CSADD, CSDDD, CSPD),

b. a list containing all components of the space communication system that are subject to configuration control (CSDDD),

c. the simulations and demonstrations used to verify the design, to resolve design conflicts, and to select options (CSVP), and

d. the definitions of operational procedures (CSOM).

5.2.4 Implementation

5.2.4.1 General

Space communication system implementation is the realization of the communication system according to the design and to meet all of the specified requirements. This is a supplier activity.

5.2.4.2 Activities

The activities performed during space communication system implementation shall include:

a. the procurement of system components (hardware and software) from sub-contractors and suppliers, including the acceptance testing of those components to confirm that they meet their requirements specification;

b. the manufacture of system components (hardware and software) according to the design specification, and the subsequent testing of those components to confirm that they meet their requirements specification;

c. the integration of all components, both manufactured and procured, to produce the complete space communication system;

d. testing of the complete space communication system to confirm that it meets the agreed specification, including correction of any faults that prevent the completed system from meeting the agreed specification;

e. execution of inter-operability and compatibility tests and generation of test result reports;

f. the management of the implementation activities according to the agreed management plan and using the approved management tools and procedures, to ensure the timely delivery of the space communication system within the allotted budget;

g. review of link margin analysis and updating.

5.2.4.3 Outputs

a. The principal output from the space communication system implementation activity shall be the delivery of the complete communication system to the customer.

b. Other outputs shall include:

   1. all plans and designs for the space communication system, including the designs of the system itself, as well as designs for test and check-out equipment used to verify the system (CSADD, CSDDD, CSVP);
   2. all test and check-out procedures used to verify the system (CSVP);
   3. all simulations and demonstrations used in the manufacture and verification of the system, including environment models used to simulate external effects on the system (CSVP);
   4. documents relating to the execution and results of verification tests, and inter-operability and compatibility tests (CSVP);
   5. documents detailing any deviation from the original design, including details of changes made as a result of verification testing, and changes made to the test procedures (CSADD, CSDDD, CSVP).

5.2.5 Verification

5.2.5.1 General

Space communication system verification is the demonstration before the customer that the system meets the agreed specification. This is usually a combined customer and supplier activity.

5.2.5.2 Activities

The activities performed during space communication system verification shall include:

a. the execution in a fully controlled environment of all agreed verification tests and procedures;

b. the formal recording and subsequent analysis of all verification test results, and the completion of compliance and characterization matrices for the space communication system;

c. review of link margin analysis and updating.

5.2.5.3 Outputs

The outputs from the space communication system verification activity shall include:

a. a verification test report detailing the results of the execution of all verification tests, and including relevant system characterization data (CSPD);

b. a mutually signed certificate of acceptance between the customer and supplier confirming that the customer agrees that the system meets all of the specifications.

5.2.6 Operations

5.2.6.1 General

Space communication system operations is the operation of the communication system during the spacecraft mission in order to achieve the aims of that mission. Depending on the contractual arrangements, this can be entirely a customer activity, entirely a supplier activity, or an activity conducted by both the customer and the supplier.

5.2.6.2 Activities

The activities performed during space communication system operations shall include:

a. operation of the space communication system as and when specified by the mission to achieve the objectives of the mission;

b. maintenance, including planned upgrades of the system and reconfiguration for different phases of the mission;

c. provision of additional support for spacecraft trouble shooting and contingency operations;

d. execution of the decommissioning procedures at end-of-life, including stopping spacecraft transmissions, and notification of the ITU-R of the availability of the frequencies for re-use.

5.2.6.3 Outputs

a. The primary output from the space communication system operations shall be the operation of the communication system to meet the mission's system requirements.

b. Other outputs shall include periodic reports on utilization and performance to assist in maintenance planning.

5.3 Space communication system

5.3.1 Bandwidth allocation

a. The space communication system shall allocate bandwidth according to the data transmission requirements and the operational mode of the spacecraft.

b. During emergency operations, bandwidth allocation priority shall be given to essential commands and telemetry.

