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Space engineering — Space segment operability

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National foreword

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A list of organizations represented on this committee can be obtained on request to its secretary.

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**CEN-CENELEC Management Centre:
Avenue Marnix 17, B-1000 Brussels**

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Foreword

This document (EN 16603-70-11:2015) has been prepared by Technical Committee CEN/CLC/TC 5 “Space”, the secretariat of which is held by DIN.

This standard (EN 16603-70-11:2015) originates from ECSS-E-ST-70-11C.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by July 2015, and conflicting national standards shall be withdrawn at the latest by July 2015.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

This document has been developed to cover specifically space systems and has therefore precedence over any EN covering the same scope but with a wider domain of applicability (e.g. : aerospace).

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

The operability of the space segment has an impact on total life cycle cost inasmuch as increased operability can increase development costs, but certainly decreases operations and maintenance costs. Therefore, the adoption of specific operability goals for a given mission is decided by careful balancing of costs, risks, and schedules for both the development and the operations and maintenance phases.

The objective of this standard is to define operability requirements that:

- ensure that the space segment can be operated in a safe and cost-effective manner;
- facilitate the tasks of preparation for, and execution and evaluation of, space segment check-out and mission operations activities;
- facilitate the tasks of space segment suppliers when preparing a proposal in response to a request for proposal (RFP).

1

Scope

This Standard contains provisions for the design of on-board functions for unmanned space segments in order to ensure that the space segment can be operated in-flight in any nominal or predefined contingency situation.

The requirements in this Standard are grouped in two clauses, containing general operability requirements and detailed operability requirements, respectively. The general operability requirements can be applied to all missions, whilst the detailed operability requirements are only applicable if the corresponding on-board function is implemented.

The operability of the space segment to meet mission-specific requirements is outside the scope of this standard.

To support the users of this Standard in tailoring the requirements to the needs of their particular mission, Annex B contains a table that indicates, for each requirement, the potential impact of its omission.

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

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.

EN reference	Reference in text	Title
EN 16601-00-01	ECSS-S-ST-00-01	ECSS system – Glossary of terms
EN 16603-50-03	ECSS-E-ST-50-03	Space engineering – Space data links – Telemetry transfer frame protocol
EN 16603-50-04	ECSS-E-ST-50-04	Space engineering – Space data links – Telecommand protocols, synchronization and channel coding
EN 16603-70-41	ECSS-E-ST-70-41	Space engineering – Telemetry and telecommand packet utilization

Terms, definitions and abbreviated terms

3.1 Terms from other standards

For the purpose of this Standard, the terms and definitions from ECSS-S-ST-00-01 apply.

3.2 Terms specific to the present standard

3.2.1 Categories of operability

3.2.1.1 commandability

provision of adequate control functions to configure the on-board systems for the execution of nominal mission operations, failure detection, identification, isolation, diagnosis and recovery, and maintenance operations

3.2.1.2 compatibility

ability of two or more systems or components to perform their specified functions without interference

3.2.1.3 deactivation

capability to undertake planned operations to terminate the mission at the end of its useful lifetime

NOTE Terminate can mean to deactivate the spacecraft, to de-orbit it, or both.

3.2.1.4 flexibility

capability to configure and make optimum use of existing on-board functions, the capacity of the space-Earth communications links, and any redundancy built into the design in order to meet the reliability targets

3.2.1.5 observability

availability to the ground segment and to on-board functions of information on the status, configuration and performance of the space segment

3.2.1.6 testability

capability to test the on-board functions of the space segment including those that are "off-line"

NOTE "Off-line" means functions that do not form part of the current operational configuration.

3.2.2 Terms pertaining to critical functions

3.2.2.1 commandable vital function

vital function that is commandable by high-priority commands without the involvement of on-board software

3.2.2.2 high priority command

pulse command that is routed directly to hardware by means of an on-board command pulse distribution unit (CPDU)

3.2.2.3 high priority telemetry

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

NOTE High priority telemetry can be managed by a mechanism that is independent of the one used for standard housekeeping telemetry and normally without any microprocessor involvement.

