



Space engineering

Communications

Foreword

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.

This Standard has been prepared by the ECSS-E-ST-50C Revision Working Group, reviewed by the ECSS Executive Secretariat and approved by the ECSS Technical Authority.

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Change log

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Table of contents

Change log	3
Introduction	8
1 Scope	9
2 Normative references	10
3 Terms, definitions and abbreviated terms	11
3.1 Terms defined in other standards	11
3.2 Terms specific to the present standard	11
3.3 Abbreviated terms.....	13
4 Space communications engineering principles	15
4.1 Context.....	15
4.2 Overall space communication.....	16
4.3 Space communication domains	21
4.3.1 Overview.....	21
4.3.2 Space network	21
4.3.3 Space link	22
4.3.4 Ground network	23
4.4 Communications engineering process	24
4.4.1 Introduction	24
4.4.2 Communication engineering activities	24
4.4.3 Process milestones.....	26
4.5 Relationship with other standards.....	26
4.6 <<deleted>>	27
4.7 Spacecraft control considerations.....	27
5 Requirements	28
5.1 Introduction.....	28
5.2 Space communication system engineering process.....	28
5.2.1 Requirements engineering	28
5.2.2 Analysis	29
5.2.3 Design and configuration.....	30
5.2.4 Implementation	31
5.2.5 Verification	33
5.2.6 Operations	34

5.3	Space communication system	35
5.3.1	Bandwidth allocation	35
5.3.2	Congestion.....	35
5.3.3	Cessation of emission	35
5.4	Telecommanding	36
5.4.1	Commandability at all attitudes and rates.....	36
5.4.2	Telecommand delivery service.....	36
5.4.3	Erroneous telecommand rejection.....	36
5.4.4	Essential telecommand distribution	36
5.4.5	Command authentication	37
5.4.6	Command encryption	37
5.4.7	Commanding-in-the-blind	37
5.4.8	Telecommand acknowledgement.....	37
5.4.9	Hot redundancy of on-board telecommand chains	38
5.4.10	Telecommand destination identification.....	38
5.5	Telemetry	38
5.5.1	Telemetry at all attitudes and rates	38
5.5.2	Essential telemetry acquisition	38
5.5.3	Telemetry source identification.....	39
5.5.4	Telemetry-in-the-blind	39
5.5.5	Telemetry data time stamping	40
5.5.6	Simultaneous support of differing source rates.....	40
5.5.7	Telemetry authentication and encryption.....	40
5.6	Space link.....	41
5.6.1	Introduction	41
5.6.2	Directionality	41
5.6.3	Short contact periods	42
5.6.4	Interoperability	42
5.6.5	Orbits	42
5.6.6	Noise sources	42
5.6.7	Mission phases	42
5.6.8	Link setup times	43
5.6.9	Mixed isochronous and asynchronous traffic.....	43
5.6.10	Mixed housekeeping and payload data	43
5.6.11	Space link performance	43
5.6.12	Space link frequency.....	46
5.6.13	Space link protocol.....	47

5.6.14	Space link service	48
5.7	Space network.....	51
5.7.1	On-board network	51
5.7.2	On-board network services	52
5.7.3	Inter-spacecraft network.....	53
5.7.4	Inter-spacecraft network services.....	54
5.8	Ground network.....	55
5.8.1	Overview.....	55
5.8.2	Data labelling	55
5.8.3	Security.....	55
5.8.4	Error rates.....	55
5.8.5	Hot redundant operation of ground network nodes.....	55
5.8.6	Ground network availability	56
Annex A (normative) Communication system requirements document (CSR) - DRD		57
A.1.1	Requirement identification and source document.....	57
A.1.2	Purpose and objective.....	57
A.2.1	Scope and content	57
A.2.2	Special remarks	61
Annex B (normative) Communication system baseline definition (CSBD) - DRD		62
B.1.1	Requirement identification and source document.....	62
B.1.2	Purpose and objective.....	62
B.2.1	Scope and content	62
B.2.2	Special remarks	67
Annex C (normative) Communication system analysis document (CSAD) - DRD		68
C.1.1	Requirement identification and source document.....	68
C.1.2	Purpose and objective.....	68
C.2.1	Scope and content	68
C.2.2	Special remarks	70
Annex D (normative) Communication system verification plan (CSVP) - DRD		71
D.1.1	Requirement identification and source document.....	71
D.1.2	Purpose and objective.....	71
D.2.1	Scope and content	71
D.2.2	Special remarks	73

Annex E (normative) Communication system architectural design document (CSADD) - DRD	74
E.1.1 Requirement identification and source document.....	74
E.1.2 Purpose and objective.....	74
E.2.1 Scope and content	75
E.2.2 Special remarks	76
Annex F (normative) Communication system detailed design document (CSDDD) - DRD	77
F.1.1 Requirement identification and source document.....	77
F.1.2 Purpose and objective.....	77
F.2.1 Scope and content	78
F.2.2 Special remarks	79
Annex G (normative) Communication system profile document (CSPD) - DRD	80
G.1.1 Requirement identification and source document.....	80
G.1.2 Purpose and objective.....	80
G.2.1 Scope and content	80
G.2.2 Special remarks	81
Annex H (normative) Communication system operations manual (CSOM) - DRD	82
H.1.1 Requirement identification and source document.....	82
H.1.2 Purpose and objective.....	82
H.2.1 Scope and content	82
Annex I (informative) Documentation summary	85
Bibliography.....	88
Figures	
Figure 4-1: Example configuration of a space communication system.....	16
Figure 4-2: CCSDS and Internet space link protocols.....	20
Tables	
Table I-1 : ECSS-E-ST-50 DRD list	86

Introduction

This standard specifies requirements for the development of the end-to-end data communication system for spacecraft. Implementation aspects are defined in ECSS-E-ST-50 Level 3 standards, ECSS Adoption Notices and CCSDS standards.

The complete set of standards to define a complete communication link is project dependent and cannot be specified here. ECSS-E-HB-50 provides some guidance on this aspect, and gives some practical examples.

1

Scope

This Standard specifies the requirements for the development of the end-to-end data communications system for spacecraft.

Specifically, this standard specifies:

- 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-ST-10 standard.
- Specific requirements on space communication systems in respect of functionality and performance.

The communications links covered by this Standard are the space-ground (i.e. space-to-ground and ground-to-space) 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.

NOTE Other aspects of the ground network are covered in ECSS-E-ST-70.

This Standard may be tailored for the specific characteristics and constraints of a space project in conformance with ECSS-S-ST-00.

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-S-ST-00-01 ECSS system — Glossary of terms

Terms, definitions and abbreviated terms

3.1 Terms defined in other standards

- a. For the purpose of this Standard, the terms and definitions from ECSS-S-ST-00-01 apply, in particular for the following terms:
 1. function
 2. interface
- b. For the purpose of this Standard, the terms and definitions from ECSS-E-ST-20 apply, in particular for the following term:
 1. essential function

NOTE Synonym to the term “vital function” from ECSS-E-ST-70-11
- c. For the purpose of this Standard, the terms and definitions from ECSS-E-ST-70-11 apply, in particular for the following terms:
 1. commandable vital function
 2. high priority command
 3. high priority telemetry
 4. vital function

NOTE Synonym to the term “essential function” from ECSS-E-ST-20.
 5. vital telecommand

3.2 Terms specific to the present standard

3.2.1 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.

3.2.2 duplex service

point-to-point system composed of two or more connected parties or devices that can communicate with one another in both directions

3.2.3 entity

active element within a system

3.2.4 essential telecommand

telecommand that controls essential or vital functions

NOTE This corresponds to “high priority telecommand” in ECSS-E-ST-70-11)

3.2.5 essential telemetry

telemetry that enables a reliable determination of the current status of vital on-board equipment available under all circumstances

NOTE This correspond to “high priority telemetry” in ECSS-E-ST-70-11.

3.2.6 frame

service data unit passed, at the sending end, from the protocol sublayer to the coding and synchronization sublayer

NOTE For definition of layers see [Figure 4-2](#).

3.2.7 isochronous service

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

3.2.8 protocol

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

3.2.9 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.

3.2.10 service data unit

amount of information whose identity is preserved when transferred between peer (N+1) entities and which is not interpreted by the supporting (N) entities

NOTE Also known as: (N) service data unit.

3.2.11 simplex

communicating in one direction from data source to data sink

3.2.12 source

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

3.2.13 telecommand link

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

NOTE The term “uplink” is synonymous.

3.3 Abbreviated terms

For the purpose of this Standard, the abbreviated terms from ECSS-ST-00-01 and the following apply:

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 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/RR	ITU / Radio Regulations
LEOP	launch and early operations phase
MEC	mission experiment centre
OSI	open system interconnection
OCC	operational control centre
PDR	preliminary design review
PFD	power flux density
QR	qualification review

Abbreviation	Meaning
RF	radio frequency
SDLS	space data link security
SDU	service data unit
SRR	system requirements review
TT&C	telemetry, tracking and command

Space communications engineering principles

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 orbit determination (via e.g. ranging and/or Doppler measurements). 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 and/or Doppler measurements are used to determine the distance and/or the velocity between a ground station antenna and the spacecraft 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 (via e.g. ranging and/or Doppler measurements);
- to ensure reliable and error free end-to-end communication between ground stations and the spacecraft or between a spacecraft and a landed element;
- 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.

4.2 Overall space communication

Figure 4-1 shows an example of a configuration for a space communication system.