5.3.2 Buffering and flow control

The space communication system shall employ buffering and flow control techniques to ensure that data is not lost due to congestion.

5.3.3 Cessation of emission

The space communication system shall be designed so that all transmissions from a spacecraft can be stopped at any time by telecommand.

NOTE By implication, the telecommands used to stop transmission are essential telecommands, i.e. telecommands that are executed even when all other onboard equipment has failed.

5.4 Telecommanding

5.4.1 Commandability at all attitudes and rates

The design of the space communication system shall ensure that the spacecraft can be commanded at all spacecraft attitudes, and at all anticipated attitude rates.

5.4.2 Telecommand delivery service

A service shall be provided which guarantees in-sequence delivery of telecommands.

5.4.3 Erroneous telecommand rejection

The probability of accepting an erroneous telecommand shall be less than $10^{-2}/N$, where N is the number of telecommands expected to be transmitted to the spacecraft during its mission.

5.4.4 Essential command distribution

a. The design of the space communication system shall enable essential telecommands to be decoded and control signals distributed even when all other systems, including the CDMU, are non-operational.

b. The list of essential commands, including their encoding and effects, shall be agreed at PDR.

c. The essential telecommands should enable power to key system components to be switched on or off, and for switch-over to redundant systems to be forced.

d. For critical operations, such as switching the transmitters on and off, execution of these commands should not depend on software functions.

5.4.5 Command authentication

The space communication system shall ensure that only telecommands from authorized sources are executed onboard the spacecraft.

NOTE This can involve the use of authentication techniques.

5.4.6 Command encryption

a. The space communication system shall provide telecommand encryption services when the security requirements cannot be met by command authentication only.

b. For maximum security, encryption should be provided at the user layer, but it may also be provided at the transfer layer.

5.4.7 Commanding-in-the-blind

The space communication system shall enable commanding-in-the-blind operation, i.e. the up-linking of telecommands in the absence of any feedback telemetry or command acknowledgements from the spacecraft.

5.4.8 Telecommand acknowledgement

The space communication system shall enable telecommand acknowledgements to be returned to the telecommand source.

5.5 Telemetry

5.5.1 Telemetry at all attitudes and rates

The design of the space communication system should ensure that essential spacecraft telemetry can be transmitted at all spacecraft attitudes, and at all anticipated attitude rates.

NOTE In some missions this provision can be unachievable. Its intent is that ground controllers can always obtain telemetry from the spacecraft for contingency operations and failure recovery.

5.5.2 Essential telemetry acquisition

a. The design of the space communication system shall enable essential telemetry to be acquired from critical monitoring points and transmitted to the ground, even when all other systems, including the CDMU, are non-operational.

b. The list of essential telemetry parameters, including engineering conversion rules, parameter encoding, and transmission formats, shall be agreed at PDR.

c. Essential telemetry should include the information necessary on the ground to determine the overall condition of the spacecraft, e.g. the power system state, the status of critical systems including the onboard data handling system, and whether telecommands are being received.

d. Acquisition of these parameters should not rely on the availability of the space network, or the execution of onboard software applications.

5.5.3 Telemetry source identification

All spacecraft telemetry packets shall carry an identifier that indicates the source spacecraft from which it originates.

5.5.4 Telemetry-in-the-blind

The space communication system shall enable telemetry-in-the-blind operation, i.e. the down-linking of telemetry data in the absence of any up-link signal to the spacecraft.

5.5.5 Telemetry packet time stamping

All telemetry packets generated onboard the spacecraft shall be time stamped such that the temporal ordering of the acquired telemetry can be determined on the ground, regardless of the location of the onboard application that generated the telemetry packet.

NOTE The implication of this requirement is that the time stamp is related to a common onboard reference time.

5.5.6 Simultaneous support of differing source rates

a. The telemetry downlink shall support a range of simultaneous source data rates with a given priority and respect for maximum latency times for each data source.

b. The telemetry downlink shall not impose constraints upon the rates of individual telemetry data sources.

NOTE This implies that the data rates through the downlink are independent from the signalling rate on that link.