3.2.2.4 locally-critical function

function that, when executed in the wrong context (e.g. at the wrong time), can cause temporary or permanent degradation of the associated local functions, but does not compromise higher level functionality

3.2.2.5 mission-critical function

function that, when executed in the wrong context (e.g. at the wrong time), or wrongly executed, can cause permanent mission degradation

3.2.2.6 permanent degradation of space segment function

situation where a given on-board function cannot be achieved either on the nominal or on any redundant chain for the remainder of the mission lifetime

3.2.2.7 permanent mission degradation

situation where space segment functions or performances affecting mission product generation or primary mission objectives cannot be achieved either on the nominal or on any redundant chain for the remainder of the mission lifetime

3.2.2.8 temporary degradation of space segment function

situation where a given on-board function cannot be achieved either on the nominal or on any redundant chain for a limited period of time

3.2.2.9 temporary mission degradation

situation where space segment functions or performance affecting mission product generation or primary mission objectives cannot be achieved either on the nominal or on any redundant chain for a limited period of time

NOTE For example, a mission outage following transition to survival mode.

3.2.2.10 vital function

function that is essential to mission success and that can cause permanent mission degradation if not executed when it should be, or wrongly executed, or executed in the wrong context

3.2.2.11 vital telecommand

telecommand that activates a commandable vital function

3.2.3 Other terms

3.2.3.1 application process

on-board entity capable of generating telemetry source data and receiving telecommand data

3.2.3.2 authorization

right of an authenticated entity to perform a function or access a data item or data stream

3.2.3.3 chain

set of hardware or software units that operate together to achieve a given function

NOTE For example, an attitude and orbit control subsystem (AOCS) processor and its software and a set of AOCS sensors and actuators together constitute an AOCS chain.

3.2.3.4 confidentiality

property that information is not made available or disclosed to unauthorized individuals, entities or processes

3.2.3.5 control function

mechanism to maintain a parameter or a set of parameters within specified limits

NOTE A control function normally consists of a set of measurements and responses (commands) related according to a function, algorithm, or set of rules.

3.2.3.6 data integrity

property that the data has not been altered or destroyed in an unauthorized manner

3.2.3.7 data origin authentication

corroboration that the source of the data received is as claimed

3.2.3.8 datation

attachment of time information to telemetry data

NOTE This includes payload measurement data.

3.2.3.9 device telecommand

telecommand that is routed to and executed by on-board hardware

NOTE For example, a relay switching telecommand, a telecommand to load an on-board register.

3.2.3.10 housekeeping telemetry

telemetry provided for the purposes of monitoring the health and functioning of the space segment

3.2.3.11 loss of mission

state where the ground segment can no longer control the space segment (e.g. due to loss of contact), or where the space segment can no longer achieve the mission goals (e.g. due to anomalies)

3.2.3.12 memory

on-board data storage area

NOTE 1 This includes main memory and storage memory.

NOTE 2 Examples of memory are disk, tape, and bubble-memory.

3.2.3.13 mode

operational state of a spacecraft, subsystem or payload in which certain functions can be performed

3.2.3.14 mode transition

transition between two operational modes

3.2.3.15 on-board autonomy

capability of the space segment to manage nominal or contingency operations without ground segment intervention for a given period of time

3.2.3.16 on-board monitoring

on-board application of checking functions to a set of on-board parameters in conformance with predefined criteria

NOTE Monitoring functions include limit-checking, expected-value-checking and delta-checking.

3.2.3.17 on-board operations procedure

monitoring and control procedure that is stored on-board and whose activation is under ground segment control

3.2.3.18 on-board operations schedule

on-board facility for storing and releasing telecommands that were loaded in advance from the ground

NOTE In its simplest form, the on-board operations schedule stores time-tagged telecommands loaded from the ground and releases them to the destination application process when their on-board time is reached.

3.2.3.19 operability

capability of the space segment to be operated by the ground segment during the complete mission lifetime, whilst optimizing the use of resources and maximizing the quality, quantity, and availability (or timeliness of delivery) of mission products, without compromising space segment safety

3.2.3.20 operations

activities undertaken by the ground and space segments in order to ensure the timely provision of mission products or services, recover from on-board contingencies, carry out routine maintenance activities and manage on-board resources in order to maximize the provision of mission products or services and the mission lifetime

3.2.3.21 parameter

lowest level of elementary data item on-board

3.2.3.22 parameter validity

condition that defines whether the interpretation of a telemetry parameter is reliable and meaningful

NOTE The angular output of a gyro only has a valid engineering meaning if the power to the gyro is “on”, while at other times the output is random. Such a parameter is deemed conditionally valid, with its validity determined from the power status.