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

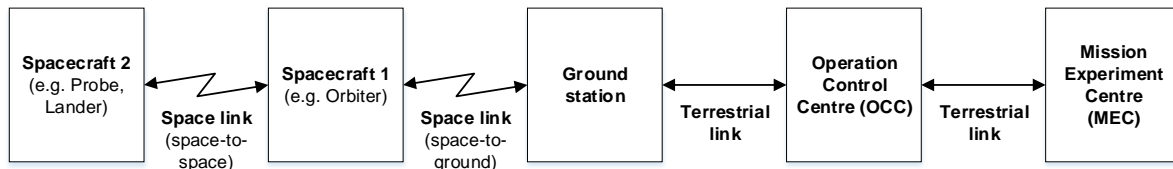


Figure 4-1: Example configuration of a space communication system

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-ground). This spacecraft 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;
- other spacecraft, landers, and probes linked together forming an inter-spacecraft network (see clause 4.3.2.3) not shown in Figure 4-1;

- a ground station that forms the terrestrial end of the space-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 processing for transferring data from a sending element to a receiving element of the space communication system via an external link consists of:

- For the downlink data stream:
 - At the sending element
 - Acquisition of data from subsystems or next element (e.g. probe or lander).
 - Processing and formatting of the data stream.
 - Transmission of the data stream to the ground via the external (space) link as telemetry.
 - At the receiving element
 - Acquisition of the data stream from the sender via the external link.
 - De-formatting and processing for delivery to receiver internal elements (e.g. space system user when ground station and OCC are in the same system) and for transfer to the next element via an external link (e.g. transfer from ground station to OCC).
 - Delivery of data to receiver internal elements.
 - Transmission of data to the next element via external (terrestrial) link.
- For the uplink data stream:
 - At the sending element
 - Acquisition of data from space system user.
 - Processing and formatting of the data stream.
 - Transmission of the data stream to the spacecraft via the external (space) link as telecommand.

- At the receiving element
 - Acquisition of the data stream from the sender via the external link.
 - De-formatting and processing for delivery to receiver internal elements (e.g. commands to spacecraft subsystems for a link between ground station and spacecraft) and for transfer to the next element (e.g. probe or lander) via an external link.
 - Delivery of data to receiver internal elements.
 - Transmission of data to the next element via external (space-to-space) link.

In the case of space-to-space links, the processing for transferring data from a sending element to a receiving element of the space communication system via return and forward link is similar to the one described for downlink and uplink.

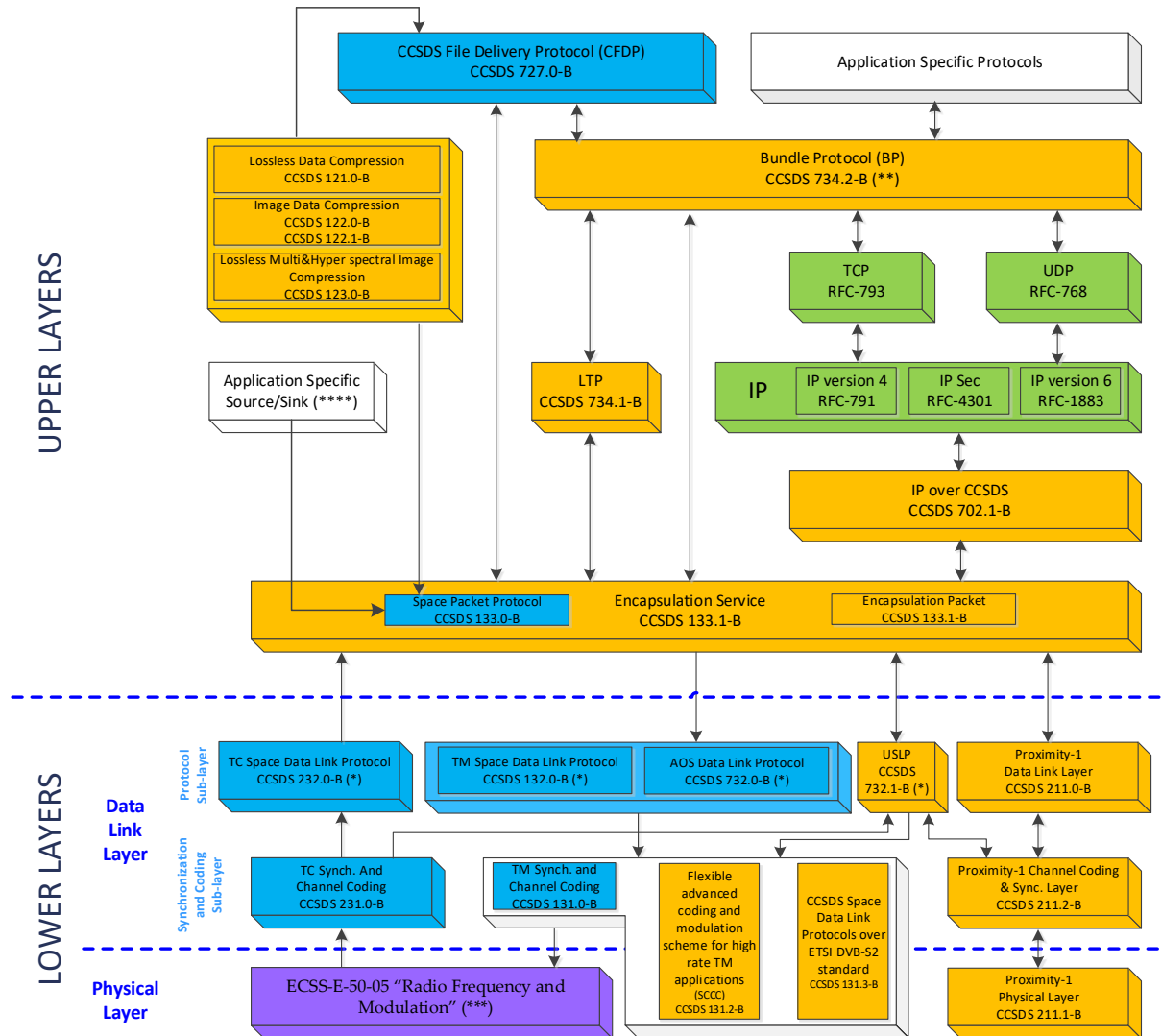
The type of data to be transmitted can be telemetry, files, video, and digital voice for the downlink, and telecommands, files, video, and digital voice for the uplink. The same type of data can be transmitted for return and forward links in space-to-space transmission.

For each type of data transmission, protocols defined by CCSDS or other standardization bodies can be used. [Figure 4-2](#) shows some of the CCSDS and internet protocols that can be used over the space links (i.e. space-ground and space-to-space). Connections among standards are marked with arrow highlighting the most usual data flow direction as seen on-board (e.g. the TC data flow enters the spacecraft from the bottom while the TM data flow exits the spacecraft towards the bottom; i.e. RF standards). However, not all the possible connections among boxes are shown to avoid making the picture too complex; e.g. the fact that CFDP can run directly on top of either TCP or UDP is not shown. This figure illustrates some relationship to the seven ISO reference model layers defined in ISO 7498. Data Link Layer (including the two Protocol and Coding & Synchronization sublayers) and Physical Layer are shown in detail while the other layers are grouped as Upper Layers.

It is also important that some of the CCSDS Standards are formally adopted by ECSS via Adoptions Notices, namely:

ECSS Adoption Notice	Based on CCSDS	Superseded ECSS	Part of ECSS Standard superseded
ECSS-E-AS-50-21	CCSDS 131.0-B - TM Synchronization and Channel Coding	ECSS-E-ST-50-01C 31 July 2008	Whole ECSS Standard
ECSS-E-AS-50-22	CCSDS 132.0-B - TM Space Data Link Protocol	ECSS-E-ST-50-03C 31 July 2008	Topic "TM Transfer Frame"
ECSS-E-AS-50-23	CCSDS 732.0-B - AOS Space Data Link Protocol		ECSS-E-ST-50-03 was limited to the TM Transfer Frame. It did not include the AOS Transfer Frame
ECSS-E-AS-50-24	CCSDS 231.0-B - TC Synchronization and Channel Coding	ECSS-E-ST-50-04C 31 July 2008	Clause 8 (Synchronization and coding sublayer) Clause 9 (Physical layer)
ECSS-E-AS-50-25	CCSDS 232.0-B - TC Space Data Link Protocol		Clause 5 (Segmentation sublayer) Clause 6 (Transfer sublayer)
ECSS-E-AS-50-26	CCSDS 232.1-B - Communications Operation Procedure-1		Clause 7 (COP-1)

Figure 4-2 references the Proximity-1 suite of standards, that is however just one possible choice for communications over proximity links.



- NOTES:
- CCSDS standard formally adopted by ECSS CCSDS standard not formally adopted by ECSS
 - Internet TCP/IP standard ECSS standard
 - (*) including Space Data Link Security Protocol (optional) CCSDS 355.0-B
 - (**) including the Bundle Security Protocol (BSP) CCSDS 734.5-B (under development).
 - (***) CCSDS has its own Physical Layer standard (401.0-B) which includes additional options with respect to ECSS-E-50-05 "Radio Frequency and Modulation"
 - (****) An example of «Application Specific Source/Sink» is the ECSS-E-ST-70-41C «Telemetry and telecommand packet utilization»
 - Future Optical Communication Standards: CCSDS 141.0-B «Optical Communications Physical Layer» and CCSDS 142.0-B «Optical Communications Coding and Synchronization» are not shown in figure
 - Uni-directional arrows are applicable to the On-Board segment, they are reversed in the Ground segment

Figure 4-2: CCSDS and Internet space link protocols

Each layer provides services and protocols defined either in ECSS standards, or by other explicitly referenced standards such as CCSDS recommended standards. Depending on their profile, users access services provided by any of the on-board or ground layers. Communications internal to the on-board and ground segments are performed via the local transfer protocols and sub-networks, which are not covered by this Standard. End-to-end communications between space and ground segments are via the spacelink upper layers protocols and Data Link and Physical layers (i.e. the lower layers), which do form part of this Standard.

The space link Data Link and Physical layers enable access to the space link medium and provide basic services for the transmission of delimited or undelimited data across the link. The space link upper and lower 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 on-board TT&C and Data Handling subsystems. On the ground they can reside completely in the ground station, or can be partitioned between ground station and control centre or customer facility.

The ground and on-board upper 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 on-board and ground upper layers make use of the services provided by the space link upper and lower layers to transfer data from data system to data system.

The ground and on-board layers (upper and lower) implement the services and protocols used for the independent operation of the on-board and ground systems.

4.3 Space communication domains

4.3.1 Overview

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.

4.3.2 Space network

4.3.2.1 Overview

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.