5.6 Space link

5.6.1 Overview

The space link is described in subclause 4.3.3.

5.6.2 Performance

For inter-spacecraft links, the performance requirements given for up- and down-links should be applied.

5.6.3 Directionality

a. Each space link shall be treated as a simplex communication channel.

b. Data integrity mechanisms, such as ARQ, on other contra-flowing space links shall be supported.

NOTE Space links can be operated as point-to-point or point-to-multi-point communication channels.

5.6.4 Short contact periods

The space link shall be capable of operating when the spacecraft contact period is of short duration and sporadic.

NOTE Short, sporadic contact periods can prevail during normal operation in some missions, but can occur only during emergency operations in other missions.

5.6.5 Interoperability

The space link shall be designed to provide interoperability for a wide range of mission types, for science, control and housekeeping data, and a similarly wide range of ground segments including control centres and user receive only earth stations.

5.6.6 Orbits

a. The design of the space link shall enable optimization for its specific use in the orbit chosen.

b. For each mission the space link shall be optimized for its specific orbit in terms of, for example, power and bandwidth.

5.6.7 Noise sources

The design of the space link shall take account of continuous background noise (natural or man-made) sources as well as burst sources such as those due to solar events or structural interference.

5.6.8 Mission phases

All mission phases shall be supported including AIT, pre-launch, launch, operations execution, and end of life.

5.6.9 Link setup times

a. Link setup times shall be kept to a minimum.

NOTE This is primarily to cope with short contact periods with the spacecraft.

b. To support contingency situations, the design shall enable the transfer of meaningful commands and status reports within very short acquisition periods.

5.6.10 Mixed isochronous and asynchronous traffic

The design of the space link shall enable isochronous and asynchronous data traffic to be carried within a single link.

5.6.11 Mixed housekeeping and payload data

The design shall enable the transfer of spacecraft housekeeping telemetry and payload data on a single space link.

5.6.12 Diversity reception signal selection

The selection of signals received using diversity antenna systems shall be such as to minimize the unnecessary rejection of frames.

NOTE Usually, this is performed by monitoring the signal strength over time, and switching between frames.

5.6.13 Space link performance

5.6.13.1 Doppler shift and Doppler rate

The space link shall be capable of operating under the worst-case Doppler shift and Doppler rate conditions expected for the mission.

NOTE Doppler shift can be highly variable and induced by high orbital velocities or by accelerating or manoeuvring spacecraft.

5.6.13.2 Operation during tumbling

a. The space link shall be designed to operate in the worst case tumbling conditions expected for the spacecraft.

b. The ability to cope with these conditions shall be demonstrated by simulation during the analysis, implementation, and verification phases.

5.6.13.3 Tolerance of run lengths and transition densities

a. The space link shall be designed to tolerate the worst case run lengths and transition densities that can occur in the data, e.g. runs of zeros or ones, or data patterns that result in very high or very low transition densities in the modulated signal.

b. The ability to operate under the worst case run length and transition densities shall be demonstrated by simulation during the analysis, implementation, and verification phases.

5.6.13.4 Failure modes

The space link shall be adaptable to a range of failure modes including:

a. loss of link,

b. reduction in link margin, and

c. sporadic carrier acquisition.

5.6.13.5 Uplink assumed bit error rate (BER)

Uplink budget calculations shall be based on a BER of 10^{-5} at the input to the telecommand decoder.

5.6.13.6 Uplink frame rejection rate

For a link BER of 10^{-5}, the uplink frame rejection rate for a frame size of 256 octets shall be less than 10^{-5}.

5.6.13.7 Probability of accepting corrupted uplink frames

The probability of accepting a corrupted uplink frame shall be compatible with the requirement defined in 5.4.3.

NOTE For the error rate defined in 5.6.13.5 and using the error control mechanisms defined in ECSS-E-50-04 and ISO 12172, ISO 12173, and ISO 12174, the probability of undetected frame error can be made to be below 10^{-18} using frame error control, and below 10^{-8} without frame error control.

5.6.13.8 Downlink frame rejection rate

The downlink frame rejection rate should be less than 10^{-5}.