3.2.3.23 peer-entity authentication

corroboration that a peer entity in an association is the one claimed

3.2.3.24 safe state

safe condition for a system, subsystem or payload

3.2.3.25 space segment status

information from which the operational status of the space segment is assessed and the criteria driving operational decisions are determined

3.2.3.26 survival mode

configuration of a spacecraft in which it can remain safely without ground segment intervention for a specified period

3.2.3.27 telecommand function

operationally self-contained control action initiated by telecommand that can comprise or invoke one or more lower level control actions

3.3 Abbreviated terms

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

Abbreviation	Meaning
AOCS	attitude and orbit control subsystem
APID	application process identifier
CPDU	command pulse distribution unit
CPU	central processor unit
CRC	cyclic redundancy check
EEPROM	electrically erasable programmable read-only memory
FDIR	failure detection, isolation and recovery
GPS	global positioning system
I/O	input/output
ID	identifier
MAP	multiplexed access point
OBT	on-board time
RAM	random access memory
RF	radio frequency
RFI	radio frequency interference
RFP	request for proposal
TT&C	telemetry, tracking and command
UTC	universal time coordinated

3.4 Conventions

Some requirements introduce quantities for which values cannot be defined across the board, but only on a mission-by-mission basis (e.g. time intervals or response times). These are termed mission constants and are identified within this Standard in angular brackets.

NOTE For example, <TC_VERIF_DELAY>

Example values are indicated in some cases. These mission constants are summarized in Annex A.

4

General requirements

4.1 Introduction

This clause contains general (high-level) requirements that pertain to the different categories of operability identified in clause 3.2.1. The requirements can be applied to missions of all classes (e.g. science, telecommunications or Earth observation) and orbit-type (e.g. geostationary, low-Earth orbiting or interplanetary).

4.2 Observability

- a. The space segment shall provide visibility of its internal status, configuration and performance to the ground segment in conformance with the level of detail and the time delays specified for all routine and specified contingency operations, including subsequent diagnostic activities.

NOTE 1 For detailed operability requirements reflecting these objectives, refer to clause 5.2.

NOTE 2 Specified contingency operations are derived during the failure analysis performed in the mission development process (e.g. the failure modes, effects and criticality analysis (FMECA)).

4.3 Commandability

- a. The control functions (telecommands) provided at each level of the system hierarchy shall be capable of achieving the mission objectives under all specified circumstances.

NOTE 1 This can include the use of redundant equipment to meet the overall system reliability requirements.

NOTE 2 Detailed operability requirements reflecting these objectives appear in clause 5.5.

4.4 Compatibility

- a. The space segment shall conform to all on-board design standards specified for the mission in order to ensure compatibility with the specified ground systems.
- b. The space segment design shall be such that its operation is not constrained by, nor adversely constrains, the availability or capacity of the space-Earth communications links.

4.5 Safety and fault tolerance

- a. No single command function executed at the wrong time or in the wrong configuration shall lead to the loss of the mission.

NOTE For a mission-critical command function, this can be ensured by the provision of two independent commands, both to be executed (e.g. ARM and FIRE).

- b. Except for explicitly agreed single point failures, the capability shall be provided to recover all on-board functions after a single failure within a specific function.

NOTE The impact of several non-correlated failures occurring at the same time has to be assessed at mission-level.

- c. No single unintentional ground command or failure in one space segment element shall cause a failure in another space segment element.
- d. The design of the space segment failure detection, isolation and recovery (FDIR) function shall be such that all anticipated on-board failures can be overcome either by autonomous on-board action or by clear, unambiguous and timely notification of the problem to the ground segment.
- e. The FDIR design shall ensure that the space segment is safe without ground segment intervention for the specified duration in the presence of a single failure.
- f. No reconfiguration of the spacecraft shall lead to a configuration where new single point failures are introduced.

NOTE With the exception of reconfigurations that are triggered on-board as the result of genuine failures.

4.6 Flexibility

- a. All authorized combinations of prime and redundant equipment shall exhibit the same operational characteristics.

NOTE 1 This requirement does not prevent a change of calibration data, but it precludes different operational procedures.

NOTE 2 This does not include any reduced redundancy that exists following a failure.

- b. The capability shall be provided for the ground segment to allocate which of the redundant units are included in the nominal chain and which in the redundant chain.

NOTE 1 This enables redundancy to be restored without reconfiguring the on-board hardware and also enables a failed unit to be removed from both the nominal and redundant chains while maintaining the rest of the redundancy of the chain.

NOTE 2 Software-selectable units, rather than hardware, are more suitable for use where the extent of cross-strapping provided is determined from the reliability analysis.