4.3.2.2 On-board network

On-board network is limited to intra-spacecraft links within a given spacecraft. The type of network medium and topologies of the on-board network are highly varied, often being based on proprietary protocols. The emphasis of this Standard in this case is on the definition of appropriate upper layers services that maintain freedom of choice in the on-board Data Link and Physical layers, while also moving towards harmonization and better definition of the on-board Data Link and Physical layers.

Except in very rare circumstances, the on-board network cannot be maintained or upgraded during a mission. Usually, the technology used to implement the on-board 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.

4.3.2.3 Inter-spacecraft network

An inter-spacecraft network is a set of spacecraft connected by inter-spacecraft links. An increasing number of missions involve a space segment consisting of multiple elements possibly from different organizations, e.g. constellations of spacecraft, or planetary missions consisting of an orbiter and lander, or orbiter-lander-rover. These type of missions impact the nature of the space network by including spacecraft-to-spacecraft unreliable/intermittent wireless links (e.g. spacecraft constellations, and links between spacecraft and landed elements such as orbiter-lander or orbiter-lander-rover configurations) and introducing the potential for a variable network topology.

NOTE CCSDS 734.2-B-1 provides a Bundle Protocol (BP) which defines end-to-end protocol, block formats, and abstract service descriptions for the exchange of messages (bundles) that support Delay Tolerant Networking (DTN). For DTN, CCSDS-734.1-B-1 also provides a Licklider Transmission Protocol (LTP) that provides optional reliability mechanisms on top of an underlying (usually data link) communication service.

4.3.3 Space link

The space link is essentially a point-to-point wireless link between a ground station and a spacecraft or between two spacecraft as shown in [Figure 4-1](#). 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 on-board or on ground, do not generally use the space link services directly, accessing these services instead through their local ground or on-board sub-networks, which are not covered by this Standard. 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 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 on-board 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 (e.g. ground-to-space) and one for return (e.g. space-to-ground) communication links. However, it is assumed that emergency control of the spacecraft can be achieved with only a uni-directional link, e.g. with only the forward link operational. Emergency and degraded scenarios are further elaborated in clause 4.7.

In a space-ground link the forward link corresponds to the uplink, i.e. the telecommand link.

In a space-to-space link the forward link corresponds to the portion of a proximity space link in which the caller transmits and the responder receives (typically a command link).

4.3.4 Ground network

The ground network comprises ground-based equipment and terrestrial links that are used to support the mission operations. The ground segment is largely described by ECSS-E-ST-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 services and protocols used to transfer spacecraft data between nodes in the ground network and nodes in the space network.

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-ST-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 Overview

Spacecraft communications engineering comprises the following activities:

- communications 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 life cycle.

The goals and activities to be performed for the communications engineering management are described in ECSS-E-ST-10 clauses 5.1 and 5.6.

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-ST-10 clause 5.2.

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-ST-10 clause 5.3.

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 in ECSS-E-ST-10 clause 5.4 and ECSS-M-ST-40.

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 in ECSS-E-ST-10 clause 5.5 and fully detailed in ECSS-E-ST-10-02.

4.4.2.8 Operations

Once the space communication system is implemented and verified, it enters its operations activity. This continues throughout the operational lifetime of the spacecraft. However, the start of the operations activity 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

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;
- operational readiness review, ORR;
- flight readiness review, FRR.

During the planning phase for a project, the need for additional reviews can be identified, and then documented and incorporated into the project plan. Project phasing and planning is covered by ECSS-M-ST-10.

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 and external standards.

Specifically ECSS-E-ST-70 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 standards, or other external standards such as ISO or CCSDS standards.

4.6 <<deleted>>

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 on-board 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 on-board 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 on-board failures or incorrect operation of the on-board 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 on-board 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 on-board 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 commanding in the blind to tolerate the loss of the return link.

In a space-ground link the return link corresponds to the downlink, i.e. the telemetry link.

In a space-to-space link the return link corresponds to the portion of a proximity space link in which the responder transmits and the caller receives (typically a telemetry link).

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.

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

Clauses 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.

Clauses 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 Overview

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 of the communication system, and the results of this activity are then communicated to the supplier of the system.

5.2.1.2 Activities

ECSS-E-ST-50_0970001

- a. During communication system requirements engineering the customer shall perform the following activities:
 1. analysis of top level mission requirements specifications,
 2. identification and expression of requirements specific to the space communication system, and
 3. formulation of new communication system requirements not derived from other mission documentation.

5.2.1.3 Outputs

ECSS-E-ST-50_0970002

- a. As an output from the requirements engineering activity, the customer shall produce the space communication system requirements specification (CSRD) in conformance with the DRD of Annex A.

5.2.2 Analysis

5.2.2.1 Overview

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

ECSS-E-ST-50_0970003

- a. During communication system analysis, the supplier shall perform the following activities:
 1. feasibility analysis of the communication system requirements,
 2. technical analysis of e.g. data rates, link margins, commandability, Doppler effects on carrier and data signals;
 3. criticality analysis of the space communication system;
 4. definition of the top-level space communication system architecture;
 5. definition of the system verification plan, including compatibility and inter-operability testing;
 6. identification of potential solutions for the realization of the space communication system;
 7. identification and request for assignment of globally managed parameters such as radio frequencies and spacecraft identifiers;
 8. identification of telemetry parameters, their criticality classification, and their need for time stamping at source;
 9. identification of telecommand parameters;
 10. identification of data flows between system elements;
 11. identification of ranging requirements.

5.2.2.3 Outputs

ECSS-E-ST-50_0970004

- a. The supplier shall provide a communication link margin analysis and Doppler margin analysis reports, in conformance with the DRD in Annex C (CSAD).

ECSS-E-ST-50_0970005

- b. The supplier shall provide a criticality analysis report, in conformance with the DRD in Annex C (CSAD).

ECSS-E-ST-50_0970006

- c. The supplier shall provide a system verification plan (CSVP), in conformance with Annex D.

ECSS-E-ST-50_0970007

- d. The supplier shall provide a inter-operability and compatibility test plans (CSVP), in conformance with Annex D.

5.2.3 Design and configuration

5.2.3.1 Overview

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

ECSS-E-ST-50_0970008

- a. During communication system design and configuration the supplier shall perform the following activities:
 1. partitioning of the detailed design from the analysis phase into system components that can be realized separately;
 2. allocation of unique names or identifiers to all of the system components in accordance with the project's configuration management methodology;
 3. generation of requirement specifications for all system components;
 4. definition of manual and automatic operational procedures, including link acquisition procedure, link release procedure, synchronization procedure, and data rate and frequency negotiation procedures;
 5. review link margin analysis and update.

5.2.3.3 Outputs

ECSS-E-ST-50_0970009

- a. The supplier shall provide a detailed design of the space communication system (CSBD, CSADD, CSDDD, CSPD) in conformance with the DRD in Annex B, Annex E, Annex F and Annex G,

ECSS-E-ST-50_0970010

- b. The supplier shall provide a list containing all components of the space communication system that are subject to configuration control (CSDDD), in conformance with the DRD in Annex F,

ECSS-E-ST-50_0970011

- c. The supplier shall provide the simulations and demonstrations used to verify the design, to resolve design conflicts, and to select options (CSAD), in conformance with the DRD in Annex C, and

ECSS-E-ST-50_0970012

- d. The supplier shall provide the definitions of operational procedures (CSOM), in conformance with the DRD in Annex H.

5.2.4 Implementation

5.2.4.1 Overview

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

ECSS-E-ST-50_0970013

- a. During space communication system implementation the supplier shall perform the following activities:
 1. 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;
 2. 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;
 3. the integration of all components, both manufactured and procured, to produce the complete space communication system;

4. 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;
5. execution of inter-operability and compatibility tests and generation of test result reports;
6. 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;
7. review of link margin analysis and updating.

5.2.4.3 Outputs

ECSS-E-ST-50_0970014

- a. During the space communication system implementation activity the supplier shall deliver the complete communication system to the customer.

ECSS-E-ST-50_0970015

- b. The supplier shall provide 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), in conformance with the DRD in Annex E, Annex F and Annex D;

ECSS-E-ST-50_0970016

- c. The supplier shall provide all test and check-out procedures used to verify the system (CSVP), in conformance with the DRD in Annex D;

ECSS-E-ST-50_0970017

- d. The supplier shall provide 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), in conformance with the DRD in Annex D;

ECSS-E-ST-50_0970018

- e. The supplier shall provide documents relating to the execution and results of verification tests, and inter-operability and compatibility tests (CSVP), in conformance with the DRD in Annex D;

ECSS-E-ST-50_0970019

- f. The supplier shall provide 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), in conformance with the DRD in Annex E, Annex F and Annex D, respectively.

5.2.5 Verification

5.2.5.1 Overview

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: evidence of verification is provided by the supplier, and accepted by the customer.

5.2.5.2 Activities

ECSS-E-ST-50_0970020

- a. During space communication system verification the supplier shall perform the following activities:
 1. the execution in a fully controlled environment of all agreed verification tests and procedures;
 2. the formal recording and subsequent analysis of all verification test results, and the completion of compliance and characterization matrices for the space communication system;
 3. review of link margin analysis and updating.

5.2.5.3 Outputs

ECSS-E-ST-50_0970021

- a. The supplier shall provide a verification test report detailing the results of the execution of all verification tests, in conformance with the Verification report DRD in Annex F of ECSS-E-ST-10-02.

ECSS-E-ST-50_0970022

- b. A declaration of acceptance shall be signed by the customer and supplier to confirm the customer acceptance of the delivered product.

ECSS-E-ST-50_0970235

- c. The supplier shall provide relevant system characterization data (CSPD) in conformance with the Communication system profile document (CSPD) DRD in Annex G.

5.2.6 Operations

5.2.6.1 Overview

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

ECSS-E-ST-50_0970023

- a. The activities performed during space communication system operations shall include:
 1. operation of the space communication system as and when specified by the mission to achieve the objectives of the mission;
 2. maintenance, including planned upgrades of the system and reconfiguration for different phases of the mission;
 3. provision of additional support for spacecraft trouble shooting and contingency operations;
 4. 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

ECSS-E-ST-50_0970024

- a. During the space communication system operation activities, the space communication system shall be operated to meet the mission's system requirements.