5.6.13.9 Probability of accepting corrupted downlink frames

The probability of accepting a corrupted downlink frame for maximum sized frames should be less than 10^{-12}.

5.6.13.10 Low delay

The space link shall be designed to minimize the end-to-end delay of delivery of space link service data units.

5.6.13.11 Downlink rates

a. The downlink data rates shall be selected to be compatible with the data transmission requirements of all phases of the mission.

b. The downlink data rates shall be constrained in bandwidths compatible with ITU-RR in terms of frequency and bandwidth allocation.

5.6.14 Space link frequency

5.6.14.1 Space link media

a. The space link media shall be used to communicate between spacecraft and ground segment and between one spacecraft and another spacecraft.

b. The total number of frequencies used by a project should be minimized.

5.6.14.2 Frequency band selection

a. Frequency bands for space communication systems shall be selected from bands allocated for this service by the ITU-RR in accordance with the type of service of the spacecraft mission.

b. An application for frequency assignment shall be made to the Radio Communication Bureau of the ITU for the selected space communication frequencies prior to the SRR.

c. The use of the radio frequency assigned for space communication use shall be subject to the regulations of the Radio Communication Bureau of the ITU.

NOTE The space communication system frequencies and selection procedures are detailed in ECSS‐E‐50‐05.

5.6.14.3 Unwanted RF emissions

Unwanted RF emissions shall be kept at a level such that they do not interfere with users of other bands.

NOTE Requirements on spurious emissions address both:

- a global limitation on the level of the spurious signals over the whole frequency spectrum, and
- special protection applicable to the band of the particularly interference-sensitive services: radio astronomy and deep space.

5.6.14.4 Power flux density limits

a. In certain of the bands allocated to space services, power flux density (PFD) limits on the Earth’s surface shall apply.

NOTE These are described in ECSS‐E‐50‐05.

b. These PFD limits shall apply during all phases of the mission.

NOTE This can involve means of reducing the transmit power onboard the spacecraft.

5.6.14.5 Power limits for earth station RF emissions

The earth station RF emissions shall conform to the ITU/RR.

NOTE Specifications for the maximum equivalent isotropic radiated power (EIRP) that can be transmitted in a direction towards the horizon are described in ECSS-E-50-05.

5.6.15 Space link modulation and coding

5.6.15.1 Modulation

The space link modulation scheme shall be selected to minimize the occupied bandwidth of the transmitted signals.

NOTE Suitable modulation schemes are defined in ECSS-E-50-05.

5.6.15.2 Coding

The space link channel coding scheme shall be selected to minimize the power required on the space link.

NOTE This is in order to minimize the potential for harmful interference to other users. Suitable channel coding schemes are defined in relevant ECSS-E-50 Level 3 Standards (e.g. ECSS-E-50-01 and ECSS-E-50-04).

5.6.16 Space link protocol

5.6.16.1 Spacecraft and link identification

Formatted data units used on the space link shall include a specific identification of the spacecraft and link involved in a ground to space communication.

5.6.16.2 Data unit identifier

Formatted data units used on the space link shall include an identifier that identifies the source, the destination, or both source and destination of the data unit.

NOTE The data unit identifier need only be unique to the specific spacecraft domain. Universally unique identification of the source and or destination can therefore involve reference to several identifiers in combination, such as the data unit identifier in combination with the spacecraft identifier.

5.6.16.3 Sequence identifier

Formatted data units used on the space link shall include a sequence identifier that identifies the data units position in a stream of data units on the space link in order to detect duplication or omission of data units.

5.6.16.4 Error detection

a. The space link protocol should include an error detection capability.

b. The probability of an undetected error on the space link shall be specified as a project specific item.

NOTE The error detection performance can differ on the uplink and downlink.

c. For both the uplink and downlink, the error detection used should be compatible with the telecommand and telemetry performances set out in subclause 5.6.13.

NOTE The error control schemes defined in ECSS-E-50-01 and ECSS-E-50-04 provide the means to do this at various link bit error rate operating points.