- c. Any selection of prime or redundant equipment shall be reversible.

NOTE This implies that the space segment design supports switching between prime and redundant equipment in both directions.

- d. For each on-board function, there shall be at least one alternative configuration that can achieve the same function using different on-board units.

- e. On-board functions shall have well-defined inputs and outputs that are accessible from the ground for workaround solutions in case of contingency operations.

NOTE Whilst inputs to on-board functions can be modified from the ground (e.g. threshold settings), this does not include the manipulation of on-board measurements.

- f. On-board storage and buffer areas should be resizable to cater for non-nominal mission events.

NOTE There can be operational restrictions on how this is achieved.

- g. The allocation of budgets for on-board resources shall provide the specified spare capacity for each subsystem and each payload.

NOTE 1 For example, mass memory, power, fuel.

NOTE 2 This spare capacity is provided in order to ensure flexibility during the mission.

- h. The capability shall be provided to determine, at any point in the mission and with the specified accuracy, the remaining on-board resources that impact on mission lifetime.

NOTE 1 For example, power, cooling fluid, fuel.

NOTE 2 The accuracy is specified to be compatible with the mission requirements.

4.7 Testability

- a. Each application process shall provide the capability to perform a set of end-to-end test functions which can be exercised under ground control.

NOTE For example, an “are you alive” function which generates a response for testing the end-to-end connection between the ground and an application process.

- b. For test purposes, the capability should be provided to operate redundant on-board equipment in an “off-line” manner (i.e. in parallel with, but without any disturbance to, the prime equipment).

NOTE This capability can be unfeasible if the redundant unit has an unacceptable disturbing influence such as in the case of a momentum wheel.

- c. The capability should be provided to confirm the health of a currently unused unit prior to operational utilization.

NOTE This applies in particular to units that are vital for the health and control of the space segment. The selection of units is to be made on a case-by-case basis, taking into account the impact on the space segment design (e.g. the telemetry definition).

- d. The capability shall be provided to load and check redundant memory prior to operational utilization.

4.8 Deactivation

- a. On-board resources shall be provided for configuring the spacecraft into a safe state at the end of its life.

NOTE 1 This can include de-orbiting (essential for LEO spacecraft) or bringing the spacecraft to a graveyard orbit (GEO spacecraft).

NOTE 2 Safe state means safe for the space environment.

- b. The capability shall be provided to completely deactivate the spacecraft at the end of its life.

NOTE This can include the removal of all internal energy sources, e.g. power and fuel.

5

Detailed requirements

5.1 Introduction

Requirements in this clause are grouped according to function, in contrast to Clause 4 where they are grouped according to operability class. It follows therefore that the requirements are only applicable if the corresponding function is actually implemented on-board. Some of these functions correspond to services defined within ECSS-E-ST-70-41 (the packet utilization standard), which are, by definition, all optional. The services are:

- statistical data reporting;
- memory management;
- function management;
- on-board operations scheduling;
- on-board monitoring;
- large data transfer;
- telemetry generation and forwarding;
- on-board storage and retrieval;
- on-board traffic management;
- on-board operations procedures;
- event-to-action coupling.

5.2 Mission-level

5.2.1 Security

- a. The space segment shall be designed such that the following can be ensured:
 1. the integrity of each data stream produced;
 2. the confidentiality of each data stream produced;
 3. the authentication of each telecommand received;
 4. the authorization of each telecommand received.

- b. The space segment shall be designed such that continued access to both the telemetry and telecommand transmission functions in the presence of specified external influences outside the control of the mission control team can be ensured.

NOTE The external influences to be accommodated are identified during the spacecraft design phase, i.e. at mission analysis level. They generally include RFI and adverse weather conditions. However, other influences, such as meteorite impacts or malicious dazzling of the uplink, clearly cannot be accommodated.

- c. The space segment shall be designed such that the recovery of access to both the telemetry and telecommand transmission functions can be ensured after all specified space and ground segment configuration changes.

5.2.2 Control functions

- a. The design of the overall mission operations system (i.e. constituting both the ground and space segments) shall ensure that control functions that have response times shorter than <GRND_RESP_TIME> are implemented on-board.
- b. Under all circumstances, the elapsed time for an application process to build and release telemetry source packets shall be such that the overall delay between the generation of a packet and its reception at the mission control centre is consistent with the response times <GRND_RESP_TIME> (there can be several such parameters for a given mission) that have been identified for ground control functions.
- c. The frequency of generation of telemetry source packets shall be consistent with <GRND_RESP_TIME>.
- d. The time differences between the release of packets containing data and packets containing ancillary information used for its ground processing shall be such that the effective operational information (i.e. after ground processing) is available within delays consistent with <GRND_RESP_TIME>.