ECSS-E-ST-50_0970025

- b. During the space communication system operation activities, periodic reports on utilization and performance to assist in maintenance planning shall be produced.

5.3 Space communication system

5.3.1 Bandwidth allocation

ECSS-E-ST-50_0970026

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

ECSS-E-ST-50_0970027

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

NOTE For essential telecommand see 5.4.4b. For essential telemetry, see 5.5.2b

5.3.2 Congestion

ECSS-E-ST-50_0970028

- a. The space communication system shall ensure that data is not lost due to congestion.

NOTE This can be ensured by using buffering and flow control techniques.

5.3.3 Cessation of emission

ECSS-E-ST-50_0970029

- a. 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

ECSS-E-ST-50_0970030

- a. 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

ECSS-E-ST-50_0970031

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

5.4.3 Erroneous telecommand rejection

ECSS-E-ST-50_0970032

- a. 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 telecommand distribution

ECSS-E-ST-50_0970033

- 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.

ECSS-E-ST-50_0970034

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

ECSS-E-ST-50_0970035

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

ECSS-E-ST-50_0970036

- d. For critical operations, execution of the essential telecommands shall not depend on software functions.

NOTE Example of critical operations is switching the transmitters on and off.

5.4.5 Command authentication

ECSS-E-ST-50_0970037

- a. 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

ECSS-E-ST-50_0970038

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

NOTE Authentication and encryption can be provided, together or separately, at the upper layers, but it can also be provided at the Protocol sub layer of the Data Link layer e.g via the Space Data Link Security (SDLS) option provided in ECSS-E-AS-50-25.

ECSS-E-ST-50_0970222

- b. <<deleted>>

5.4.7 Commanding-in-the-blind

ECSS-E-ST-50_0970040

- a. The space communication system shall enable commanding-in-the-blind operation.

NOTE Commanding-in-the-blind is the up-linking of telecommands in the absence of any feedback telemetry or command acknowledgements from the spacecraft.

5.4.8 Telecommand acknowledgement

ECSS-E-ST-50_0970041

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

5.4.9 Hot redundancy of on-board telecommand chains

ECSS-E-ST-50_0970236

- a. When the on-board telecommand chain features multiple input channels, the selection process of the active input channel shall prevent that the channel with lower signal quality, inducing a significant frame rejection rate, is repeatedly selected.

NOTE Dual lock issue is described in clause 4.4.5.2 of ECSS-E-HB-50 "Communications guidelines".

5.4.10 Telecommand destination identification

ECSS-E-ST-50_0970237

- a. All telecommands shall carry an identifier that indicates the destination spacecraft to which it is addressed.

NOTE This clause applies to transmission over the space link.

5.5 Telemetry

5.5.1 Telemetry at all attitudes and rates

ECSS-E-ST-50_0970042

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

NOTE 1 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.

NOTE 2 In some deep space missions (additional) essential telemetry can be implemented by the transmission of basic health status information via dedicated sub-carriers only or tones modulation (semaphores approach).

5.5.2 Essential telemetry acquisition

ECSS-E-ST-50_0970043

- 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 only one of the redundant parts of the other systems, including the CDMU, is operational.

ECSS-E-ST-50_0970044

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

ECSS-E-ST-50_0970045

- c. Essential telemetry shall include the information necessary on the ground to determine the overall condition of the spacecraft.

NOTE For example, the power system state, the status of critical systems including the on-board data handling system, and whether telecommands are being received.

ECSS-E-ST-50_0970223

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

5.5.3 Telemetry source identification

ECSS-E-ST-50_0970047

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

NOTE When telemetry data are de-formatted and processed to propagate through the ground network, the spacecraft identifier is normally retained e.g. as data annotation.

5.5.4 Telemetry-in-the-blind

ECSS-E-ST-50_0970048

- a. The space communication system shall enable telemetry-in-the-blind operation.

NOTE Telemetry-in-the-blind is the down-linking of telemetry data in the absence of any up-link signal to the spacecraft.

5.5.5 Telemetry data time stamping

ECSS-E-ST-50_0970049

- a. All telemetry data generated on-board 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 on-board application that generated the telemetry data.

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

5.5.6 Simultaneous support of differing source rates

ECSS-E-ST-50_0970050

- 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.

ECSS-E-ST-50_0970051

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

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

5.5.7 Telemetry authentication and encryption

ECSS-E-ST-50_0970238

- a. The space communication system shall provide telemetry authentication and encryption services when the security requirements cannot be met by other means.

NOTE Authentication and encryption can be provided, together or separately, at the upper layers, but it can also be provided at the Protocol sub layer of the Data Link layer e.g via the Space Data Link Security (SDLS) option provided in ECSS-E-AS-50-22 and ECSS-E-AS-50-23.

5.6 Space link

5.6.1 Introduction

5.6.1.1 Overview

The space link modulation scheme is selected to minimize the occupied bandwidth of the transmitted signals. Suitable modulation schemes are defined in ECSS-E-ST-50-05.

The space link channel coding scheme is selected to minimize the power to be used by the space link in order to minimize the potential for harmful interference to other users. Suitable channel coding schemes are defined in relevant ECSS-E-ST-50 Standards (e.g. ECSS-E-AS-50-21 and ECSS-E-AS-50-24).

The space link is described in clause 4.3.3.

5.6.1.2 Conformity to ITU/RR

The space link is subjected to the ITU/RR regulations, in particular:

- Downlink data rates (see NOTE to requirement 5.6.11.11a).
- use of the radio frequency assigned for space communication (see NOTE 1 to requirement 5.6.12.2a)
- frequency bands for space communication systems (see NOTE 2 to requirement 5.6.12.2a).
- Earth station RF emissions. This limits the radiated power. Specifications for the maximum equivalent isotropic radiated power (EIRP) that can be transmitted in a direction towards the horizon are described in ECSS-E-ST-50-05.

5.6.2 Directionality

ECSS-E-ST-50_0970052

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

ECSS-E-ST-50_0970053

- 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.

5.6.3 Short contact periods

ECSS-E-ST-50_0970054

- a. 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.

5.6.4 Interoperability

ECSS-E-ST-50_0970055

- a. 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 customer receive only ground stations.

NOTE The concept of “housekeeping” is described in ECSS-E-ST-70-11.

5.6.5 Orbits

ECSS-E-ST-50_0970056

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

ECSS-E-ST-50_0970057

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

5.6.6 Noise sources

ECSS-E-ST-50_0970058

- a. 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.

5.6.7 Mission phases

ECSS-E-ST-50_0970059

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

5.6.8 Link setup times

ECSS-E-ST-50_0970060

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

NOTE Link setup times are kept to a minimum in order to cope with short contact periods with the spacecraft.

5.6.9 Mixed isochronous and asynchronous traffic

ECSS-E-ST-50_0970061

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

5.6.10 Mixed housekeeping and payload data

ECSS-E-ST-50_0970062

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

5.6.11 Space link performance

5.6.11.1 Doppler shift and Doppler rate

ECSS-E-ST-50_0970063

- a. 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.

5.6.11.2 Operation during tumbling

ECSS-E-ST-50_0970064

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

ECSS-E-ST-50_0970065

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

5.6.11.3 Tolerance of run lengths and transition densities

ECSS-E-ST-50_0970066

- a. The space link shall be designed to tolerate the worst case run lengths and transition densities that can occur in the data.

NOTE For example, runs of zeros or ones, or data patterns that result in very high or very low transition densities in the modulated signal.

ECSS-E-ST-50_0970067

- 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.

5.6.11.4 Failure modes

ECSS-E-ST-50_0970068

- a. The space link shall be adaptable to a range of failure modes including:
1. loss of link,
 2. reduction in link margin, and
 3. sporadic carrier acquisition.

5.6.11.5 Uplink assumed bit error rate (BER)

ECSS-E-ST-50_0970069

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

5.6.11.6 Uplink frame rejection rate

ECSS-E-ST-50_0970070

- a. 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} .

NOTE When using the BCH error control mechanisms defined in ECSS-E-AS-50-24 this corresponds to a frame rejection rate greater than 10^{-5} for a frame size of 1024 octets. When this performance is not adequate for a given mission, a better BER at the input to the telecommand decoder is needed. ECSS-E-AS-50-24 also offers an LDPC error control mechanisms with better performances than BCH.

5.6.11.7 Probability of accepting corrupted uplink frames

ECSS-E-ST-50_0970071

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

NOTE For the error rate defined in clause 5.6.11.5 and using the BCH error control mechanisms defined in ECSS-E-AS-50-24, ECSS-E-AS-50-25 and ECSS-E-AS-50-26, 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.

5.6.11.8 Downlink frame rejection rate

ECSS-E-ST-50_0970224

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

5.6.11.9 Probability of accepting corrupted downlink frames

ECSS-E-ST-50_0970225

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

5.6.11.10 Low delay

ECSS-E-ST-50_0970074

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

5.6.11.11 Downlink rates

ECSS-E-ST-50_0970075

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

NOTE It is important to ensure that the downlink data rates are constrained in bandwidths compatible with ITU-RR in terms of frequency and bandwidth allocation.

5.6.12 Space link frequency

5.6.12.1 Space link media

ECSS-E-ST-50_0970076

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

ECSS-E-ST-50_0970226

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

5.6.12.2 Frequency band selection

ECSS-E-ST-50_0970078

- a. 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.

NOTE 1 The use of the radio frequency assigned for space communication use is subject to the regulations of the Radio Communication Bureau of the ITU. The space communication system frequencies and selection procedures are detailed in ECSS-E-ST-50-05.

NOTE 2 It is important to ensure that the frequency bands for space communication systems are selected from bands allocated for this service by the ITU-RR in accordance with the type of service of the spacecraft mission.

5.6.12.3 Unwanted RF emissions

ECSS-E-ST-50_0970079

- a. 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 are described in ECSS-E-ST-50-05 and 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.

5.6.12.4 Power flux density limits

ECSS-E-ST-50_0970080

- a. In the bands allocated to space services, power flux density (PFD) limits on the Earth's surface shall apply during all phases of the mission.