5.6.16.5 ARQ settings

ARQ settings shall be verified in end-to-end simulations under all expected conditions to ensure that there is neither unnecessary loss of data nor excessive re-transmission.

5.6.17 Space link service

5.6.17.1 Space link sub-network services

The space link shall provide sub-network services as defined in ISO 7498 to overlying layers.

NOTE This is intended to enable the use of existing and forthcoming terrestrial commercial protocols in the external transfer layers, and to enable simple relaying into internal ground and onboard sub-networks.

5.6.17.2 Connection establishment and maintenance

The space link shall provide a connection establishment and maintenance function.

NOTE Space link connection establishment involves the acquisition of carrier and configuration of the link for data transfer at the beginning of a contact period, and the ordered disconnection at the end of a contact period. This can include negotiation of signalling rates to suit the RF characteristics of the link at establishment time. Link maintenance is the management of the connection after link establishment and can include periodic re-negotiation of signalling rates as the RF characteristics of the link change during a contact period.

5.6.17.3 Guaranteed delivery

The space link shall provide a guaranteed delivery service which ensures that SDUs are delivered and preserves the ordering of SDUs.

NOTE The space link can also provide other services or grades of service that do not guarantee delivery, or do not preserve the order of space link SDUs.

5.6.17.4 Expedited delivery

The space link shall provide a service for expedited delivery of SDUs, i.e. a service that processes SDUs with priority over other SDUs already submitted for transmission.

NOTE ISO 7498 considers expedited services to be used only in connection-mode transmissions. However, in the space link this concept is applied to connection-mode and connectionless-mode transmissions. In connectionless-mode, expedited services SDUs are transmitted before any other SDUs queued for transmission on the space link.

5.6.17.5 Isochronous services

The space link shall provide isochronous duplex services when supporting time critical delivery of voice and video data.

5.6.17.6 Isochronous requirements

The isochronous services should be specified as a nominal data rate, a maximum nominal latency and a maximum deviation characteristic from that latency.

5.6.17.7 Time correlation

The space link shall provide a time correlation capability that enables the time maintained on the spacecraft, the onboard time, to be correlated with the time maintained on the ground.

5.6.17.8 Ranging

The space link shall provide a ranging capability that enables the distance between a ground station antenna and the spacecraft antenna to be determined.

5.6.17.9 Voice and video services

The space link should provide symmetrical voice and video services for spacecraft to ground interaction.

NOTE These services are primarily for manned missions.

5.6.17.10 Telecommand receipt confirmation

The space link should provide a telecommand receipt confirmation function that confirms receipt of telecommands at the space network gateway.

NOTE This function confirms that telecommands were received onboard the spacecraft, but does not necessarily imply that they were routed through the space network or delivered to the end destination.

5.6.17.11 Space link exception reporting

a. The space link shall provide an exception reporting function that enables the reporting of all detected errors.

b. Exceptions should include receipt of erroneous data units, even if corrected, receipt of undeliverable SDUs, failure to deliver SDUs, link reconfiguration, and unexpected loss of link.

5.7 Space network

5.7.1 Overview

5.7.1.1 General

The space network is described in subclause 4.3.2.

5.7.1.2 Deterministic performance

The space network performance should be deterministic under all loads.

5.7.1.3 Synchronous command and control

The space network shall provide the capability of synchronous command and control of onboard sensors and actuators.

5.7.1.4 Asynchronous data transfers

The space network shall provide the capability of performing asynchronous data transfers between connected nodes.

5.7.1.5 Isochronous data transfers

The space network should provide the capability of performing isochronous data transfers between connected nodes.

5.7.1.6 Space network medium access

The space network shall provide medium access mechanisms to enable all connected nodes to access the onboard sub-network in order to transfer data.

5.7.1.7 Hot redundant operation of space network nodes

The space network shall enable the hot redundant operation of all connected nodes.

5.7.1.8 Environment tolerance

The space network shall be designed to operate under the worst case environmental conditions (e.g. EMC and radiation) expected for the mission.