5.2.3 Uplink and downlink

- a. Different downlink bandwidths shall be allocated to different classes of data using physical channels and virtual channels.
- b. The assignment of virtual channels to different data classes shall not be changed during the mission.

NOTE Data classes means distinct data streams, such as real-time housekeeping telemetry, science data or playback data rather than different packet types within the same stream.

- c. The allocation of bandwidth to different virtual channels shall be modifiable during the mission.
- d. The capability shall be provided to transmit real-time telemetry data and deferred telemetry data simultaneously.
- e. Request-driven telemetry source packets (e.g. telecommand verification packets) shall be routed to the originating source of the telecommand.

NOTE 1 The source can be either the ground or an on-board application process. In the case of telecommands released from an on-board schedule, the source is the ground.

NOTE 2 On-board autonomous activities are reported to the ground segment using event report packets.

5.3 Telemetry

5.3.1 Telemetry design

- a. Telemetry data shall be provided, as defined for all mission phases, for the ground segment to determine the status of the spacecraft subsystems and payloads and to monitor the execution of nominal and anticipated contingency operations.
- b. The data specified in requirement 5.3.1a shall include sensor readings, register readouts, equipment status (including power status), function status, reports of on-board events and actions taken by autonomous functions, and processor and memory auto-test results.
- c. The data specified in requirement 5.3.1a shall be telemetred to the ground segment in a complete, unambiguous, and timely manner.
- d. Event-based reporting shall be achieved by means of dedicated event report packets (progress or anomaly reports) which are generated on-board, e.g. by a failure detection and recovery function.
- e. The design of event reporting mechanisms and of the event report packets themselves shall be such that the utilization of the downlink bandwidth does not adversely affect the availability of other operational information to the ground segment.
- f. Essential space segment status data shall be derived from direct measurements.

NOTE This means that the essential status of the space segment is observable directly from the telemetry without the need for ground processing.

- g. The design of telemetry shall be such that preconditions for the switching of on-board equipment and units are acquired independently, i.e. they are not dependent on the status of the equipment or unit to be switched.

NOTE 1 To comply with this requirement, power status and thermal data used prior to unit switch-on are managed at a higher level.

NOTE 2 This provides the capability of monitoring and assessing the status of a unit even when it is switched off.

- h. The values of telemetred parameters shall be self-contained.

NOTE This precludes, for instance, the telemetring of delta-changes or status changes.

- i. If operationally-significant parameters monitored on-board (e.g. pyro currents) can change value at a frequency in excess of the telemetry sampling frequency, the event shall be memorized and the memorized value telemetred.
- j. The resolution and range of analogue telemetry parameters shall be such that monitoring can be performed in all nominal and anticipated contingency situations.
- k. Vital space segment health functions shall be monitored with redundant telemetry parameters (e.g. primary bus current and voltage, and propellant tank pressure).
- l. Telemetry shall be provided to enable detection and diagnosis of any failure identified during the failure analysis phase (e.g. as defined in the FMECA) at least down to function or equipment level.
- m. Where telemetry measurements are processed on-board, the capability shall be provided to downlink the raw data to the ground segment, on request.

NOTE For example, AOCS sensor data.

- n. For elements in hot redundancy, telemetry shall be provided to enable an independent and unambiguous evaluation of the status of each chain.
- o. For elements in redundancy, the loss or failure of one chain shall not prevent access to the telemetry of the other chain.
- p. Where parameters are conditionally valid, the parameters determining their validity shall be telemetred with a frequency that is the same as, or higher than, the conditionally-valid parameter.
- q. Sampling sequences and frequencies shall be specified for all related parameters that are correlated or combined for the purposes of space segment monitoring or performance evaluation to ensure that no information of operational significance is lost.
- r. Where the interpretation of a parameter in a variable packet depends on the values of other on-board parameters, these parameters shall all be telemetred in the same packet.

NOTE When the interpretation of a parameter in a variable packet depends on the values of other onboard parameters, the first parameter is a deduced parameter, as defined in ECSS-E-ST-70-41.

- s. A telemetry parameter shall always have the same structure and interpretation, even if it appears in different telemetry source packets.