NOTE 1 These are described in ECSS-E-ST-50-05.

NOTE 2 This can involve means of reducing the transmit power on-board the spacecraft.

ECSS-E-ST-50_0970081

- b. <<deleted>>

5.6.13 Space link protocol

5.6.13.1 Spacecraft and link identification

ECSS-E-ST-50_0970082

- a. Frames used on the space link shall include a specific identification of the spacecraft and link involved in a space-ground communication.

NOTE The frame version number defined in ECSS-E-AS-50-22 and ECSS-E-AS-50-23 and ECSS-E-AS-50-25 can be used to identify the link.

5.6.13.2 Data unit identifier

ECSS-E-ST-50_0970083

- a. 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.

5.6.13.3 Sequence identifier

ECSS-E-ST-50_0970084

- a. 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.

5.6.13.4 Error detection

ECSS-E-ST-50_0970085

- a. The space link protocol shall include an error detection capability.

ECSS-E-ST-50_0970086

- 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.

ECSS-E-ST-50_0970227

- c. For both the uplink and downlink, the error detection used should be compatible with the telecommand and telemetry performances set out in clause 5.6.11.

NOTE The error control schemes defined in ECSS-E-AS-50-21 and ECSS-E-AS-50-24 provide the means to do this at various link bit error rate operating points.

5.6.13.5 ARQ settings

ECSS-E-ST-50_0970088

- a. 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.

5.6.14 Space link service

5.6.14.1 Connection establishment and maintenance

ECSS-E-ST-50_0970089

- a. 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 space link data 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 space link

data rates as the RF characteristics of the link change during a contact period.

5.6.14.2 Guaranteed delivery

ECSS-E-ST-50_0970090

- a. 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.

5.6.14.3 Expedited delivery

ECSS-E-ST-50_0970091

- a. 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.

5.6.14.4 Isochronous services

ECSS-E-ST-50_0970092

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

5.6.14.5 Isochronous requirements

ECSS-E-ST-50_0970093

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

5.6.14.6 Time correlation

ECSS-E-ST-50_0970094

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

5.6.14.7 Ranging and Doppler tracking

ECSS-E-ST-50_0970095

- a. The space link shall provide at least one of the two following capabilities that enables determining the distance or the velocity or both between a ground station antenna and the spacecraft antenna:
 1. ranging capability,
 2. Doppler tracking capability.

NOTE Suitable methods are defined in ECSS-E-ST-50-02 Ranging and Doppler tracking. Missions requiring very accurate orbit determination often use Pseudo-Noise (PN) Ranging Systems and/or Delta DOR.

5.6.14.8 Telecommand receipt confirmation

ECSS-E-ST-50_0970096

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

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

5.6.14.9 Space link exception reporting

ECSS-E-ST-50_0970097

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

ECSS-E-ST-50_0970228

- b. Exceptions to be reported as specified in requirement 5.6.14.9a 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 On-board network

5.7.1.1 Overview

The on-board network is described in clause 4.3.2.2.

5.7.1.2 Deterministic performance

ECSS-E-ST-50_0970099

- a. The on-board network performance shall be deterministic under all loads.

5.7.1.3 Synchronous command and control

ECSS-E-ST-50_0970100

- a. The on-board network shall provide the capability of synchronous command and control of on-board sensors and actuators.

5.7.1.4 Asynchronous data transfers

ECSS-E-ST-50_0970101

- a. The on-board network shall provide the capability of performing asynchronous data transfers between connected nodes.

5.7.1.5 On-board network medium access

ECSS-E-ST-50_0970102

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

5.7.1.6 Hot redundant operation of space network nodes

ECSS-E-ST-50_0970103

- a. The on-board network should enable the hot redundant operation of all connected nodes.

5.7.1.7 <<deleted>>

ECSS-E-ST-50_0970104

- a. <<deleted>>

5.7.1.8 On-board network error rates

ECSS-E-ST-50_0970105

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

5.7.2 On-board network services

5.7.2.1 Data transfer services

ECSS-E-ST-50_0970106

- a. The on-board network shall provide data transfer services that enable each application in the on-board network domain to exchange data units with other applications in the on-board network domain with a reliable quality of service that guarantees the delivery of data units to the destination or, if the data unit cannot be delivered, notifies the sender that the data unit is not deliverable.

5.7.2.2 <<deleted>>

ECSS-E-ST-50_0970107

- a. <<deleted>>

5.7.2.3 Expedited transfer services

ECSS-E-ST-50_0970108

- a. The on-board network shall provide the capability of expediting data transfers that processes those data units with priority over other data units already submitted for transfer.

5.7.2.4 On-board network management service

ECSS-E-ST-50_0970109

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

5.7.2.5 On-board network redundancy management

ECSS-E-ST-50_0970110

- a. The on-board 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 On-board network exception reporting

ECSS-E-ST-50_0970111

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

ECSS-E-ST-50_0970112

- 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

ECSS-E-ST-50_0970113

- a. The on-board network shall provide a telecommand delivery confirmation capability that confirms delivery of telecommands to the end destination within the on-board 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

ECSS-E-ST-50_0970114

- a. The on-board network shall provide a time distribution capability that enables a unique reference time to be maintained throughout the on-board network.

5.7.3 Inter-spacecraft network

5.7.3.1 Overview

The inter-spacecraft network is described in clause 4.3.2.3.

5.7.3.2 Deterministic performance

ECSS-E-ST-50_0970239

- a. The inter-spacecraft network performance should be deterministic under all loads.

5.7.3.3 Asynchronous data transfers

ECSS-E-ST-50_0970240

- a. The inter-spacecraft network shall provide the capability of performing asynchronous data transfers between connected nodes.

5.7.4 Inter-spacecraft network services

5.7.4.1 Data transfer services

ECSS-E-ST-50_0970241

- a. The inter-spacecraft network shall provide data transfer services that enable each application in the inter-spacecraft network domain to exchange data units with other applications in the inter-spacecraft network domain.

ECSS-E-ST-50_0970242

- b. The inter-spacecraft network shall provide two qualities of service:
 1. a best effort quality of service, and
 2. a reliable quality of service that guarantees the delivery of data units to the destination or, if the data unit cannot be delivered, notifies the sender that the data unit is not deliverable.

5.7.4.2 Expedited transfer services

ECSS-E-ST-50_0970243

- a. The inter-spacecraft network shall provide the capability of expediting data transfers that processes those data units with priority over other data units already submitted for transfer.

5.7.4.3 Inter-spacecraft network management service

ECSS-E-ST-50_0970244

- a. The inter-spacecraft network shall provide a network management service supporting configuration, operations, monitoring, and provisioning of the network in order to provide high reliability and availability of the inter-spacecraft network.

5.7.4.4 Inter-spacecraft network exception reporting

ECSS-E-ST-50_0970245

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

5.7.4.5 Time synchronization

ECSS-E-ST-50_0970246

- a. The inter-spacecraft network should provide time synchronization services that enables aligning the network nodes clocks to a common reference time.

5.8 Ground network

5.8.1 Overview

The ground segment and many of its associated requirements are largely defined in ECSS-E-ST-70, and the ground network is described in clause 4.3.4.

5.8.2 Data labelling

ECSS-E-ST-50_0970115

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

5.8.3 Security

ECSS-E-ST-50_0970116

- a. 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

ECSS-E-ST-50_0970117

- a. 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

ECSS-E-ST-50_0970118

- a. 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

ECSS-E-ST-50_0970119

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

Annex A (normative)

Communication system requirements document (CSRSD) - DRD

A.1 DRD identification

A.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-50, requirement 5.2.1.3a.

A.1.2 Purpose and objective

The communication system requirements document (CSRSD) contains the top level assumptions, constraints and communication system requirements for a given mission to enable the supplier of the communication system to elaborate a design for the communication system.

The CSRSD is written by the space project customer and is the highest level requirements document defining the requirements on the space communication system. The supplier of the space communication system formally responds to the CSRSD with the communication system baseline definition (CSBD, see ECSS-E-ST-50 Annex B) where all the requirements in the CSRSD can be traced to a proposed implementation.

A.2 Expected response

A.2.1 Scope and content

<1> Introduction

ECSS-E-ST-50_0970120

- a. The CSRSD shall contain a description of the purpose, objective, content and the reason prompting its preparation.

<2> Applicable and reference documents

ECSS-E-ST-50_0970121

- a. The CSRSD shall list the applicable and reference documents in support to the generation of the document.

<3> Mission overview**ECSS-E-ST-50_0970122**

- a. The CSRD shall briefly describe:
 - 1. the main objectives and characteristics of the space mission;
 - 2. the spacecraft;
 - 3. the instruments on-board the spacecraft;
 - 4. the ground segment for the control and operations of the spacecraft, the instruments, and the ground segment itself;
 - 5. the operations to achieve the goal of the space project.

<4> Project responsibilities**ECSS-E-ST-50_0970123**

- a. The CSRD shall briefly describe the distribution of responsibilities within the space project, including the responsibilities of the space project customer and those of the communication system supplier.

<5> Major project milestones**ECSS-E-ST-50_0970124**

- a. The CSRD shall summarize the major project milestones relating to the space segment.

ECSS-E-ST-50_0970125

- b. The CSRD shall summarize the major project milestones relating to the ground segment.

ECSS-E-ST-50_0970126

- c. The CSRD shall summarize major project milestones relating to the communication system.

<6> Mission constraints**ECSS-E-ST-50_0970127**

- a. The CSRD shall include the following launch information
 - 1. The launch vehicle, the launch site location and the ascent trajectory.
 - 2. For orbital vehicles, the orbit injection characteristics.

ECSS-E-ST-50_0970128

- b. The CSRD shall describe the trajectory by summarizing the following:
 - 1. The trajectory of the spacecraft.

2. Any significant constraints or parameters associated with each part of the trajectory.
3. Any notable periods arising from the trajectory during which communications with the spacecraft are difficult or impossible.
4. For orbital vehicles, the intended orbital period and visibility periods and characteristics during which communication can be performed.

ECSS-E-ST-50_0970129

- c. The CSRD shall describe the operational phases by summarizing the following:
 1. Each distinct operational phase of the space mission.
 2. Any constraints on, and expected characteristics of the communication system for each phase.