5.7.1.9 Space network error rates

The probability of errors occurring during the transfer of data across the space network shall be lower than that specified for the space link.

5.7.2 Space network services

5.7.2.1 Packet transfer service

The space network shall provide a packet transfer service that enables each application in the space network domain to exchange data packets with other applications in the space network domain and the ground network domain.

5.7.2.2 Reliable packet transfer

The space network shall provide a reliable packet transfer service that guarantees the delivery of data packets to the destination or, if the packet cannot be delivered, notifies the sender that the packet is not deliverable.

5.7.2.3 Expedited transfer services

The space network shall provide the capability of expediting data transfers.

NOTE Expedited data is transferred before any non-expedited data.

5.7.2.4 Space network management service

The space network shall provide a network management service that maintains the space network routing and configuration tables in order to provide high reliability and availability of the space network.

5.7.2.5 Space network redundancy management

The space network shall provide services that manage the redundancy, including for example selection between underlying buses and reconfiguration of addresses and routing tables to accommodate switching to redundant units.

5.7.2.6 Space network exception reporting

a. The space network shall provide an exception reporting function that enables all detected errors to be reported.

b. Exceptions shall include receipt of erroneous data units, even if corrected, receipt of undeliverable SDUs, failure to deliver SDUs, loss of sub-network links, and reconfiguration due to fault detection.

5.7.2.7 Telecommand delivery confirmation

The space network shall provide a telecommand delivery confirmation capability that confirms delivery of telecommands to the end destination within the space network domain.

NOTE This service confirms that telecommands were delivered to the end destination, but does not necessarily imply that they were executed. Confirmation of execution is a requirement on the application responsible for execution, and is outside the scope of this Standard.

5.7.2.8 Time distribution

The space network shall provide a time distribution capability that enables a reference time maintained onboard the spacecraft to be distributed throughout the space network.

5.8 Ground network

5.8.1 Overview

The ground network and many of its associated requirements are largely defined in ECSS-E-70, and described in subclause 4.3.4.

5.8.2 Data labelling

The ground network shall ensure that all items of data acquired from the spacecraft are uniquely labelled so that the parameter name, the sampling time, and the time received on ground can be determined.

5.8.3 Security

The ground network shall provide security mechanisms to prevent unauthorized access to the ground facilities to command or acquire data from the spacecraft.

5.8.4 Error rates

Error rates on the ground network shall be significantly lower than those on both the space link and the space network.

5.8.5 Hot redundant operation of ground network nodes

The ground network shall enable the hot redundant operation of nodes used for the control and operation of critical mission functions.

5.8.6 Ground network availability

a. The ground network shall be available for all scheduled operations on the spacecraft.

b. The ground network should also be accessible during non-scheduled operations for contingency purposes.

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Annex A (normative)

Documentation

Table A-1 identifies the list of the document requirements definitions (DRDs) associated with this Standard.

Table A-1: ECSS-E-50 DRD list

DRD Id	DRD Title	DRD summary content	Applicable to (phase)	Delivered	Remarks
ECSS‐E‐50 Part 2* Annex A	Communication System Requirement Document (CSRD)	Formally describes the requirements from the customer on the spacecraft communication system. Covers ground network, space link, and space network requirements, design, development, and operation.	Requirement engineering	SRR	
ECSS‐E‐50 Part 2* Annex B	Communication system baseline definition (CSBD)	Formal response to the CSRD that constitutes the technical baseline for the design and implementation of the spacecraft communication system. Includes a compliance matrix with the CSRD and any derived requirements. Documents any major assumptions and constraints and non-compliances.	Analysis	PDR	
ECSS‐E‐50 Part 2* Annex C	Communication system analysis document (CSAD)	Contains a full technical analysis of the communication system leading to the selection of frequencies, protocols, protocol options, redundancy strategy, and operational concept.	Analysis	PDR	
ECSS‐E‐50 Part 2* Annex D	Communication system verification plan (CSVP)	Describes the verification test plan for the spacecraft communication system. Plan covers tests carried out during verification phase and tests that may be used during operations.	Analysis, verification	PDR	
ECSS‐E‐50 Part 2* Annex E	Communication system architectural design document (CSADD)	Describes the architectural design of the spacecraft communication system and shows the relationships between the communication system and other mission systems.	Design and configuration	PDR	
ECSS‐E‐50 Part 2* Annex F	Communication system detailed design document (CSDDD)	Describes the detailed design of the spacecraft communication system.	Design and configuration	CDR	

* To be published.