NOTE Mission phases usually include LEOP, commissioning, routine operations, and disposal. Other phases that can be included are contingency operations, critical manoeuvres, and hibernation.

ECSS-E-ST-50_0970130

- d. The CSRD shall describe any constraints imposed on the communication system by the spacecraft.

NOTE For example power limitations, antenna pointing constraints, and prohibited frequencies.

ECSS-E-ST-50_0970131

- e. The CSRD shall describe any other constraints not covered in the preceding categories, and other essential mission information that impacts on the design of the communication system.

<7> Communication system requirements**<7.1> General****ECSS-E-ST-50_0970132**

- a. The CSRD shall list the high level requirements on the space communication system, at a level appropriate to enable all significant aspects of the communication system technical baseline to be elaborated.

NOTE This in turn enables:

- informed decision making concerning the development and procurement of the communication system components, and

- the communication system design drivers to be established.

ECSS-E-ST-50_0970133

- b. The list specified in <7.1>a shall include the communication system requirements that address the following major system elements:
1. functional;
 2. performance;
 3. reliability;
 4. availability;
 5. interface;
 6. design (implementation);
 7. maintainability;
 8. security.

ECSS-E-ST-50_0970134

- c. Where the requirements for a particular system element differ for different operational or mission phases, the requirements shall first be listed for the normal operational phases and then those that are different for other mission phases.

<7.2> Organization of the communication system requirements**ECSS-E-ST-50_0970135**

- a. The CSRD shall list the overall system requirements on the communication system including requirements related to:
1. overall system availability and reliability,
 2. end-to-end performance,
 3. communication system lifetime,
 4. design and implementation,
 5. interfaces to existing external entities, and
 6. compatibility with specific communications protocols.

ECSS-E-ST-50_0970136

- b. The CSRD shall list the security requirements for the communication system.

NOTE As specified in ECSS-E-ST-50, this is based on a threat analysis of the mission.

ECSS-E-ST-50_0970137

- c. The CSRD shall list the communication system requirements for the space network, which comprises all of the nodes of the flight segment of the mission.

ECSS-E-ST-50_0970138

- d. For missions that involve multiple space segment elements, such as cluster missions, orbiter-lander combinations, lander-rover combinations, and missions with deployable probes, the CSRD shall list the requirements on the communications between those elements.

ECSS-E-ST-50_0970139

- e. The CSRD shall list the requirements for the link between the ground station and the spacecraft including requirements regarding:
 - 1. uplink and downlink performance,
 - 2. RF frequencies,
 - 3. contact periods and outages,
 - 4. link acquisition, and
 - 5. link failure modes.

ECSS-E-ST-50_0970140

- f. The CSRD shall list the communication system requirements for the ground network, which comprises all of the ground communication facilities used in the mission, including requirements for redundancy, availability, and accessibility.

A.2.2 Special remarks

None.

Annex B (normative)

Communication system baseline definition (CSBD) - DRD

B.1 DRD identification

B.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-50, requirement 5.2.3.3a.

B.1.2 Purpose and objective

The communication system baseline definition (CSBD) is the top level design document produced by the communication system supplier to define the communication system to be developed for the mission. The CSBD forms the basis for all other specification and design activities undertaken by the communication system supplier, as well as constituting the baseline for generating cost and schedule information.

The CSBD constitutes the formal response to the CSRD (see ECSS-E-ST-50 Annex A). All requirements in the CSRD are traced in the CSBD and appropriately apportioned into specific CSBD clauses. Furthermore, any additional requirements can be derived in the CSBD to ensure common understanding and unambiguous interpretation of the CSRD requirements.

B.2 Expected response

B.2.1 Scope and content

<1> Introduction

ECSS-E-ST-50_0970141

- a. The CSBD shall contain a description of the purpose, objective, content and the reason prompting its preparation.

<2> Applicable and reference documents

ECSS-E-ST-50_0970142

- a. The CSBD shall list the applicable and reference documents in support to the generation of the document.

<3> Mission description and communication system overview**ECSS-E-ST-50_0970143**

- a. The CSBD shall describe the main objectives and characteristics of the space mission.

ECSS-E-ST-50_0970144

- b. The CSBD shall describe the communication system, including:
1. the intended communication system implementation,
 2. the main concepts of the proposed communication system,
 3. the system components of the communication system, indicating where they are located and how they interrelate, and
 4. the proposed protocols and communication frequencies to be used within the intended communication system.

<4> Mission constraints and implementation assumptions**ECSS-E-ST-50_0970145**

- a. The CSBD shall describe all mission constraints that affect the communication system.

NOTE These can include trajectory induced constraints such as out of contact, or hibernation mode, attitude induced constraints such as tumbling mode or antenna pointing limitations, and ground induced constraints such as ground station availability.

ECSS-E-ST-50_0970146

- b. The CSBD shall describe all of the assumptions made in establishing the communication system baseline definition.

<5> Communication system interfaces**ECSS-E-ST-50_0970147**

- a. The CSBD shall summarize the interfaces between the space network elements of the communication system and other entities onboard the spacecraft including:
1. the control interfaces for the onboard elements of the communication system, indicating how the onboard data handling system manages space link communication;
 2. the data interfaces that enable onboard entities to send data to and receive data from the ground;

ECSS-E-ST-50_0970148

- b. For missions that have multiple space segment elements, the CSBD shall summarize:
 - 1. how the communication links between those elements are controlled, and
 - 2. how data is transferred across them;

ECSS-E-ST-50_0970149

- c. The CSBD shall summarize the interfaces between the ground network elements of the communication system and other ground entities, including:
 - 1. the control interfaces for the ground elements of the communication system, indicating how the ground system manages space link communication;
 - 2. the data interfaces that enable ground entities to send data to and receive data from the spacecraft.

<6> Communication system analysis

ECSS-E-ST-50_0970150

- a. The CSBD shall describe:
 - 1. all of the communication system analysis and system studies to design a communication system that meets the objectives of the space mission, and
 - 2. the justification of the analysis and studies referred to in B.2.1<6>a1.

ECSS-E-ST-50_0970229

- b. The CSBD should:
 - 1. list all communication system issues to be resolved by modelling or simulation, and
 - 2. describe the modelling or simulation technique to be applied.

ECSS-E-ST-50_0970152

- c. The CSBD shall list the expected performances that can be achieved by the proposed communication system and indicate whether these fully meet the mission needs.

<7> Communication system design and implementation

ECSS-E-ST-50_0970153

- a. The CSBD shall describe the technical approach to the design and implementation of the overall communication system and each of its components.

<8> Communication system integration and technical verification and validation

ECSS-E-ST-50_0970154

- a. The CSBD shall describe the technical approach to the integration and testing of the communication system elements, and the technical verification and validation of the communication system as a whole.

<9> Communication system operations

ECSS-E-ST-50_0970155

- a. The CSBD shall describe all of the operational procedures relating to the communication system for normal operations.

ECSS-E-ST-50_0970156

- b. The CSBD shall describe all of the operational procedures relating to the maintenance of the communication system.

ECSS-E-ST-50_0970157

- c. The CSBD shall describe special operational procedures to be used for contingency operation of the communication system, i.e. in case of degradation of its normal performance.

NOTE These operational procedures can include unidirectional operation of the communication system, e.g. command-in-the-blind and telemetry-in-the-blind, and operation at reduced space link data rates.

ECSS-E-ST-50_0970158

- d. The CSBD shall describe the technical approach to monitoring the health and performance of the communication system.

ECSS-E-ST-50_0970159

- e. The CSBD shall describe any communication system specific operations not covered in items B.2.1<9>a to d.

NOTE For example, these can include procedures to support in-flight communications experiments, reconfiguration of the communication system to support new mission parameters such as the addition of new flight elements, and procedures to adapt the communication system for use on other missions.

<10> Special project facilities**ECSS-E-ST-50_0970160**

- a. The CSBD shall describe any special project facilities for the development and implementation of the communication system (e.g. the modification of existing ground facilities, or the adaptation of reused flight software).

<11> Support to other disciplines**ECSS-E-ST-50_0970161**

- a. The CSBD shall describe the support to be provided to other spacecraft disciplines by the communication system supplier.

NOTE This can include the provision of simulation models of communication system components, and test harnesses.

<12> Required input and output items and services**ECSS-E-ST-50_0970162**

- a. The CSBD shall list all of the deliverable items and services to be provided by the communication system supplier to support the mission.

ECSS-E-ST-50_0970163

- b. The CSBD shall list all of the items and services to be provided by the communication system customer in order to support the development of the communication system.

NOTE These can include:

- space segment design documents and information;
- ground segment design documents and information;
- access to testbeds, prototypes, and engineering models for integration and testing;
- simulation models of the ground and space segments.

<13> CSRD vs. CSBD traceability matrix**ECSS-E-ST-50_0970164**

- a. The CSBD shall provide a CSRD versus CSBD traceability matrix, summarized in a table, providing the following information for each entry:
1. requirements - containing a list of all requirements in the CSRD;

2. reference - providing a cross reference indicating one or more CSBD paragraphs where the requirement is fulfilled;
3. compliance - indicating the level of the suppliers' compliance of the CSBD to the CSRD with one of the following values:
 - COMPLIANT,
 - PARTIALLY COMPLIANT, or
 - NON-COMPLIANT;
4. notes - briefly describing the justification in those cases where column three indicates partial or non-compliance.

<14> To-be-resolved items

ECSS-E-ST-50_0970165

- a. The CSBD shall list all of the items for which a clear resolution has not yet been found.

<15> To-be-determined and to-be-confirmed items

ECSS-E-ST-50_0970166

- a. The CSBD shall list all of the items for which a specific communication system implementation cannot be committed without further information.

B.2.2 Special remarks

None

Annex C (normative)

Communication system analysis document (CSAD) - DRD

C.1 DRD identification

C.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-50, requirements 5.2.2.3a, 5.2.2.3b and 5.2.3.3c.

C.1.2 Purpose and objective

The communication system analysis document (CSAD) is produced by the communication system supplier to capture the results of analysis and testing of the communication system. The first issue of the CSAD is produced for the PDR, but it is updated throughout the project as further communication system analysis and testing is carried out and, as specified in ECSS-E-ST-50, is reviewed at each major project milestone following the PDR.

The results of all analysis and testing carried out on the communication system are reported in the CSAD. This document is therefore critical for tracking the development of the communication system throughout the project, ensuring that the communication system continues to meet the functional and performance requirements as the design and implementation are elaborated. The CSAD is used as a reference for the identification and resolution of any design issues throughout the development of the communication system.

C.2 Expected response

C.2.1 Scope and content

<1> Introduction

ECSS-E-ST-50_0970167

- a. The CSAD shall contain a description of the purpose, objective, content and the reason prompting its preparation.

<2> Applicable and reference documents**ECSS-E-ST-50_0970168**

- a. The CSAD shall list the applicable and reference documents in support to the generation of the document.

<3> Mission description and communication system overview**ECSS-E-ST-50_0970169**

- a. The CSAD shall describe the main objectives and characteristics of the space mission.

ECSS-E-ST-50_0970170

- b. The CSAD shall describe the intended communication system implementation.

<4> Overview of analysis approach**ECSS-E-ST-50_0970171**

- a. The CSAD shall provide an overview of the analysis approach applied to the communication system.

ECSS-E-ST-50_0970172

- b. The CSAD shall describe the goals and objectives of the analyses.

ECSS-E-ST-50_0970173

- c. The CSAD shall describe the different analysis techniques used on the communication system.

ECSS-E-ST-50_0970230

- d. The CSAD should contain a list of the communication system issues to be resolved by analysis.

<5> Description and results of analysis**ECSS-E-ST-50_0970175**

- a. The CSAD shall describe each of the analysis techniques applied to the communication system together with the results of that analysis.

ECSS-E-ST-50_0970176

- b. For each technique referred to in C.2.1<5>a, the CSAD shall include at least the following:

1. the objective of the analysis,
2. a detailed description of the analysis technique,
3. a description of any tools used to carry out the analysis,
4. a list of any assumptions made concerning the communication system or its environment during the analysis,
5. a list of starting conditions for the analysis,
6. copies of all inputs to the analysis,
7. the results of the analysis,
8. an appraisal of the analysis drawing conclusions and inferences with respect to the communication system, and
9. recommendations for the communication system based on the analysis.

NOTE The objective is that the analysis results can be reviewed offline, and the analyses can be repeated.

ECSS-E-ST-50_0970231

- c. The conclusions referred to in C.2.1<5>b.8 should indicate whether the communication system meets its functional and performance requirements.

ECSS-E-ST-50_0970232

- d. The recommendations referred to in C.2.1<5>b.9 should include recommendations on design changes.

C.2.2 Special remarks

None.

Annex D (normative)

Communication system verification plan (CSVP) - DRD

D.1 DRD identification

D.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-50, requirements 5.2.2.3c, 5.2.2.3d, 5.2.4.3b, 5.2.4.3c, 5.2.4.3d, 5.2.4.3e and 5.2.4.3f.

D.1.2 Purpose and objective

The communication system verification plan (CSVP) is produced by the communication system supplier to describe the verification strategy and specific verification tests used to ensure that the communication system complies with the requirements established in the CSRD and CSBD. The first issue of the CSVP is produced for the PDR but, as specified in ECSS-E-ST-50, is updated throughout the project as more detailed tests are defined and critical issues are identified, and is reviewed at each major project milestone following the PDR.

The CSVP defines the tests to be conducted on the communication system to verify conformity to CSRD (see ECSS-E-ST-50 Annex A) and CSBD (see ECSS-E-ST-50 Annex B) requirements and therefore derives from these two documents. The results of the verification tests and any analysis to be conducted as a part of the verification process are reported in the CSAD (see ECSS-E-ST-50 Annex C).

D.2 Expected response

D.2.1 Scope and content

<1> Introduction

ECSS-E-ST-50_0970179

- a. The CSVP shall contain a description of the purpose, objective, content and the reason prompting its preparation.

<2> Applicable and reference documents**ECSS-E-ST-50_0970180**

- a. The CSVP shall list the applicable and reference documents in support to the generation of the document.

<3> Mission description and communication system overview**ECSS-E-ST-50_0970181**

- a. The CSVP shall describe the main objectives and characteristics of the space mission.

ECSS-E-ST-50_0970182

- b. The CSVP shall describe the intended communication system implementation.

<4> Verification approach**ECSS-E-ST-50_0970183**

- a. The CSVP shall describe the approach to the communication system verification.

ECSS-E-ST-50_0970184

- b. The CSVP shall describe the techniques to be used for the verification.

ECSS-E-ST-50_0970185

- c. The CSVP shall list any special tools or facilities to be used.

<5> Verification schedule**ECSS-E-ST-50_0970186**

- a. The CSVP shall describe the communication system verification schedule explaining how the communication system verification schedule matches the development schedules for both the ground segment and flight segment of the space mission.

ECSS-E-ST-50_0970187

- b. The CSVP shall include a list of all tools and equipment to be used for the communication system verification activities, identifying for each tool
1. who is responsible for supplying it,
 2. where it is provided,
 3. the equipment configuration to use, and

4. the duration for which it is used.

<6> **Support to other verification activities**

ECSS-E-ST-50_0970188

- a. The CSVP shall describe the tools, equipment, and facilities associated with the communication system that can be made available to support other verification activities, such as the ground system or flight system verification.

ECSS-E-ST-50_0970189

- b. The CSVP shall describe the nature of the tool, equipment, or facility.

ECSS-E-ST-50_0970190

- c. The CSVP shall describe the capability of each tool.

ECSS-E-ST-50_0970191

- d. The CSVP shall describe when and where each tool can be made available.

<7> **Verification tests**

ECSS-E-ST-50_0970192

- a. The CSVP shall describe each verification test to be performed, including the following information for each one:
 1. a statement of the purpose of the verification test;
 2. a detailed description of the test;
 3. a list of the tools, equipment, or facilities to perform the test;
 4. a definition of the configuration of the test environment and the unit under test at the start of the test (i.e. pre-conditions);
 5. a description of the expected result (i.e. post-conditions);
 6. pass and fail criteria for the test.

NOTE The purpose of these test description is to ensure that the verification tests can be repeated.

D.2.2 Special remarks

None.

Annex E (normative)

Communication system architectural design document (CSADD) - DRD

E.1 DRD identification

E.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-50, requirements 5.2.3.3a, 5.2.4.3b and 5.2.4.3f

E.1.2 Purpose and objective

The communication system architectural design document (CSADD) describes the architectural design of the communication system defined in the CSBD (see ECSS-E-ST-50 Annex B).

The CSADD describes the design to the level where its functionality and operation can be understood for the purposes of the PDR. Furthermore, the CSADD enables the requirements for the individual system components, and the interfaces to those components, to be elaborated so that detailed design of the components can proceed.

The CSADD is produced by the communication system supplier to describe the architectural design of the communication system.

The CSADD is produced for the PDR, and its acceptance at the PDR by the communication system customer implies a commitment to proceed with the detailed design consistent with the architecture described. As specified in ECSS-E-ST-50, the CSADD is frozen after acceptance at the PDR.

The communication system architectural design document describes the high level architecture of the communication system and is therefore derived from the CSBD. In turn, the communication system detailed design document (CSDDD) is derived from the CSADD.

The interfaces identified within the CSADD, both between the communication system components, and to other external entities, are subject to tests defined in the CSVP. The functionality and performance of the communication system components identified in the CSADD can be the subject of specific analysis activities in the CSAD.

E.2 Expected response

E.2.1 Scope and content

<1> Introduction

ECSS-E-ST-50_0970193

- a. The CSADD shall contain a description of the purpose, objective, content and the reason prompting its preparation.

<2> Applicable and reference documents

ECSS-E-ST-50_0970194

- a. The CSADD shall list the applicable and reference documents in support to the generation of the document.

<3> Mission description and communication system overview

ECSS-E-ST-50_0970195

- a. The CSADD shall briefly describe:
 1. the main objectives and characteristics of the space mission, and
 2. the intended communication system baseline as defined in the CSBD.

<4> Communication system architectural design

ECSS-E-ST-50_0970196

- a. The CSADD shall contain a description of the architectural design of the communication system in a human readable format, and include the justification of all critical architectural design decisions.

ECSS-E-ST-50_0970197

- b. As a minimum, the architectural design of the communication system shall:
 1. list each major component of the communication system,
 2. describe the function and performance of each major component in terms of top level requirements,
 3. list and broadly describe all of the internal interfaces (i.e. interfaces between components of the communication system), and

4. list and broadly describe all of the external interfaces (i.e. interfaces between external entities and components of the communication system).

<5> **Requirement applicability matrix**

ECSS-E-ST-50_0970198

- a. This CSADD shall provide a requirement applicability matrix, including the following information:
 1. requirements - containing a list of all requirements in the CSRD plus any derived requirements contained in the CSBD;
 2. applicability - indicating the applicability of each requirement to each major communication system component. Usually, this column can be subdivided into a series of columns, one for each major system component, and completed check-box style;
 3. notes – providing any special information associated with a given requirement in respect of its allocation to a communication system component.

E.2.2 Special remarks

ECSS-E-ST-50_0970199

- a. Although this DRD imposes no constraints on the tools used to elaborate the architectural design, the architectural design shall be viewable without the use of the design tool.

Annex F (normative)

Communication system detailed design document (CSDDD) - DRD

F.1 DRD identification

F.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-50, requirements 5.2.3.3a, 5.2.3.3b , 5.2.4.3b and 5.2.4.3f

F.1.2 Purpose and objective

The communication system detailed design document (CSDDD) is produced by the communication system supplier and describes the detailed design of the communication system. Further elaborating the architectural design described in the CSADD, it derives from the CSBD (see ECSS-E-ST-50 Annex B) and CSADD (see ECSS-E-ST-50 Annex E).

The CSDDD describes the detailed design of each of the of the major communication system components identified in the CSADD.

The CSDDD is produced for the CDR, and its acceptance at the CDR by the communication system customer implies a commitment to proceed with the implementation of the system according to that detailed design.