Table A-1: ECSS-E-50 DRD list *(continued)*

DRD Id	DRD Title	DRD summary content	Applicable to (phase)	Delivered	Remarks
ECSS-E-50 Part 2* Annex G	Communication system profile document (CSPD)	Documents the communication system profile, including frequency assignments, protocol selection, protocol options, address assignments, channel assignments, spacecraft identifier assignments, spacelink bandwidth allocations, and onboard bus bandwidth allocations for TM and TC.	Design and configuration	CDR	a. The CSPD constitutes the formal statement of compliance to ECSS-E-50. b. Level 3 ECSS standards applied to the communication system have their own profile documents.
ECSS-E-50 Part 2* Annex H	Communication system operations manual (CSOM)	Formally describes all procedures for the operation of the spacecraft communication system. Covers normal and contingency operations. Normal operations include procedures such as spacecraft signal acquisition, loss of signal, and hand-over, as well as communication system management activities such as address initialization and router configuration and maintenance. Contingency operations cover uni-directional communications (uplink only, downlink only) and unexpected loss and discontinuous signal.	Analysis	PDR	

* To be published.

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Bibliography

ECSS-E-50-02 [2)]	Space engineering – Ranging
ECSS-E-50-12A	SpaceWire – Links, nodes, routers and networks
ECSS-E-10	Space engineering – System engineering
ECSS-E-20	Space engineering – Electrical and electronic
ECSS-E-40	Space engineering – Software engineering
ECSS-E-70	Space engineering – Ground systems and operations
ECSS-M-00-02A	Space project management - Tailoring of space standards
ECSS-M-30	Space project management - Project phasing and planning
ISO 11103:1991	Space data and information transfer systems - Radio metric and orbit data
ISO 11104:1991	Space data and information transfer systems – Time code formats
ISO 11754:2003	Space data and information transfer systems – Telemetry channel coding
ISO 12171:2002	Space data and information transfer systems – Telecommand – Channel service
ISO 12172:2003	Space data and information transfer systems – Telecommand - Data routing service
ISO 12173:2003	Space data and information transfer systems – Telecommand – Command operation procedures
ISO 12174:2003	Space data and information transfer systems – Telecommand – Data management service – Architectural specification
ISO 13419:2003	Space data and information transfer systems – Packet telemetry
ISO 13420:1997	Space data and information transfer systems – Advanced orbiting systems – Networks and data links – Architectural specification
ISO 15887:2000	Space data and information transfer systems – Data systems – Lossless data compression

2) To be published.

MIL-STD-1553	1553 Data bus interface
CCSDS 103-0-B2	Packet Telemetry services – Blue Book, Issue 2, June 2001
CCSDS 320.0-B-3	CCSDS Global Spacecraft Identification Field Code Assignment Control Procedures - Blue Book. Issue 3, April 2003
CCSDS 727-B-2	CCSDS File delivery Protocol (CFDP) - Blue Book, Issue 2, October 2002
CCSDS 910.4-B-1	CCSDS Cross Support system description Volume 4, May 1996

ECSS Document Improvement Proposal

1. Document I.D.	**2. Document date**	**3. Document title**
ECSS-E-50 Part 1A	20 October 2003	Communications — Part 1: Principles and requirements
4. Recommended improvement (identify clauses, subclauses and include modified text or graphic, attach pages as necessary)		
5. Reason for recommendation		
6. Originator of recommendation		
Name:	Organization:	
Address:	Phone: Fax: e-mail:	**7. Date of submission:**
8. Send to ECSS Secretariat		
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Note: The originator of the submission should complete items 4, 5, 6 and 7.

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