As specified in ECSS-E-ST-50, the CSDDD is frozen after acceptance at the CDR.

Specific detailed tests for the components described in the communication system detailed design document are further described in the CSV (see ECSS-E-ST-50 Annex D). Any specific analysis activities to justify the detailed design are contained in the CSAD (see ECSS-E-ST-50 Annex C).

As specified in ECSS-E-ST-50, the implementation or procurement of all of the communication system components is based on the communication system detailed design document.

F.2 Expected response

F.2.1 Scope and content

<1> Introduction

ECSS-E-ST-50_0970200

- a. The CSDDD shall contain a description of the purpose, objective, content and the reason prompting its preparation.

<2> Applicable and reference documents

ECSS-E-ST-50_0970201

- a. The CSDDD shall list the applicable and reference documents in support to the generation of the document.

<3> Mission description and communication system overview

ECSS-E-ST-50_0970202

- a. The CSDDD shall describe the main objectives and characteristics of the space mission.

ECSS-E-ST-50_0970203

- b. The CSDDD shall describe the architectural design contained in the CSADD.

<4> Communication system detailed design

ECSS-E-ST-50_0970204

- a. The CSDDD shall contain the detailed design of the communication system, with all critical detailed design decision justifications, including:
 1. the requirements applicable to each of the major components of the communication system identified in the CSADD,
 2. the detailed design of each major component of the communication system,
 3. a justification of all design decisions relating to the detailed design of each component, and
 4. a complete description of all of the interfaces to each component.

<5> **ICDs of the major components**

ECSS-E-ST-50_0970205

- a. The CSDDD shall include the ICDs for each of the major components of the communication system.

F.2.2 Special remarks

ECSS-E-ST-50_0970233

- a. This DRD imposes no constraints on the tools used to elaborate the detailed design, and some elements of the detailed design, that can only be viewed with the aid of the tools used in the elaboration of the design, may be accepted.

Annex G (normative)

Communication system profile document (CSPD) - DRD

G.1 DRD identification

G.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-50, requirements 5.2.3.3a and 5.2.5.3c.

G.1.2 Purpose and objective

The communication system profile document (CSPD) is produced by the communication system supplier as a formal statement of the compliance of the communication system to the ECSS-E-ST-50 requirements and can be used for the establishment of interoperability agreements involving the communication system. The CSPD describes the frequencies, protocols and protocol options, address assignments, channel assignments, spacecraft identifier assignments, space link bandwidth allocations, and on-board bus bandwidth allocations used in the communication system.

The final version of the communication system profile document is available at FRR. First version is produced at CDR.

G.2 Expected response

G.2.1 Scope and content

<1> Introduction

ECSS-E-ST-50_0970207

- a. The CSPD shall contain a description of the purpose, objective, content and the reason prompting its preparation.

<2> Applicable and reference documents

ECSS-E-ST-50_0970208

- a. The CSPD shall list the applicable and reference documents in support to the generation of the document.

<3> **Mission description and communication system overview**

ECSS-E-ST-50_0970209

- a. The CSPD shall describe the main objectives and characteristics of the space mission, and

ECSS-E-ST-50_0970210

- b. The CSPD shall describe the communication system to which this profile document relates.

<4> **Communication system profile**

ECSS-E-ST-50_0970211

- a. The CSPD shall consist of all tables, matrices, compliance statements, and compliance pro-formas to fully describe the characteristics of the communication system.

NOTE This DRD imposes no constraints on the way in which this information is presented. Generally, any standard protocols that are used can be defined by the compliance pro-forma associated with that protocol. For other, mission specific characteristics such as the spacecraft identifier values, spacelink frequencies, channel allocations, and address assignments, it is good practice that an appropriate mission pro-forma is defined early in the programme and populated as the values become known.

G.2.2 Special remarks

None.

Annex H (normative)

Communication system operations manual (CSOM) - DRD

H.1 DRD identification

H.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-50, requirement 5.2.3.3d.

H.1.2 Purpose and objective

The communication system operations manual (CSOM) formally describes all procedures for the operation of the communication system. The operational procedures include normal and contingency operations. Normal operations include procedures for 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 space link (uplink only, downlink only), unexpected loss of signal, and discontinuous signal.

The CSOM is produced by the communication system supplier to describe the operations procedures for normal and contingency operation of the communication system.

The final version of the communication system operations manual is available for FRR. The first version is produced at PDR.

The communication system operations manual constitutes the user manual for the communication system. It is used in the development of the overall space mission operations procedures, and can be relevant to the definition of the on-board software.

H.2 Expected response

H.2.1 Scope and content

<1> Introduction

ECSS-E-ST-50_0970212

- a. The CSOM shall contain a description of the purpose, objective, content and the reason prompting its preparation.

<2> Applicable and reference documents**ECSS-E-ST-50_0970213**

- a. The CSOM shall list the applicable and reference documents in support to the generation of the document.

<3> Mission description and communication system overview**ECSS-E-ST-50_0970214**

- a. The CSOM shall briefly describe:
1. the main objectives and characteristics of the space mission, and
 2. the communication system implementation.

<4> Communication systems operations**ECSS-E-ST-50_0970215**

- a. The CSOM shall describe the procedures used to commission the communication system during the early phases of the mission;

ECSS-E-ST-50_0970216

- b. The CSOM shall describe the communication system test procedures used to verify the correct operation of the communication system during the mission;

ECSS-E-ST-50_0970217

- c. The CSOM shall describe all of the routine operations procedures that are used during the mission, i.e. once the communication system is commissioned and operating normally;

ECSS-E-ST-50_0970234

- d. The CSOM should include any procedure for the communication system reconfiguration that can be expected during the mission, such as the switch-over to a redundant communication chain, or the update of onboard routing tables;

ECSS-E-ST-50_0970219

- e. The CSOM shall describe the contingency operations procedures to be used during abnormal operating conditions, e.g. when failures occur in the communication system.

<5> Decommissioning procedure

ECSS-E-ST-50_0970220

- a. This CSOM shall describe the procedures used to decommission the communication system at the end of the mission.

<6> Additional operating procedures

ECSS-E-ST-50_0970221

- a. The CSOM shall describe any operating procedures applicable to the communication system not described in items H.2.1<4> and <5>.

NOTE For example, these can include procedures to extend the capability of the communication system during the mission, e.g. by adding spacecraft to an existing constellation.

Annex I (informative)

Documentation summary

Table I-1 identifies the list of the document requirements definitions (DRDs) associated with this Standard. The intention of this table is to indicate the relationship of documents associated to communication engineering activities which support project review objectives as specified in ECSS-M-ST-10.

NOTE This table constitutes a first indication for the data package content at various reviews. The full content of such data package is established as part of the business agreement, which also defines the delivery of the document between reviews.

Table I-1 lists the documents generated by the engineering organization necessary for the project reviews (identified by “X”). Those documents can be delivered as stand-alone documents, or combined, or their content can be included in satellite/system level documentation.

NOTE All documents, even when not marked as deliverables in Table I-1, are expected to be available (either as stand-alone or combined documents as agreed in a given project) and maintained under configuration management as per ECSS-M-ST-40 (e.g. to allow for backtracking in case of changes).

Table I-1: ECSS-E-ST-50 DRD list

DRD Id	DRD Title	DRD summary content	Applicable to (phase)	First Delivery at	Remarks
ECSS-E-ST-50 Annex A	Communication system requirements document (CSR D)	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	Updated/Finalized at PDR
ECSS-E-ST-50 Annex B	Communication system baseline definition (CSBD)	Formal response to the CSR D that constitutes the technical baseline for the design and implementation of the spacecraft communication system. Includes a compliance matrix with the CSR D and any derived requirements. Documents any major assumptions and constraints and non-compliances.	Analysis	PDR	
ECSS-E-ST-50 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	Updated/Finalized at CDR
ECSS-E-ST-50 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	Updated/Finalized at CDR, QR and AR
ECSS-E-ST-50 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-ST-50 Annex F	Communication system detailed design document (CSDDD)	Describes the detailed design of the spacecraft communication system.	Design and configuration	CDR	

DRD Id	DRD Title	DRD summary content	Applicable to (phase)	First Delivery at	Remarks
ECSS-E-ST-50 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	<ul style="list-style-type: none"> 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. c. Updated/Finalized at AR, ORR and FRR
ECSS-E-ST-50 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	Updated/Finalized at CDR, AR, ORR and FRR

Bibliography

ECSS-S-ST-00	ECSS system – Description, implementation and general requirements
ECSS-E-ST-10	Space engineering – System engineering general requirements
ECSS-E-ST-10-02	Space engineering – Verification
ECSS-E-HB-50	Space engineering – Communications guidelines
ECSS-E-ST-50-05	Space engineering – Radio frequency and modulation
ECSS-E-AS-50-21	Space engineering – ECSS Adoption Notice of CCSDS 131.0-B - TM Synchronization and Channel Coding
ECSS-E-AS-50-22	Space engineering – ECSS Adoption Notice of CCSDS 132.0-B - TM Space Data Link Protocol
ECSS-E-AS-50-23	Space engineering – ECSS Adoption Notice of CCSDS 732.0-B - AOS Space Data Link Protocol
ECSS-E-AS-50-24	Space engineering – ECSS Adoption Notice of CCSDS 231.0-B - TC Synchronization and Channel Coding
ECSS-E-AS-50-25	Space engineering – ECSS Adoption Notice of CCSDS 232.0-B - TC Space Data Link Protocol
ECSS-E-AS-50-26	Space engineering – ECSS Adoption Notice of CCSDS 232.1-B - Communications Operation Procedure-1
ECSS-E-ST-70	Space engineering – Ground systems and operations
ECSS-M-ST-10	Space project management – Project planning and implementation
ECSS-M-ST-40	Space project management – Configuration and information management
CCSDS 734.1-B-1 (May 2015)	Licklider Transmission Protocol (LTP) for CCSDS
CCSDS 734.2-B-1 (September 2015)	CCSDS Bundle Protocol Specification
ISO 7498:1984	ISO Information processing systems – Open systems interconnection – Basic reference model